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SIP: Session Initiation Protocol

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Abstract

The Session Initiation Protocol (SIP) is an application-layer control (signaling) protocol for creating, modifying and terminating sessions with one or more participants. These sessions include Internet telephone calls, multimedia distribution and multimedia conferences.

SIP invitations used to create sessions carry session descriptions which allow participants to agree on a set of compatible media types. SIP makes use of elements called proxy servers to help route requests to the users current location, authenticate and authorize users for services, implement provider call routing policies, and provide features to users. SIP also provides a registration function that allows them to upload their current location for use by proxy servers. SIP runs ontop of several different transport protocols.

Contents

1 Introduction **8**

2 Overview of SIP Functionality **8**

3 Terminology **9**

4 Overview of Operation **9**

5 Structure of the Protocol **14**

6 Definitions **16**

7 SIP Messages **20**
7.1 Requests 20
7.2 Responses 21

7.3 Header Fields . . . 22
7.3.1 Header Field Format . . . 22
7.3.2 Header Field Classification . . . 24
7.3.3 Compact Form . . . 24
7.4 Bodies . . . 24
7.4.1 Message Body Type . . . 25
7.4.2 Message Body Length . . . 25
7.5 Framing SIP messages . . . 25

8 General User Agent Behavior 25
8.1 UAC Behavior . . . 26
8.1.1 Generating the Request . . . 26
8.1.2 Sending the Request . . . 29
8.1.3 Processing Responses . . . 30
8.2 UAS Behavior . . . 32
8.2.1 Method Inspection . . . 32
8.2.2 Header Inspection . . . 32
8.2.3 Content Processing . . . 34
8.2.4 Applying Extensions . . . 34
8.2.5 Processing the Request . . . 34
8.2.6 Generating the Response . . . 34
8.2.7 Stateless UAS Behavior . . . 35
8.3 Redirect Servers . . . 36

9 Canceling a Request 37
9.1 Client Behavior . . . 37
9.2 Server Behavior . . . 38

10 Registrations 38
10.1 Overview . . . 38
10.2 Constructing the REGISTER Request . . . 39
10.2.1 Adding Bindings . . . 41
10.2.2 Removing Bindings . . . 41
10.2.3 Fetching Bindings . . . 42
10.2.4 Refreshing Bindings . . . 42
10.2.5 Setting the Internal Clock . . . 42
10.2.6 Discovering a Registrar . . . 42
10.2.7 Transmitting a Request . . . 43
10.2.8 Error Responses . . . 43
10.3 Processing REGISTER Requests . . . 43

11 Querying for Capabilities 45
11.1 Construction of OPTIONS Request . . . 45
11.2 Processing of OPTIONS Request . . . 46

12 Dialogs 47

12.1 Creation of a Dialog . . . 47
12.1.1 UAS behavior . . . 48
12.1.2 UAC behavior . . . 48
12.2 Requests within a Dialog . . . 49
12.2.1 UAC Behavior . . . 49
12.2.2 UAS behavior . . . 50
12.3 Termination of a Dialog . . . 51

13 Initiating a Session **51**
13.1 Overview . . . 51
13.2 Caller Processing . . . 52
13.2.1 Creating the Initial INVITE . . . 52
13.2.2 Processing INVITE Responses . . . 54
13.3 Callee Processing . . . 55
13.3.1 Processing of the INVITE . . . 55

14 Modifying an Existing Session **57**
14.1 UAC Behavior . . . 57
14.2 UAS Behavior . . . 58

15 Terminating a Session **59**
15.1 Terminating a Dialog with a BYE Request . . . 60
15.1.1 UAC Behavior . . . 60
15.1.2 UAS Behavior . . . 60

16 Proxy Behavior **61**
16.1 Overview . . . 61
16.2 Stateful Proxy . . . 61
16.3 Request Validation . . . 62
16.4 Making a Routing Decision . . . 64
16.5 Request Processing . . . 66
16.6 Response Processing . . . 71
16.7 Processing Timer C . . . 76
16.8 Handling Transport Errors . . . 76
16.9 CANCEL Processing . . . 76
16.10 Stateless Proxy . . . 76
16.11 Summary of Proxy Route Processing . . . 77
16.11.1 Examples . . . 78

17 Transactions **81**
17.1 Client Transaction . . . 83
17.1.1 INVITE Client Transaction . . . 83
17.1.2 non-INVITE Client Transaction . . . 87
17.1.3 Matching Responses to Client Transactions . . . 88
17.1.4 Handling Transport Errors . . . 89
17.2 Server Transaction . . . 89

17.2.1 INVITE Server Transaction 89
17.2.2 non-INVITE Server Transaction 91
17.2.3 Matching Requests to Server Transactions 93
17.2.4 Handling Transport Errors 93
17.3 RTT Estimation 94

18 Reliability of Provisional Responses **94**
18.1 UAS Behavior 95
18.2 UAC Behavior 96

19 Transport **97**
19.1 Clients 97
19.1.1 Sending Requests 97
19.1.2 Receiving Responses 99
19.2 Servers 99
19.2.1 Receiving Requests 99
19.2.2 Sending Responses 99
19.3 Framing 100
19.4 Error Handling 100

20 Usage of HTTP Authentication **100**
20.1 Framework 101
20.2 User-to-User Authentication 102
20.3 Proxy-to-User Authentication 103
20.4 The Digest Authentication Scheme 105

21 S/MIME **106**
21.1 S/MIME Certificates 106
21.2 S/MIME Key Exchange 107
21.3 Securing MIME bodies 108
21.4 Tunneling SIP in MIME 109
21.4.1 Integrity and Confidentiality Properties of SIP Headers 109
21.4.2 Tunneling Integrity and Authentication 110
21.4.3 Tunneling Encryption 112

22 Security Considerations **113**
22.1 Attacks and Threat Models 113
22.1.1 Registration Hijacking 113
22.1.2 Impersonating a Server 114
22.1.3 Tampering with Message Bodies 114
22.1.4 Tearing Down Sessions 115
22.1.5 Denial of Service and Amplification 115
22.2 Security Mechanisms 116
22.2.1 Transport and Network Layer Security 116
22.2.2 HTTP Authentication 117
22.2.3 S/MIME 117

22.3 Implementing Security Mechanisms 117
22.3.1 Requirements for Implementers of SIP 117
22.3.2 Security Solutions 118
22.4 Limitations 121
22.4.1 HTTP Digest 121
22.4.2 S/MIME 122
22.4.3 TLS 122
22.5 Privacy 123

23 Common Message Components **123**
23.1 SIP Uniform Resource Indicators 123
23.1.1 SIP URI Components 123
23.1.2 Character Escaping Requirements 126
23.1.3 Example SIP URIs 127
23.1.4 SIP URI Comparison 127
23.1.5 Forming Requests from a SIP URI 128
23.1.6 Relating SIP URIs and tel URLs 129
23.2 Option Tags 130
23.3 Tags 131

24 Header Fields **131**
24.1 Accept 134
24.2 Accept-Encoding 134
24.3 Accept-Language 135
24.4 Alert-Info 135
24.5 Allow 135
24.6 Authentication-Info 136
24.7 Authorization 136
24.8 Call-ID 136
24.9 Call-Info 136
24.10 Contact 137
24.11 Content-Disposition 137
24.12 Content-Encoding 138
24.13 Content-Language 138
24.14 Content-Length 138
24.15 Content-Type 139
24.16 CSeq 139
24.17 Date 139
24.18 Error-Info 139
24.19 Expires 140
24.20 From 140
24.21 In-Reply-To 141
24.22 Max-Forwards 141
24.23 Min-Expires 141
24.24 MIME-Version 141

24.25 Organization . . . 141
24.26 Priority . . . 142
24.27 Proxy-Authenticate . . . 142
24.28 Proxy-Authorization . . . 142
24.29 Proxy-Require . . . 143
24.30 RAck . . . 143
24.31 Record-Route . . . 143
24.32 Reply-To . . . 143
24.33 Require . . . 144
24.34 Retry-After . . . 144
24.35 Route . . . 144
24.36 RSeq . . . 144
24.37 Server . . . 144
24.38 Subject . . . 145
24.39 Supported . . . 145
24.40 Timestamp . . . 145
24.41 To . . . 145
24.42 Unsupported . . . 146
24.43 User-Agent . . . 146
24.44 Via . . . 146
24.45 Warning . . . 147
24.46 WWW-Authenticate . . . 148

25 Response Codes **148**
25.1 Provisional 1xx . . . 148
25.1.1 100 Trying . . . 149
25.1.2 180 Ringing . . . 149
25.1.3 181 Call Is Being Forwarded . . . 149
25.1.4 182 Queued . . . 149
25.1.5 183 Session Progress . . . 149
25.2 Successful 2xx . . . 149
25.2.1 200 OK . . . 149
25.3 Redirection 3xx . . . 149
25.3.1 300 Multiple Choices . . . 149
25.3.2 301 Moved Permanently . . . 150
25.3.3 302 Moved Temporarily . . . 150
25.3.4 305 Use Proxy . . . 150
25.3.5 380 Alternative Service . . . 150
25.4 Request Failure 4xx . . . 150
25.4.1 400 Bad Request . . . 151
25.4.2 401 Unauthorized . . . 151
25.4.3 402 Payment Required . . . 151
25.4.4 403 Forbidden . . . 151
25.4.5 404 Not Found . . . 151
25.4.6 405 Method Not Allowed . . . 151

25.4.7 406 Not Acceptable . . . 151
25.4.8 407 Proxy Authentication Required . . . 151
25.4.9 408 Request Timeout . . . 152
25.4.10 410 Gone . . . 152
25.4.11 413 Request Entity Too Large . . . 152
25.4.12 414 Request-URI Too Long . . . 152
25.4.13 415 Unsupported Media Type . . . 152
25.4.14 416 Unsupported URI Scheme . . . 152
25.4.15 420 Bad Extension . . . 152
25.4.16 421 Extension Required . . . 152
25.4.17 423 Registration Too Brief . . . 153
25.4.18 480 Temporarily Unavailable . . . 153
25.4.19 481 Call/Transaction Does Not Exist . . . 153
25.4.20 482 Loop Detected . . . 153
25.4.21 483 Too Many Hops . . . 153
25.4.22 484 Address Incomplete . . . 153
25.4.23 485 Ambiguous . . . 153
25.4.24 486 Busy Here . . . 154
25.4.25 487 Request Terminated . . . 154
25.4.26 488 Not Acceptable Here . . . 154
25.4.27 491 Request Pending . . . 154
25.4.28 493 Undecipherable . . . 154
25.5 Server Failure 5xx . . . 154
25.5.1 500 Server Internal Error . . . 155
25.5.2 501 Not Implemented . . . 155
25.5.3 502 Bad Gateway . . . 155
25.5.4 503 Service Unavailable . . . 155
25.5.5 504 Server Time-out . . . 155
25.5.6 505 Version Not Supported . . . 155
25.5.7 513 Message Too Large . . . 155
25.6 Global Failures 6xx . . . 156
25.6.1 600 Busy Everywhere . . . 156
25.6.2 603 Decline . . . 156
25.6.3 604 Does Not Exist Anywhere . . . 156
25.6.4 606 Not Acceptable . . . 156

26 Examples **156**
26.1 Registration . . . 156
26.2 Session Setup . . . 158

27 Augmented BNF for the SIP Protocol **162**
27.1 Basic Rules . . . 162

28 IANA Considerations **177**
28.1 Option Tags . . . 178

28.1.1 Registration of 100rel 178
28.2 Warn-Codes 179
28.3 Header Field Names 179
28.4 Method and Response Codes 179

29 Changes From RFC 2543 **180**
29.1 Major Functional Changes 180
29.2 Minor Functional Changes 183

30 Acknowledgments **183**

31 Authors' Addresses **184**

32 Normative References **185**

33 Non-Normative References **187**

1 Introduction

There are many applications of the Internet that require the creation and management of a session, where a session is considered an exchange of data between an association of participants. The implementation of these services is complicated by the practices of participants; users may move between endpoints, they may be addressable by multiple names, and they may communicate in several different media - sometimes simultaneously. Numerous protocols have been authored that carry various forms of real-time multimedia session data such as voice, video, or text messages. SIP works in concert with these protocols by enabling Internet endpoints (called "user agents") to discover one another and to agree on a characterization of a session they would like to share. For locating prospective session participants, and for other functions, SIP enables creation of an infrastructure of network hosts (called "proxy servers") to which user agents can send registrations, invitations to sessions and other requests. SIP is an agile, general-purpose tool for creating, modifying and terminating sessions that works independently of underlying transport protocols and without dependency on the type of session that is being established.

2 Overview of SIP Functionality

The Session Initiation Protocol (SIP) is an application-layer control protocol that can establish, modify, and terminate multimedia sessions (conferences) such as Internet telephony calls. SIP can also invite participants to already existing sessions, such as multicast conferences. Media can be added to (and removed from) an existing session. SIP transparently supports name mapping and redirection services, which supports *personal mobility* [29, p. 44] - users can maintain a single externally visible identifier (SIP URI) regardless of their network location.

SIP supports five facets of establishing and terminating multimedia communications:

User location: determination of the end system to be used for communication;

User availability: determination of the willingness of the called party to engage in communications;

User capabilities: determination of the media and media parameters to be used;

Session setup: “ringing”, establishment of session parameters at both called and calling party;

Session management: including transfer and termination of sessions, modifying session parameters, and invoking services.

SIP is not a vertically integrated communications system. SIP is rather a component that can be used with other IETF protocols to build a complete multimedia architecture. Typically, these architectures will include protocols such as the real-time transport protocol (RTP) (RFC 1889 [32]) for transporting real-time data and providing QoS feedback, the real-time streaming protocol (RTSP) (RFC 2326 [35]) for controlling delivery of streaming media, the Media Gateway Control Protocol (MEGACO) (RFC 3015 [43]) for controlling gateways to the Public Switched Telephone Network (PSTN), and the session description protocol (SDP) (RFC 2327 [11]) for describing multimedia sessions. Therefore, SIP should be used in conjunction with other protocols in order to provide complete services to the users. However, the basic functionality and operation of SIP does not depend on any of these protocols.

SIP does not provide services. SIP rather provides primitives that can be used to implement different services. For example, SIP can locate a user and deliver an opaque object to his current location. If this primitive is used to deliver a session description written in SDP, for instance, the parameters of a session can be agreed between endpoints. If the same primitive is used to deliver a photo of the caller as well as the session description, a ”caller ID” service can be easily implemented. As this example shows, a single primitive is typically used to provide several different services.

SIP does not offer conference control services such as floor control or voting and does not prescribe how a conference is to be managed. SIP can be used to initiate a session that uses some other conference control protocol. Since SIP messages and the sessions they establish can pass through entirely different networks, SIP cannot, and does not, provide any kind of network resource reservation capabilities.

The nature of the services provided by SIP make security particularly important. To that end, SIP provides a suite of security services, which include denial-of-service prevention, authentication (both user to user and proxy to user), integrity protection, and encryption and privacy services.

SIP works with both IPv4 and IPv6.

3 Terminology

In this document, the key words “MUST”, “MUST NOT”, “REQUIRED”, “SHALL”, “SHALL NOT”, “SHOULD”, “SHOULD NOT”, “RECOMMENDED”, “MAY”, and “OPTIONAL” are to be interpreted as described in RFC 2119 [24] and indicate requirement levels for compliant SIP implementations.

4 Overview of Operation

This section introduces the basic operations of SIP using simple examples. This section is tutorial in nature and does not contain any normative statements.

The first example shows the basic functions of SIP: location of an end point, signal of a desire to communicate, negotiation of session parameters to establish the session, and teardown of the session once established.

Figure 1 shows a typical example of a SIP message exchange between two users, Alice and Bob. (Each message is labeled with the letter “F” and a number for reference by the text.) In this example, Alice uses a SIP application on her PC (referred to as a softphone) to call Bob on his SIP phone over the Internet. Also shown are two SIP proxy servers that act on behalf of Alice and Bob to facilitate the session establishment. This typical arrangement is often referred to as the “SIP trapezoid” as shown by the geometric shape of the dashed lines in Figure 1.

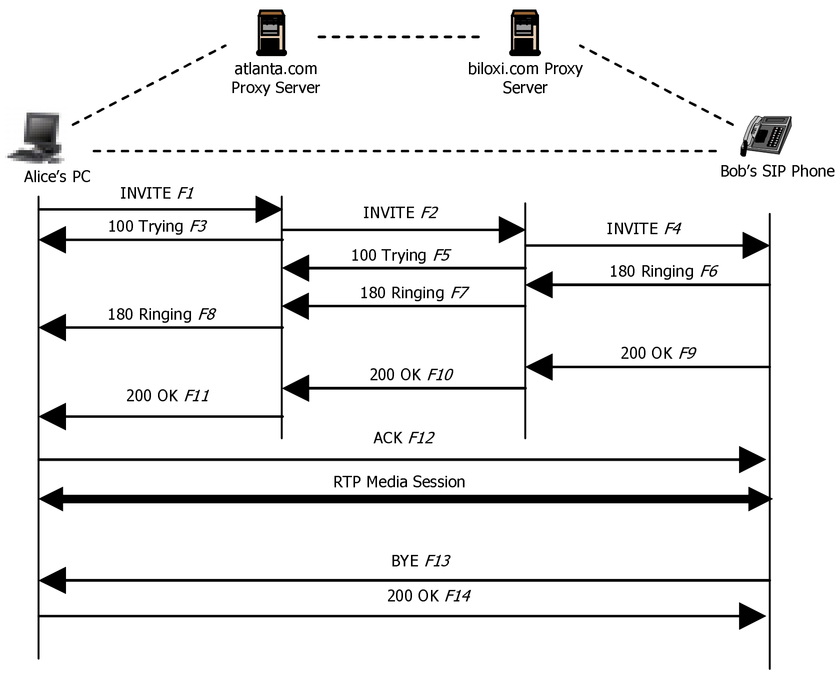


Figure 1: SIP session setup example with SIP trapezoid

Alice “calls” Bob using his SIP identity, a type of Uniform Resource Identifier (URI) called a SIP URI and defined in Section 23.1. It has a similar form to an email address, typically containing a username and a host name. In this case, it is sip:bob@biloxi.com, where biloxi.com is the domain of Bob’s SIP service provider (which can be an enterprise, retail provider, etc). Alice also has a SIP URI of sip:alice@atlanta.com. Alice might have typed in Bob’s URI or perhaps clicked on a hyperlink or an entry in an address book.

SIP is based on an HTTP-like request/response transacton model. Each transaction consists of a request that invokes a particular “Method”, or function, on the server, and at least one response. In this example, the transaction begins with Alice’s softphone sending an INVITE request addressed to Bob’s SIP URI. INVITE is an example of a SIP method which specifies the action that the requestor (Alice) wants the server (Bob) to take. The INVITE request contains a number of header fields. Header fields are named attributes that provide additional information about a message. The ones present in an INVITE include a unique identifier for the call, the destination address, Alice’s address, and information about the type of session that Alice wishes to establish with Bob. The INVITE (message F1 in Figure 1) might look like this:

```
INVITE sip:bob@biloxi.com SIP/2.0
Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bK776asdhds
To: Bob <sip:bob@biloxi.com>
```

```
From: Alice <sip:alice@atlanta.com>;tag=1928301774
Call-ID: a84b4c76e66710
CSeq: 314159 INVITE
Contact: <sip:alice@pc33.atlanta.com>
Max-Forwards: 70
Content-Type: application/sdp
Content-Length: 142

(Alice’s SDP not shown)
```

The first line of the text-encoded message contains the method name (INVITE). The lines that follow are a list of header fields. This example contains a minimum required set. The headers are briefly described below:

Via contains the address (pc33.atlanta.com) on which Alice is expecting to receive responses to this request. It also contains a branch parameter that contains an identifier for this transaction.

To contains a display name (Bob) and a SIP URI (sip:bob@biloxi.com) towards which the request was originally directed. Display names are described in RFC 2822 [20].

From also contains a display name (Alice) and a SIP URI (sip:alice@atlanta.com) that indicate the originator of the request. This header field also has a tag parameter containing a pseudorandom string (1928301774) that was added to the URI by the softphone. It is used for identification purposes.

Call-ID contains a globally unique identifier for this call, generated by the combination of a pseudorandom string and the softphone’s IP address. The combination of the To, From, and Call-ID completely define a peer-to-peer SIP relationship betwee Alice and Bob, and is referred to as a “dialog”.

CSeq or Command Sequence contains an integer and a method name. The CSeq number is incremented for each new request, and is a traditional sequence number.

Contact contains a SIP URI that represents a direct route to reach or contact Alice, usually composed of a username at an FQDN. While an FQDN is preferred, many end systems do not have registered domain names, so IP addresses are permitted. While the Via header field tells other elements where to send the response, the Contact header field tells other elements where to send future requests for this dialog.

Content-Type contains a description of the message body (not shown).

Content-Length contains an octet (byte) count of the message body.

The complete set of SIP header fields is defined in Section 24.

The details of the session, type of media, codec, sampling rate, etc. are not described using SIP. Rather, the body of a SIP message contains a description of the session, encoded in some other protocol format. One such format is Session Description Protocol (SDP) [11]. This SDP message (not shown in the example) is carried by the SIP message in a way that is analogous to a document attachment being carried by an email message, or a web page being carried in an HTTP message.

Since the softphone does not know the location of Bob or the SIP server in the biloxi.com domain, the softphone sends the INVITE to the SIP server that serves Alice’s domain, atlanta.com. The IP address of the atlanta.com SIP server could have been configured in Alice’s softphone, or it could have been discovered by DHCP, for example.

The atlanta.com SIP server is a type of SIP server known as a proxy server. A proxy server receives SIP requests and forwards them on behalf of the requestor. In this example, the proxy server receives the INVITE request and sends a 100 (Trying) response back to Alice’s softphone. The 100 (Trying) response indicates that the INVITE has been received and that the proxy is working on her behalf to route the INVITE to the destination. Responses in SIP use a three-digit code followed by a descriptive phrase. This response contains the same To, From, Call-ID, and CSeq as the INVITE, which allows Alice's softphone to correlate this response to the sent INVITE. The atlanta.com proxy server locates the proxy server at biloxi.com, possibly by performing a particular type of DNS (Domain Name Service) lookup to find the SIP server that serves the biloxi.com domain. This is described in [2]. As a result, it obtains the IP address of the biloxi.com proxy server and forwards, or proxies, the INVITE request there. Before forwarding the request, the atlanta.com proxy server adds an additional Via header field that contains its own IP address (the INVITE already contains Alice's IP address in the first Via). The biloxi.com proxy server receives the INVITE and responds with a 100 (Trying) response back to the Atlanta.com proxy server to indicate that it has received the INVITE and is processing the request. The proxy server consults a database, generically called a location service, that contains the current IP address of Bob. (We shall see in the next section how this database can be populated.) The biloxi.com proxy server adds another Via header with its own IP address to the INVITE and proxies it to Bob's SIP phone.

Bob's SIP phone receives the INVITE and alerts Bob to the incoming call from Alice so that Bob can decide whether or not to answer the call, i.e., Bob's phone rings. Bob's SIP phone sends an indication of this in a 180 (Ringing) response, which is routed back through the two proxies in the reverse direction. Each proxy uses the Via header to determine where to send the response and removes its own address from the top. As a result, although DNS and location service lookups were required to route the initial INVITE, the 180 (Ringing) response can be returned to the caller without lookups or without state being maintained in the proxies. This also has the desirable property that each proxy that sees the INVITE will also see all responses to the INVITE.

When Alice's softphone receives the 180 (Ringing) response, it passes this information to Alice, perhaps using an audio ringback tone or by displaying a message on Alice's screen.

In this example, Bob decides to answer the call. When he picks up the handset, his SIP phone sends a 200 (OK) response to indicate that the call has been answered. The 200 (OK) contains a message body with the SDP media description of the type of session that Bob is willing to establish with Alice. As a result, there is a two-phase exchange of SDP messages; Alice sent one to Bob, and Bob sent one back to Alice. This two-phase exchange provides basic negotiation capabilities and is based on a simple offer/answer model of SDP exchange. If Bob did not wish to answer the call or was busy on another call, an error response would have been sent instead of the 200 (OK), which would have resulted in no media session being established. The complete list of SIP response codes is in Section 25. The 200 (OK) (message F9 in Figure 1) might look like this as Bob sends it out:

```
SIP/2.0 200 OK
Via: SIP/2.0/UDP server10.biloxi.com;branch=z9hG4bKnashds8
Via: SIP/2.0/UDP bigbox3.site3.atlanta.com;branch=z9hG4bK77ef4c2312983.1
Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bK776asdhds
To: Bob <sip:bob@biloxi.com>;tag=a6c85cf
From: Alice <sip:alice@atlanta.com>;tag=1928301774
Call-ID: a84b4c76e66710
CSeq: 314159 INVITE
Contact: <sip:bob@192.0.2.8>
Content-Type: application/sdp
Content-Length: 131
```

```
(Bob’s SDP not shown)
```

The first line of the response contains the response code (200) and the reason phrase (OK). The remaining lines contain header fields. The Via header fields, To, From, Call- ID, and CSeq are all copied from the INVITE request. (There are three Via headers - one added by Alice’s SIP phone, one added by the atlanta.com proxy, and one added by the biloxi.com proxy.) Bob’s SIP phone has added a tag parameter to the To header field. This tag will be incorporated by both User Agents into the dialog and will be included in all future requests and responses in this call. The Contact header field contains a URI at which Bob can be directly reached at his SIP phone. The Content-Type and Content-Length refer to the message body (not shown) that contains Bob’s SDP media information.

In additon to DNS and location service lookups shown in this example, proxy servers can make flexible “routing decisions” to decide where to send a request. For example, if Bob’s SIP phone returned a 486 (Busy Here) response, the biloxi.com proxy server could proxy the INVITE to Bob’s voicemail server. A proxy server can also send an INVITE to a number of locations at the same time. This type of parallel search is known as “forking”.

In this case, the 200 (OK) is routed back through the two proxies and is received by Alice’s softphone which then stops the ringback tone and indicates that the call has been answered. Finally, an acknowledgement message, ACK, is sent by Alice to Bob to confirm the reception of the final response (200 (OK)). In this example, the ACK is sent directly from Alice to Bob, bypassing the two proxies. This is because, through the INVITE/200 (OK) exchange, the two SIP user agents have learned each other’s IP address through the Contact header fields, which was not known when the initial INVITE was sent. The lookups performed by the two proxies are no longer needed, so they drop out of the call flow. This completes the INVITE/200/ACK three-way handshake used to establish SIP sessions and is the end of the transaction. Full details on session setup are in Section 13.

Alice and Bob’s media session has now begun, and they send media packets using the format agreed to in the exchange of SDP. In general, the end-to-end media packets take a different path from the SIP signaling messages.

During the session, either Alice or Bob may decide to change the characteristics of the media session. This is accomplished by sending a re-INVITE containing a new media description. If the change is accepted by the other party, a 200 (OK) is sent, which is itself responded to with an ACK. This re-INVITE references the existing dialog so the other party knows that it is to modify an existing session instead of establishing a new session. If the change is not accepted, an error response, such as a 406 (Not Acceptable), is sent, which also receives an ACK. However, the failure of the re-INVITE does not cause the existing call to fail - the session continues using the previously negotiated characteristics. Full details on session modification are in Section 14.

At the end of the call, Bob disconnects (hangs up) first, and generates a BYE message. This BYE is routed directly to Alice’s softphone, again bypassing the proxies. Alice confirms receipt of the BYE with a 200 (OK) response, which terminates the session and the BYE transaction. No ACK is sent - an ACK is only sent in response to a response to an INVITE request. The reasons for this special handling for INVITE will be discussed later, but relate to the reliability mechanisms in SIP, the length of time it can take for a ringing phone to be answered, and forking. For this reason, request handling in SIP is often classified as either INVITE or non- INVITE, referring to all other methods besides INVITE. Full details on session termination are in Section 15.

Full details of all the messages shown in the example of Figure 1 are shown in Section 26.2.

In some cases, it may be useful for proxies in the SIP signaling path to see all the messaging between the endpoints for the duration of the session. For example, if the biloxi.com proxy server wished to remain in the SIP messaging path beyond the initial INVITE, it would add to the INVITE a required routing header field known as Record-Route that contained a URI resolving to the proxy. This information would be received by both Bob's SIP phone and (due to the Record-Route header field being passed back in the 200 (OK)) Alice's softphone and stored for the duration of the dialog. The biloxi.com proxy server would then receive and proxy the ACK, BYE, and 200 (OK) to the BYE. Each proxy can independently decide to receive subsequent messaging, and that messaging will go through all proxies that elect to receive it. This capability is frequently used for proxies that are providing mid-call features.

Registration is another common operation in SIP. Registration is one way that the biloxi.com server can learn the current location of Bob. Upon initialization, and at periodic intervals, Bob's SIP phone sends REGISTER messages to a server in the biloxi.com domain known as a SIP registrar. The REGISTER messages associate Bob's SIP URI (sip:bob@biloxi.com) with the machine he is currently logged in at (conveyed as a SIP URI in the Contact header). The registrar writes this association, also called a binding, to a database, called the *location service*, where it can be used by the proxy in the biloxi.com domain. Often, a registrar server for a domain is co-located with the proxy for that domain. It is an important concept that the distinction between types of SIP servers is logical, not physical.

Bob is not limited to registering from a single device. For example, both his SIP phone at home and the one in the office could send registrations. This information is stored together in the location service and allows a proxy to perform various types of searches to locate Bob. Similarly, more than one user can be registered on a single device at the same time.

The location service is just an abstract concept. It generally contains information that allows a proxy to input a URI and get back a translated URI that tells the proxy where to send the request. Registrations are one way to create this information, but not the only way. Arbitrary mapping functions can be programmed, at the discretion of the administrator.

Finally, it is important to note that in SIP, registration is used for routing incoming SIP requests and has no role in authorizing outgoing requests. Authorization and authentication are handled in SIP either on a request-by-request, challenge/response mechanism, or using a lower layer scheme as discussed in Section 22.

The complete set of SIP message details for this registration example is in Section 26.1.

Additional operations in SIP, such as querying for the capabilities of a SIP server or client using OPTIONS, canceling a pending request using CANCEL, or supporting reliability of provisional responses using PRACK will be introduced in later sections.

5 Structure of the Protocol

SIP is structured as a layered protocol, which means that its behavior is described in terms of a set of fairly independent processing stages with only a loose coupling between each stage. The protocol is structured into layers for the purpose of presentation and conciseness; it allows the grouping of functions common across elements into a single place. It does not dictate an implementation in any way. When we say that an element "contains" a layer, we mean it is compliant to the set of rules defined by that layer.

Not every element specified by the protocol contains every layer. Furthermore, the elements specified by SIP are logical elements, not physical ones. A physical realization can choose to act as different logical elements, perhaps even on a transaction-by-transaction basis.

The lowest layer of SIP is its syntax and encoding. Its encoding is specified using a BNF. The complete BNF is specified in Section 27. However, a basic overview of the structure of a SIP message can be found in Section 7. This section provides enough understanding of the format of a SIP message to facilitate understanding the remainder of the protocol.

The next higher layer is the transport layer. This layer defines how a client takes a request and physically sends it over the network, and how a response is sent by a server and then received by a client. All SIP elements contain a transport layer. The transport layer is described in Section 19.

The next higher layer is the transaction layer. Transactions are a fundamental component of SIP. A transaction is a request, sent by a client transaction (using the transport layer), to a server transaction, along with all responses to that request sent from the server transaction back to the client. The transaction layer handles application layer retransmissions, matching of responses to requests, and application layer timeouts. Any task that a UAC accomplishes takes place using a series of transactions. Discussion of transactions can be found in Section 17. User agents contain a transaction layer, as do stateful proxies. Stateless proxies do not contain a transaction layer.

The transaction layer has a client component (referred to as a client transaction), and a server component (referred to as a server transaction), each of which are represented by an FSM that is constructed to process a particular request. The layer on top of the transaction layer is called the transaction user (TU), of which there are several types. When a TU wishes to send a request, it creates a client transaction instance and passes it the request along with the destination IP address, port, and transport to which to send the request.

A TU which creates a client transaction can also cancel it. When a client cancels a transaction, it requests that the server stop further processing, revert to the state that existed before the transaction was initiated, and generate a specific error response to that transaction. This is done with a CANCEL request, which constitutes its own transaction, but references the transaction to be cancelled. Cancellation is described in Section 9.

There are several different types of transaction users. A UAC contains a UAC core, a UAS contains a UAS core, and a proxy contains a proxy core. The behavior of the UAC and UAS cores depend largely on the method. However, there are some common rules for all methods. These rules are captured in Section 8. They primarily deal with construction of a request, in the case of a UAC, and processing of that request and generation of a response, in the case of a UAS.

UAC and UAS core behavior for the REGISTER method is described in Section 10. Registrations play an important role in SIP. In fact, a UAS that handles a REGISTER is given a special name - a registrar - and it is described in that section.

UAC and UAS core behavior for the OPTIONS method, used for determining the capabilities of a UA, are described in Section 11.

Certain other requests are sent within a *dialog.* A dialog is a peer-to-peer SIP relationship between two user agents that persists for some time. The dialog facilitates sequencing of messages and proper routing of requests between the user agents. The INVITE method is the only way defined in this specification to establish a dialog. When a UAC sends a request that is within the context of a dialog, it follows the common UAC rules as discussed in Section 8, but also the rules for mid-dialog requests. Section 12 discusses dialogs and presents the procedures for their construction, and maintenance, in addition to construction of requests within a dialog.

The UAS core can generate provisional responses to requests, which are responses that provide additional information about the request processing but do not indicate completion. Normally, provisional responses are not transmitted reliably. However, an optional mechanism exists for them to be transmitted reliably. This mechanism makes use of a method called PRACK, sent as a separate transaction within the dialog between the UAC and UAS, which is used to acknowledge a reliable provisional response.

The most important method in SIP is the INVITE method, which is used to establish a session between participants. A session is a collection of participants, and streams of media between them, for the purposes of communication. Section 13 discusses how sessions are initiated, resulting in one or more SIP dialogs. Section 14 discusses how characteristics of that session are modified through the use of an INVITE request within a dialog. Finally, section 15 discusses how a session is terminated.

The procedures of Sections 8, 10, 11, 12, 13, 14, and 15 deal entirely with the UA core (Section 9 describes cancellation, which applies to both UA core and proxy core). Section 16 discusses the proxy element, which facilitates routing of messages between user agents.

6 Definitions

This specification uses a number of terms to refer to the roles played by participants in SIP communications. The terms and generic syntax of URI and URL are defined in RFC 2396 [13]. The following terms have special significance for SIP.

Back-to-Back user agent: A back-to-back user agent (B2BUA) is a logical entity that receives a request and processes it as an user agent server (UAS). In order to determine how the request should be answered, it acts as an user agent client (UAC) and generates requests. Unlike a proxy server, it maintains dialog state and must participate in all requests sent on the dialogs it has established. Since it is a concatenation of a UAC and UAS, no explicit definitions are needed for its behavior.

Call: A call is an informal term that refers to a dialog between peers generally set up for the purposes of a multimedia conversation.

Call leg: Another name for a dialog.

Call stateful: A proxy is call stateful if it retains state for a dialog from the initiating INVITE to the terminating BYE request. A call stateful proxy is always stateful, but the converse is not true.

Client: A client is any network element that sends SIP requests and receives SIP responses. Clients may or may not interact directly with a human user. *User agent clients* and *proxies* are clients.

Conference: A multimedia session (see below) that contains multiple participants.

Dialog: A dialog is a peer-to-peer SIP relationship between a UAC and UAS that persists for some time. A dialog is established by SIP messages, such as a 2xx response to an INVITE request. A dialog is identified by a call identifier, local address, and remote address. A dialog was formerly known as a call leg in RFC 2543.

Downstream: A direction of message forwarding within a transaction that refers to the direction that requests flow from the user agent client to user agent server.

Final response: A response that terminates a SIP transaction, as opposed to a *provisional response* that does not. All 2xx, 3xx, 4xx, 5xx and 6xx responses are final.

Header: A header is a component of a sip message that conveys information about the message. It is structured as a header name, followed by a colon, followed by its value.

Home Domain: The domain providing service to a SIP user. Typically, this is the domain present in the URI in the address-of-record of a registration.

Informational Response: Same as a provisional response.

Initiator, calling party, caller: The party initiating a session (and dialog) with an INVITE request. A caller retains this role from the time it sends the initial INVITE which established a dialog, until the termination of that dialog.

Invitation: An INVITE request.

Invitee, invited user, called party, callee: The party that receives an INVITE request for the purposes of establishing a new session. A callee retains this role from the time it receives the INVITE until the termination of the dialog established by that INVITE.

Location service: A location service is used by a SIP redirect or proxy server to obtain information about a callee's possible location(s). It contains a list of bindings of adress-of-record keys to zero or more contact addresses. The bindings can be created and removed in many ways; this specification defines a REGISTER method that updates the bindings.

Loop: A request that arrives at a proxy, is forwarded, and later arrives back at the same proxy. When it arrives the second time, its Request-URI is identical to the first time, and other headers that affect proxy operation are unchanged, so that the proxy would make the same processing decision on the request it made the first time around. Looped requests are errors, and the procedures for detecting them and handling them are described by the protocol.

Loose Routing: A proxy is said to be loose routing if it follows the procedures defined in this specification for processing of the Route header field. These procedures separate the destination of the request (present in the Request-URI) from the set of proxies that need to be visited along the way (present in the Route header field). A proxy compliant to these mechanisms is also known as a loose router.

Message: Data sent between SIP elements as part of the the protocol. SIP messages are either requests or responses.

Method: The method is the primary function that a request is meant to invoke on a server. The method is carried in the request message itself. Example methods are INVITE and BYE.

Outbound proxy: A *proxy* that receives all requests from a client, even though it is not the server resolved by the Request-URI. The outbound proxy sends these requests, after any local processing, to the address indicated in the Request-URI, or to another outbound proxy. Typically, a UA is manually configured with its outbound proxy, or can learn it through auto-configuration protocols.

Parallel search: In a parallel search, a proxy issues several requests to possible user locations upon receiving an incoming request. Rather than issuing one request and then waiting for the final response before issuing the next request as in a *sequential search*, a parallel search issues requests without waiting for the result of previous requests.

Provisional response: A response used by the server to indicate progress, but that does not terminate a SIP transaction. 1xx responses are provisional, other responses are considered *final*. Normally, provisional responses are not sent reliably. A provisional response that is sent reliably is referred to as a *reliable provisional response*.

Proxy, proxy server: An intermediary entity that acts as both a server and a client for the purpose of making requests on behalf of other clients. A proxy server primarily plays the role of routing, which means its job is to ensure that a request is passed on to another entity "closer" to the targeted user. Proxies are also useful for enforcing policy (for example, making sure a user is allowed to make a call). A proxy interprets, and, if necessary, rewrites specific parts of a request message before forwarding it.

Recursion: A client recurses on a 3xx response when it generates a new request to the URIs in the Contact headers in the response.

Redirect Server: A redirect server is a server that generates 3xx responses to requests it receives, directing the client to contact an alternate URI.

Registrar: A registrar is a server that accepts REGISTER requests, and places the information it receives in those requests into the location service for the domain it handles.

Regular Transaction: A regular transaction is any transaction with a method other than INVITE, ACK, or CANCEL.

Reliable Provisional Response: A provisional response that is sent reliably from the UAS to UAC.

Request: A SIP message sent from a client to a server, for the purpose of invoking a particular operation.

Response: A SIP message sent from a server to a client, for indicating the status of a request sent from the client to the server.

Ringback: Ringback is the signaling tone produced by the calling party's application indicating that a called party is being alerted (ringing).

Route Refresh Request: A route refresh request sent within a dialog is defined as a request that can modify the *route set* of the dialog.

Server: A server is a network element that receives requests in order to service them and sends back responses to those requests. Examples of servers are proxies, user agent servers, redirect servers, and registrars.

Sequential search: In a sequential search, a proxy server attempts each contact address in sequence, proceeding to the next one only after the previous has generated a non-2xx final response.

Session: From the SDP specification: "A multimedia session is a set of multimedia senders and receivers and the data streams flowing from senders to receivers. A multimedia conference is an example of a multimedia session." (RFC 2327 [11]) (A session as defined for SDP can comprise one or more RTP sessions.) As defined, a callee can be invited several times, by different calls, to the same session. If SDP is used, a session is defined by the concatenation of the *user name*, *session id*, *network type*, *address type*, and *address* elements in the origin field.

(SIP) transaction: A SIP transaction occurs between a client and a server and comprises all messages from the first request sent from the client to the server up to a final (non-1xx) response sent from the server to the client, and the ACK for the response in the case the response was a non-2xx. The ACK for a 2xx response is a separate transaction.

Spiral: A spiral is a SIP request that is routed to a proxy, forwarded onwards, and arrives once again at that proxy, but this time, differs in a way that will result in a different processing decision than the original request. Typically, this means that the request's Request-URI differs from its previous arrival. A spiral is not an error condition, unlike a loop. A typical cause for this is call forwarding. A user calls joe@example.com. The example.com proxy forwards it to Joe's PC, which in turn, forwards it to bob@example.com. This request is proxied back to the example.com proxy. However, this is not a loop. Since the request is targeted at a different user, it is considered a spiral, and is a valid condition.

Stateful proxy: A logical entity that maintains the client and server transaction state machines defined by this specification during the processing of a request. Also known as a transaction stateful proxy. The behavior of a stateful proxy is further defined in Section 16. A stateful proxy is not the same as a call stateful proxy.

Stateless proxy: A logical entity that does not maintain the client or server transaction state machines defined in this specification when it processes requests. A stateless proxy forwards every request it receives downstream and every response it receives upstream.

Strict Routing: A proxy is is said to be strict routing if it follows the Route processing rules of RFC 2543 and many prior Internet Draft versions of this RFC. That rule caused proxies to destroy the contents of the Request-URI when a Route header field was present. Strict routing behavior is not used in this specification, in favor of a loose routing behavior. Proxies that perform strict routing are also known as strict routers.

Transaction User (TU): The layer of protocol processing that resides above the transaction layer. Transaction users include the UAC core, UAS core, and proxy core.

Upstream: A direction of message forwarding within a transaction that refers to the direction that responses flow from the user agent server to user agent client.

URL-encoded: A character string encoded according to RFC 1738, Section 2.2 [4].

User agent client (UAC): A user agent client is a logical entity that creates a new request, and then uses the client transaction state machinery to send it. The role of UAC lasts only for the duration of that transaction. In other words, if a piece of software initiates a request, it acts as a UAC for the duration of that transaction. If it receives a request later on, it assumes the role of a user agent server for the processing of that transaction.

UAC Core: The set of processing functions required of a UAC that reside above the transaction and transport layers.

User agent server (UAS): A user agent server is a logical entity that generates a response to a SIP request. The response accepts, rejects or redirects the request. This role lasts only for the duration of that transaction. In other words, if a piece of software responds to a request, it acts as a UAS for the duration of that transaction. If it generates a request later on, it assumes the role of a user agent client for the processing of that transaction.

UAS Core: The set of processing functions required at a UAS that reside above the transaction and transport layers.

User agent (UA): A logical entity that can act as both a user agent client and user agent server for the duration of a dialog.

The role of UAC and UAS as well as proxy and redirect servers are defined on a transaction-by-transaction basis. For example, the user agent initiating a call acts as a UAC when sending the initial INVITE request and as a UAS when receiving a BYE request from the callee. Similarly, the same software can act as a proxy server for one request and as a redirect server for the next request.

Proxy, location, and registrar servers defined above are *logical* entities; implementations MAY combine them into a single application.

7 SIP Messages

SIP is a text-based protocol and uses the ISO 10646 character set in UTF-8 encoding (RFC 2279 [25]).

A SIP message is either a request from a client to a server, or a response from a server to a client.

Both Request (section 7.1) and Response (section 7.2) messages use the basic format of RFC 2822 [20], even though the syntax differs in character set and syntax specifics. (SIP allows header fields that would not be valid RFC 2822 header fields, for example.)

Both types of messages consist of a start-line, one or more header fields (also known as "headers"), an empty line indicating the end of the header fields, and an optional message-body.

```
generic-message  =  start-line
                    *message-header
                    CRLF
                    [ message-body ]
```

The start-line, each message-header line, and the empty line MUST be terminated by a carriage-return line-feed sequence (CRLF). Note that the empty line MUST be present even if the message-body is not.

Except for the above difference in character sets, much of SIP's message and header field syntax is identical to HTTP/1.1. Rather than repeating the syntax and semantics here, we use [HX.Y] to refer to Section X.Y of the current HTTP/1.1 specification (RFC 2616 [15]).

However, SIP is not an extension of HTTP.

7.1 Requests

SIP requests are distinguished by having a Request-Line for a start-line. A Request-Line contains a method name, a Request-URI, and the protocol version separated by a single space (SP) character.

The Request-Line ends with CRLF. No CR or LF are allowed except in the end-of-line CRLF sequence. No LWS is allowed in any of the elements.

```
Method Request-URI SIP-Version
```

Method: This specification defines seven methods: REGISTER for registering contact information, INVITE, ACK, PRACK and CANCEL for setting up sessions, BYE for terminating sessions and OPTIONS for querying servers about their capabilities. SIP extensions, documented in standards track RFCs, may define additional methods.

Request-URI: The Request-URI is a SIP URI as described in Section 23.1 or a general URI (RFC 2396 [13]). It indicates the user or service to which this request is being addressed. The Request-URI MUST NOT contain unescaped spaces or control characters and MUST NOT be enclosed in ”<>”.

SIP elements MAY support Request-URIs with schemes other than “sip”, for example the “tel” URI scheme of RFC 2806 [19]. SIP elements MAY translate non-SIP URIs using any mechanism at their disposal, resulting in either a SIP URI or some other scheme.

SIP-Version: Both request and response messages include the version of SIP in use, and follow [H3.1] (with HTTP replaced by SIP, and HTTP/1.1 replaced by SIP/2.0) regarding version ordering, compliance requirements, and upgrading of version numbers. To be compliant with this specification, applications sending SIP messages MUST include a SIP-Version of “SIP/2.0”. The SIP-Version string is case-insensitive, but implementations MUST send upper-case.

Unlike HTTP/1.1, SIP treats the version number as a literal string. In practice, this should make no difference.

7.2 Responses

SIP responses are distinguished from requests by having a Status-Line as their start-line. A Status-Line consists of the protocol version followed by a numeric Status-Code and its associated textual phrase, with each element separated by a single SP character.

No CR or LF is allowed except in the final CRLF sequence.

SIP-version Status-Code Reason-Phrase

The Status-Code is a 3-digit integer result code that indicates the outcome of an attempt to understand and satisfy a request. The Reason-Phrase is intended to give a short textual description of the Status-Code. The Status-Code is intended for use by automata, whereas the Reason-Phrase is intended for the human user. A client is not required to examine or display the Reason-Phrase.

While this specification suggests specific wording for the reason phrase, implementations MAY choose other text, e.g., in the language indicated in the Accept-Language header field of the request.

The first digit of the Status-Code defines the class of response. The last two digits do not have any categorization role. For this reason, any response with a status code between 100 and 199 is referred to as a “1xx response”, any response with a status code between 200 and 299 as a “2xx response”, and so on. SIP/2.0 allows six values for the first digit:

1xx: Provisional – request received, continuing to process the request;

2xx: Success – the action was successfully received, understood, and accepted;

3xx: Redirection – further action needs to be taken in order to complete the request;

4xx: Client Error – the request contains bad syntax or cannot be fulfilled at this server;

5xx: Server Error – the server failed to fulfill an apparently valid request;

6xx: Global Failure – the request cannot be fulfilled at any server.

Section 25 defines these classes and describes the individual codes.

7.3 Header Fields

SIP header fields are similar to HTTP header fields in both syntax and semantics. In particular, SIP header fields follow the [H4.2] definitions of syntax for message-header, and the rules for extending header fields over multiple lines. However, the latter is specified in HTTP with implicit white space and folding. This specification conforms with RFC 2234 [28] and uses only explicit white space and folding as an integral part of the grammar.

[H4.2] also specifies that multiple header fields of the same field name whose value is a comma separated list can be combined into one header field. That applies to SIP as well, but the specific rule is different because of the different grammars. Specifically, any SIP header whose grammar is of the form:

```
header = "header-name" HCOLON header-value *(COMMA header-value)
```

allows for combining header fields of the same name into a comma separated list. This is also true for the Contact header, as long as none of the header instances have a value of "*".

7.3.1 Header Field Format

Header fields follow the same generic header format as that given in Section 2.2 of RFC 2822 [20]. Each header field consists of a field name followed by a colon (":") and the field value.

```
field-name: field-value
```

The formal grammar for a message-header specified in Section 27 allows for an arbitrary amount of whitespace on either side of the colon; however, implementations should avoid spaces between the field name and the colon and use a single space (SP) between the colon and the field-value. Thus,

```
Subject:            lunch
Subject      :      lunch
Subject            :lunch
Subject: lunch
```

are all valid and equivalent, but the last is the preferred form.

Header fields can be extended over multiple lines by preceding each extra line with at least one SP or horizontal tab (HT). The line break and the whitespace at the beginning of the next line are treated as a single SP character. Thus, the following are equivalent:

```
Subject: I know you're there, pick up the phone and talk to me!
Subject: I know you're there,
         pick up the phone
         and talk to me!
```

The relative order of header fields with different field names is not significant. However, it is RECOMMENDED that headers which are needed for proxy processing (Via, Route, Record-Route, Proxy-Require, Max-Forwards, and Proxy-Authorization, for example) appear towards the top of the message, to facilitate rapid parsing. The relative order of header fields with the same field name is important. Multiple header fields with the same field-name MAY be present in a message if and only if the entire field-value for that header field is defined as a comma-separated list (that is, if follows the grammar defined in Section 7.3). It MUST be possible to combine the multiple header fields into one “field-name: field-value” pair, without changing the semantics of the message, by appending each subsequent field-value to the first, each separated by a comma. The exception to this rule are the Authorization, Proxy-Authorization, Proxy-Authenticate and Proxy-Authorization headers. Multiple header fields with these names MAY be present in a message, but since their grammar does not follow the general form listed in Section 7.3, they MUST NOT be combined into a single header field.

Implementations MUST be able to process multiple header fields with the same name in any combination of the single-value-per-line or comma-separated value forms.

The following groups of header fields are valid and equivalent:

```
Route: <sip:alice@atlanta.com>
Subject: Lunch
Route: <sip:bob@biloxi.com>
Route: <sip:carol@chicago.com>

Route: <sip:alice@atlanta.com>, <sip:bob@biloxi.com>
Route: <sip:carol@chicago.com>
Subject: Lunch

Subject: Lunch
Route: <sip:alice@atlanta.com>, <sip:bob@biloxi.com>, <sip:carol@chicago.com>
```

Each of the following blocks is valid but not equivalent to the others:

```
Route: <sip:alice@atlanta.com>
Route: <sip:bob@biloxi.com>
Route: <sip:carol@chicago.com>

Route: <sip:bob@biloxi.com>
Route: <sip:alice@atlanta.com>
Route: <sip:carol@chicago.com>

Route: <sip:alice@atlanta.com>,<sip:carol@chicago.com>,<sip:bob@biloxi.com>
```

The format of a header field-value is defined per header-name. It will always be either an opaque sequence of TEXT-UTF8 octets, or a combination of whitespace, tokens, separators, and quoted strings. Many existing headers will adhere to the general form of a value followed by a semi-colon separated sequence of parameter-name, parameter-value pairs:

field-name: field-value *(;parameter-name=parameter-value)

Even though an arbitrary number of parameter pairs may be attached to a header field value, any given parameter-name MUST NOT appear more than once.

All new header fields MUST follow this generic format unless they have been inherited from other RFC 2822-like specifications.

When comparing header fields, field names are always case-insensitive. Unless otherwise stated in the definition of a particular header field, field values, parameter names, and parameter values are case-insensitive. Tokens are always case-insensitive. Unless specified otherwise, values expressed as quoted strings are case-sensitive.

For example,

```
Contact: <sip:alice@atlanta.com>;expires=3600
```

is equivalent to

```
CONTACT: <sip:alice@atlanta.com>;ExPiReS=3600
```

and

```
Content-Disposition: session;handling=optional
```

is equivalent to

```
content-disposition: Session;HANDLING=OPTIONAL
```

The following two header fields are not equivalent:

```
Warning: 370 devnull "Choose a bigger pipe"
Warning: 370 devnull "CHOOSE A BIGGER PIPE"
```

7.3.2 Header Field Classification

Some header fields only make sense in requests or responses. These are called request header fields and response header fields, respectively. If a header appears in a message not matching its category (such as a request header field in a response), it MUST be ignored. Section 24 defines the classification of each header field.

7.3.3 Compact Form

SIP provides a mechanism to represent common header fields in an abbreviated form. This may be useful when messages would otherwise become too large to be carried on the transport available to it (exceeding the maximum transmission unit (MTU) when using UDP, for example). These compact forms are defined in Section 24. A compact form MAY be substituted for the longer form of a header name at any time without changing the semantics of the message. The same type of header field MAY appear in both long and short forms within the same message. Implementations MUST accept both the long and short forms of each header name.

7.4 Bodies

Requests, including new requests defined in extensions to this specification, MAY contain message bodies unless otherwise noted. The interpretation of the body depends on the request method.

For response messages, the request method and the response status code determine the type and interpretation of any message body. All responses MAY include a body.

7.4.1 Message Body Type

The Internet media type of the message body MUST be given by the Content-Type header field. If the body has undergone any encoding such as compression, then this MUST be indicated by the Content-Encoding header field; otherwise, Content-Encoding MUST be omitted. If applicable, the character set of the message body is indicated as part of the Content-Type header-field value.

The "multipart" MIME type defined in RFC 2046 [8] MAY be used within the body of the message. Implementations that send requests containing multipart message bodies MUST send a session description as a non-multipart message body if the remote implementation requests this through an Accept header field that does not contain multipart.

Note that SIP messages MAY contain binary bodies or body parts.

7.4.2 Message Body Length

The body length in bytes is provided by the Content-Length header field. Section 24.14 describes the necessary contents of this header in detail.

The "chunked" transfer encoding of HTTP/1.1 MUST NOT be used for SIP. (Note: The chunked encoding modifies the body of a message in order to transfer it as a series of chunks, each with its own size indicator.)

7.5 Framing SIP messages

Unlike HTTP, SIP implementations can use UDP or other unreliable datagram protocols. Each such datagram carries one request or response. See Section 19 on constraints on usage of unreliable transports.

Likewise, implementations processing SIP messages over stream-oriented transports MUST ignore any CRLF appearing before the start-line [H4.1]

8 General User Agent Behavior

A user agent represents an end system. It contains a User Agent Client (UAC), which generates requests, and a User Agent Server (UAS) which responds to them. A UAC is capable of generating a request based on some external stimulus (the user clicking a button, or a signal on a PSTN line), and processing a response. A UAS is capable of receiving a request, and generating a response, based on user input, external stimulus, the result of a program execution, or some other mechanism.

When a UAC sends a request, it will pass through some number of proxy servers, which forward the request towards the UAS. When the UAS generates a response, the response is forwarded towards the UAC.

UAC and UAS procedures depend strongly on two factors. First, whether the request or response is inside or outside of a dialog, and second, based on the method of a request. Dialogs are discussed thoroughly in Section 12; they represent a peer-to-peer relationship between user agents, and are established by specific SIP methods, such as INVITE.

In this section, we discuss the method independent rules for UAC and UAS behavior when processing requests that are outside of a dialog. This includes, of course, the requests which themselves establish a dialog.

Security procedures for requests and responses outside of a dialog are described in Section 22. Specifically, mechanisms exist for the UAS and UAC to mutually authenticate. A limited set of privacy features are also supported through encryption of bodies using S/MIME.

8.1 UAC Behavior

This section covers UAC behavior outside of a dialog.

8.1.1 Generating the Request

A valid SIP request formulated by a UAC MUST at a minimum contain the following headers: To, From, CSeq, Call-ID, Max-Forwards, and Via; all of these headers are mandatory in all SIP messages. These six headers are the fundamental building blocks of a SIP message, as they jointly provide for most of the critical message routing services including the addressing of messages, the routing of responses, limiting message propagation, ordering of messages, and the unique identification of transactions. These headers are in addition to the mandatory request line, which contains the method, Request-URI and SIP version.

Examples of requests sent outside of a dialog include an INVITE to establish a session (Section 13) and an OPTIONS to query for capabilities (Section 11).

8.1.1.1 Request-URI The initial Request-URI of the message SHOULD be set to the value of the URI in the To field. One notable exception is the REGISTER method; behavior for setting the Request-URI of register is given in Section 10.

In some special circumstances, the presence of a pre-existing route set can affect the Request-URI of the message. A pre-existing route set is an ordered set of URIs that identify a chain of servers, to which a UAC will send outgoing requests that are outside of a dialog. Commonly, they are configured on the user agent by a user or service provider manually, or through some non-SIP mechanism. When a provider wishes to configure a UA with an outbound proxy, it is RECOMMENDED that this by done by providing it with a pre-existing route set with a single URI, that of the outbound proxy.

When a pre-existing route set is present, the procedures for populating the Request-URI and Route header field detailed in Section 12.2.1.1 MUST be followed, even though there is no dialog.

8.1.1.2 To The To field first and foremost specifies the desired "logical" recipient of the request, or the address-of-record of the user or resource that is the target of this request. This may or may not be the ultimate recipient of the request. The To header MAY contain a SIP URI, but it may also make use of other URI schemes (the tel URL [19], for example) when appropriate. All SIP implementations MUST support the SIP URI. The To header field allows for a display name.

A UAC may learn how to populate the To header field for a particular request in a number of ways. Usually the user will suggest the To header field through a human interface, perhaps inputting the URI manually or selecting it from some sort of address book. Frequently, the user will not enter a complete URI, but rather, a string of digits or letters (i.e., "bob"). It is at the discretion of the UA to choose how to interpret this input. Using it to form the user part of a SIP URL implies that the UA wishes the name to be resolved in the domain the right hand side (RHS) of the at-sign in the SIP URI (i.e., sip:bob@example.com). The RHS will frequently be the home domain of the user, which allows for the home domain to process the outgoing request. This is useful for features like "speed dial" which require interpretation of the user part in the home domain. The tel URL is used when the UA does not wish to specify the domain that should interpret the user input. Rather, each domain that the request passes through would be given that opportunity. As an example, a user in an airport might log in, and send requests through an outbound proxy in the airport. If they enter "411" (this is the phone number for local directory assistance in the United States), that needs to be interpreted and processed by the outbound proxy in the airport, not the user's home domain. In this case, tel:411 would be the right choice.

A request outside of a dialog MUST NOT contain a tag; the tag in the To field of a request identifies the peer of the dialog. Since no dialog is established, no tag is present.

For further information on the To header field, see Section 24.41. The following is an example of valid To header:

```
To: Carol <sip:carol@chicago.com>
```

8.1.1.3 From The From general-header field indicates the logical identity of the initiator of the request, possibly the user's address of record. Like the To field, it contains a URI and optionally a display name. It is used by SIP elements to determine processing rules to apply to a request (for example, automatic call rejection). As such, it is very important that the From URI not contain IP addresses or the FQDN of the host the UA is running on, since these are not logical names.

The From header field allows for a display name. A UAC SHOULD use the display name "Anonymous", along with a syntactically correct, but otherwise meaningless URI (like sip:988776a@ahhs.aa), if the identity of the client is to remain hidden.

Usually the value that populates the From header field in requests generated by a particular user agent is pre-provisioned by the user or by the administrators of the user's local domain. If a particular user agent is used by multiple users, it might have switchable profiles that include a URI corresponding to the identity of the profiled user. Recipients of requests can authenticate the originator of a request in order to ascertain that they are who their From header field claims they are (see Section 20 for more on authentication).

The From field MUST contain a new "tag" parameter, chosen by the UAC. See Section 23.3 for details on choosing a tag.

For further information on the From header see Section 24.20. Examples:

```
From: "Bob" <sip:bob@biloxi.com> ;tag=a48s
From: sip:+12125551212@server.phone2net.com;tag=887s
From: Anonymous <sip:c8oqz84zk7z@privacy.org>;tag=hyh8
```

8.1.1.4 Call-ID The Call-ID general-header field acts as a unique identifier to group together a series of messages. It MUST be the same for all requests and responses sent by either UA in a dialog. It SHOULD be the same in each registration from a UA.

In a new request created by a UAC outside of any dialog, the Call-ID header MUST be selected by the UAC as a globally unique identifier over space and time unless overridden by method specific behavior. All SIP user agents must have a means to guarantee that the Call-ID headers they produce will not be inadvertently generated by any other user agent. Note that when requests are retried after certain failure responses that solicit an amendment to a request (for example, a challenge for authentication), these retried requests are not considered new requests, and therefore do not need new Call-ID headers; see Section 8.1.3.6.

Use of cryptographically random identifiers [5] in the generation of Call-IDs is RECOMMENDED. Implementations MAY use the form "localid@host". Call-IDs are case-sensitive and are simply compared byte-by-byte.

Using cryptographically random identifiers provides some protection against session hijacking and reduces the likelihood of unintentional Call-ID collisions.

No provisioning or human interface is required for the selection of the Call-ID header field value for a request.

For further information on the Call-ID header see Section 24.8.

Example:

```
Call-ID: f81d4fae-7dec-11d0-a765-00a0c91e6bf6@foo.bar.com
```

8.1.1.5 CSeq The Cseq header serves as a way to identify and order transactions. It consists of a sequence number and a method. The method MUST match that of the request. For requests outside of a dialog, the sequence number value is arbitrary, but MUST be expressible as a 32-bit unsigned integer and MUST be less than 2**31. As long as it follows the above guidelines, a client may use any mechanism it would like to select CSeq header field values.

Section 12.2.1.1 discusses construction of the CSeq for requests within a dialog.

Example:

```
CSeq: 4711 INVITE
```

8.1.1.6 Max-Forwards The Max-Forwards header serves to limit the number of hops a request can transit on the way to its destination. It consists of an integer that is decremented by one at each hop. If the Max-Forwards value reaches 0 before the request reaches its destination, it will be rejected with a 483 Too Many Hops error response.

A UAC MUST insert a Max-Forwards header field into each request it originates with a value which SHOULD be 70. This number was chosen to be sufficiently large to guarantee that a request would not be dropped in any SIP network when there were no loops, but not so large as to consume proxy resources when a loop does occur. Lower values should be used with caution, only in networks where topologies are known by the UA.

8.1.1.7 Via The Via header is used to indicate the transport used for the transaction, and to identify the location where the response is to be sent.

When the UAC creates a request, it MUST insert a Via into that request. The protocol and version in the header MUST be SIP and 2.0, respectively. The Via header it inserts MUST contain a branch parameter. This parameter is used to uniquely identify the transaction created by that request. This parameter is used by both the client, and the server.

The branch parameter value MUST be unique across time for all requests sent by the UA. The exception to this rule is CANCEL. As discussed below, a CANCEL request will have the same value of the branch parameter as the request it cancels.

The uniqueness property of the branch ID parameter, to facilitate its use as a transaction ID, was not part of RFC 2543

The branch ID inserted by an element compliant with this specification MUST always begin with the characters “z9hG4bK”. These 7 characters are used as a magic cookie (7 is deemed sufficient to ensure that an older RFC 2543 implementation would not pick such a value), so that servers receiving the request can determine that the branch ID was constructed in the fashion described by this specification (i.e., globally unique). Beyond this requirement, the precise format of the branch token is implementation-defined.

The Via header maddr, ttl, and sent-by components will be set when the request is processed by the transport layer (Section 19).

Via processing for proxies is described in Sections 3 and sec:proxy-response-processing-via.

8.1.1.8 Contact

The Contact header provides a SIP URI that can be used to contact that specific instance of the user agent for subsequent requests. The Contact header MUST be present in any request that can result in the establishment of a dialog. For the methods defined in this specification, that includes only the INVITE request. For these requests, the scope of the Contact is global. That is, the Contact header refers to the URI at which the UA would like to receive requests, and this URI MUST be valid even if used in subsequent requests outside of any dialogs. Only a single URI MUST be present.

For further information on the Contact header, see Section 24.10.

8.1.1.9 Supported and Require

If the UAC supports extensions to SIP that can be applied by the server to the response, the UAC SHOULD include a Supported header in the request listing the option tags (Section 23.2) for those extensions. This includes support for reliability for provisional responses, which is an extension even though it is defined within this specification. The option tag for reliability of provisional responses is `100rel`.

The option-tags listed MUST only refer to extensions defined in standards-track RFCs. This is to prevent servers from insisting that clients implement non-standard, vendor-defined features in order to receive service. Extensions defined by experimental and informational RFCs are explicitly excluded from usage with the Supported header in a request, since they too are often used to document vendor-defined extensions.

If the UAC wishes to insist that a UAS understand an extension that the UAC will apply to the request in order to process the request, it MUST insert a Require header into the request listing the option tag for that extension. If the UAC wishes to apply an extension to the request and insist that any proxies that are traversed understand that extension, it MUST insert a Proxy-Require header into the request listing the option tag for that extension.

As with the Supported header, the option-tags in the Require header MUST only refer to extensions defined in standards-track RFCs.

A Require header in a request with the option tag `100rel` means that the UAC wishes for all provisional responses to this request to be transmitted reliably. This header MUST NOT be present in any requests excepting INVITE, although extensions to SIP may allow its usage with other request methods.

8.1.1.10 Additional Message Components

After a new request has been created, and the headers described above have been properly constructed, any additional optional headers are added, as are any headers specific to the method.

SIP requests MAY contain a MIME-encoded message-body. Regardless of the type of body that a request contains, certain headers must be formulated to characterize the contents of the body. For further information on these headers see Sections 24.14, 24.15 and 24.12.

8.1.2 Sending the Request

The destination for the request is then computed. Unless there is local policy specifying otherwise, then the destination MUST be determined by applying the DNS proceedures described in [2] as follows. If the first element in the route set indicated a strict router (resulting in forming the request as described in Section 12.2.1.1), the proceedures MUST be applied to the Request-URI of the request. Otherwise, the proceedures are applied to the first Route header field value in the request (if one exists), or to the request's Request-URI if there is no Route header field present. These procedures yield an ordered set of address, port, and transports to attempt.

Local policy MAY specify an alternate set of destinations to attempt. There are no restrictions on the alternate destinations if the request contains no Route headers. This provides a simple alternative to a pre-existing route set as way to specify an outbound proxy. However, that approach for configuring outbound proxy is NOT RECOMMENDED; a pre-existing route set with a single URI SHOULD be used instead. If the request contains Route headers, the request MAY be sent to any server that the UA is certain will honor the Route and Request-URI policies specified in this document (as opposed to those in RFC 2543).

The UAC SHOULD follow the procedures defined in [2] for stateful elements, trying each address until a server is contacted. Each try constitutes a new transaction, and therefore each carries a different Via header with a new branch parameter. Furthermore, the transport value in the Via header is set to whatever transport was determined for the target server.

8.1.3 Processing Responses

Responses are first processed by the transport layer and then passed up to the transaction layer. The transaction layer performs its processing and then passes it up to the TU. The majority of response processing in the TU is method specific. However, there are some general behaviors independent of the method.

8.1.3.1 Transaction Layer Errors In some cases, the response returned by the transaction layer will not be a SIP message, but rather a transaction layer event. The only event that the TU will encounter is the timeout event. When the timeout event is received from the transaction layer, it MUST be treated as if a 408 (Request Timeout) status code has been received.

8.1.3.2 Unrecognized Responses A UAC MUST treat any response it does not recognize as being equivalent to the x00 response code of that class, and MUST be able to process the x00 response code for all classes. For example, if a UAC receives an unrecognized response code of 431, it can safely assume that there was something wrong with its request and treat the response as if it had received a 400 (Bad Request) response code.

8.1.3.3 Vias If more than one Via header field is present in a response, the UAC SHOULD discard the message.

> The presence of additional Via header fields that precede the originator of the request suggests that the message was misrouted or possibly corrupted.

8.1.3.4 Processing Reliable 1xx Responses A 1xx response that contains a Require header with the option tag `100rel` is a reliable provisional response. The UA core follows the procedures in Section 18.2 to process the response, which will result in the generation of a PRACK request to acknowledge the reliable provisional response.

8.1.3.5 Processing 3xx responses Upon receipt of a redirection response (for example, a 3xx response status code), clients SHOULD use the URI(s) in the Contact header field to formulate one or more new requests based on the redirected request.

If more than one URI is present in Contact header fields within the 3xx response, the UA MUST determine an order in which these contact addresses should be processed. UAs MUST consult the "q" parameter value of the Contact header fields (see Section 24.10) if available. Contact addresses MUST be ordered from highest qvalue to lowest. If no qvalue is present, a contact address is considered to have a qvalue of 1.0. Note that two or more contact addresses might have an equal qvalue - these URIs are eligible to be tried in parallel.

Once an ordered list has been established, UACs MUST try to contact each URI in the ordered list in turn until a server responds. If there are contact addresses with an equal qvalue, the UAC MAY decide randomly on an order in which to process these addresses, or it MAY attempt to process contact addresses of equal qvalue in parallel.

Note that for example, the UAC may effectively divide the ordered list into groups, processing the groups serially and processing the destinations in each group in parallel.

If contacting an address in the list results in a failure, as defined in the next paragraph, the element moves to the next address in the list, until the list is exhausted. If the list is exhausted, then the request has failed.

Failures SHOULD be detected through failure response codes (codes greater than 399) or network timeouts. Client transaction will report any transport layer failures to the transaction user.

When a failure for a particular contact address is received, the client SHOULD try the next contact address. This will involve creating a new client transaction to deliver a new request.

In order to create a request based on a contact address in a 3xx response, a UAC MUST copy the entire URI from the Contact header into the Request-URI, except for the "method-param" and "header" URI parameters (see Section 23.1.1 for a definition of these parameters). It uses the "header" parameters to create headers for the new request, overwriting headers associated with the redirected request in accordance with the guidelines in Section 23.1.5.

Note that in some instances, headers that have been communicated in the contact address may instead append to existing request headers in the original redirected request. As a general rule, if the header can accept a comma-separated list of values, then the new header value MAY be appended to any existing values in the original redirected request. If the header does not accept multiple values, the value in the original redirected request MAY be overwritten by the header value communicated in the contact address. For example, if a contact address is returned with the following value:

```
sip:user@host?Subject=foo&Call-Info=<http://www.foo.com>
```

Then any Subject header in the original redirected request is overwritten, but the HTTP URL is merely appended to any existing Call-Info header field values.

It is RECOMMENDED that the UAC reuse the same To, From, and Call-ID used in the original redirected request, but the UAC MAY also choose to update for example the Call-ID header field value for new requests.

Finally, once the new request has been constructed, it is sent using a new client transaction, and therefore MUST have a new branch ID in the top Via field as discussed in Section 8.1.1.7.

In all other respects, requests sent upon receipt of a redirect response SHOULD re-use the headers and bodies of the original request.

In some instances, Contact header values may be cached at UAC temporarily or permanently depending on the status code received and the presence of an expiration interval; see Sections 25.3.2 and 25.3.3.

8.1.3.6 Processing 4xx responses Certain 4xx response codes require specific UA processing, independent of the method.

If a 401 (Unauthorized) or 407 (Proxy Authentication Required) response is received, the UAC SHOULD follow the authorization procedures of Section 20.2 and Section 20.3 to retry the request with credentials.

If a 413 (Request Entity Too Large) response is received (Section 25.4.11), the request contained a body that was longer than the UAS was willing to accept. If possible, the UAC SHOULD retry the request, either omitting the body or using one of a smaller length.

If a 415 (Unsupported Media Type) response is received (Section 25.4.13), the request contained media types not supported by the UAS. The UAC SHOULD retry sending the request, this time only using content with types listed in the Accept header in the response, with encodings listed in the Accept-Encoding header in the response, and with languages listed in the Accept-Language in the response.

If a 416 (Unsupported URI Scheme) response is received (Section 25.4.14, the Request-URI used a URI scheme not supported by the server. The client SHOULD retry the request, this time, using a SIP URI.

If a 420 (Bad Extension) response is received (Section 25.4.15), the request contained a Require or Proxy-Require header listing an option-tag for a feature not supported by a proxy or UAS. The UAC SHOULD retry the request, this time omitting any extensions listed in the Unsupported header in the response.

In all of the above cases, the request is retried by creating a new request with the appropriate modifications. This new request SHOULD have the same value of the Call-ID, To, and From of the previous request, but the CSeq should contain a new sequence number that is one higher than the previous.

With other 4xx responses, including those yet to be defined, a retry may or may not be possible depending on the method and the use case.

8.2 UAS Behavior

When a request outside of a dialog is processed by a UAS, there is a set of processing rules which are followed, independent of the method. Section 12 gives guidance on how a UAS can tell whether a request is inside or outside of a dialog.

Note that request processing is atomic. If a request is accepted, all state changes associated with it MUST be performed. If it is rejected, all state changes MUST NOT be performed.

8.2.1 Method Inspection

Once a request is authenticated (or no authentication was desired), the UAS MUST inspect the method of the request. If the UAS does not support the method of a request it MUST generate a 405 (Method Not Allowed) response. Procedures for generation of responses are described in Section 8.2.6. The UAS MUST also add an Allow header to the 405 (Method Not Allowed) response. The Allow header field MUST list the set of methods supported by the UAS generating the message. The Allow header field is presented in Section 24.5.

If the method is one supported by the server, processing continues.

8.2.2 Header Inspection

If a UAS does not understand a header field in a request (that is, the header is not defined in this specification or in any supported extension), the server MUST ignore that header and continue processing the message. A UAS SHOULD ignore any malformed headers that are not necessary for processing requests.

8.2.2.1 To and Request-URI The To header field identifies the original recipient of the request designated by the user identified in the From field. The original recipient may or may not be the UAS processing the request, due to call forwarding or other proxy operations. A UAS MAY apply any policy it wishes in determination of whether to accept requests when the To field is not the identity of the UAS. However, it is RECOMMENDED that a UAS accept requests even if they do not recognize the URI scheme (for example, a `tel:` URI) in the To header, or if the To header field does not address a known or current user of this UAS. If, on the other hand, the UAS decides to reject the request, it SHOULD generate a response with a 403 (Forbidden) status code and pass it to the server transaction layer for transmission.

However, the Request-URI identifies the UAS that is to process the request. If the Request-URI uses a scheme not supported by the UAS, it SHOULD reject the request with a 416 (Unsupported URI Scheme) response. If the Request-URI does not identify an address that the UAS is willing to accept requests for, it SHOULD reject the request with a 404 (Not Found) response. Typically, a UA that uses the REGISTER method to bind its address of record to a specific contact address will see requests whose Request-URI equals those contact addressess. Other potential sources of received Request-URIs include the Contact headers of requests and responses sent by the UA that establish or refresh dialogs.

8.2.2.2 Merged Requests If the request has no tag in the To, the TU checks ongoing transactions. If the To, From, Call-ID, CSeq exactly match (including tags) those of any request received previously, but the branch-ID in the topmost Via is different from those received previously, the TU SHOULD generate a 482 (Loop Detected) response and pass it to the server transaction.

The same request has arrived at the UAS more than once, following different paths, most likely due to forking. The UAS processes the first such request received and responds with a 482 (Loop Detected) to the rest of them.

8.2.2.3 Require Assuming the UAS decides that it is the proper element to process the request, it examines the Require header field, if present.

The Require general-header field is used by a UAC to tell a UAS about SIP extensions that the UAC expects the UAS to support in order to process the request properly. Its format is described in Section 24.33. If a UAS does not understand an option-tag listed in a Require header field, it MUST respond by generating a response with status code 420 (Bad Extension). The UAS MUST add an Unsupported header field, and list in it those options it does not understand amongst those in the Require header of the request. Upon receipt of the 420 (Bad Extension) the client SHOULD retry the request, this time without using those extensions listed in the Unsupported header field in the response.

Note that Require and Proxy-Require MUST NOT be used in a SIP CANCEL request, or in an ACK request sent for a non-2xx response. These headers should be ignored if they are present in these requests.

An ACK request for a 2xx response MUST contain only those Require and Proxy-Require values that were present in the initial request.

Example:

```
UAC->UAS:   INVITE sip:watson@bell-telephone.com SIP/2.0
            Require: 100rel


UAS->UAC:   SIP/2.0 420 Bad Extension
            Unsupported: 100rel
```

This behavior ensures that the client-server interaction will proceed without delay when all options are understood by both sides, and only slow down if options are not understood (as in the example above). For a well-matched client-server pair, the interaction proceeds quickly, saving a round-trip often required by negotiation mechanisms. In addition, it also removes ambiguity when the client requires features that the server does not understand. Some features, such as call handling fields, are only of interest to end systems.

8.2.3 Content Processing

Assuming the UAS understands any extensions required by the client, the UAS examines the body of the message, and the headers that describe it. If there are any bodies whose type (indicated by the Content-Type), language (indicated by the Content-Language) or encoding (indicated by the Content-Encoding) are not understood, and that body part is not optional (as indicated by the Content-Disposition header), the UAS MUST reject the request with a 415 (Unsupported Media Type) response. The response MUST contain an Accept header listing the types of all bodies it understands, in the event the request contained bodies of types not supported by the UAS. If the request contained content encodings not understood by the UAS, the response MUST contain an Accept-Encoding header listing the encodings understood by the UAS. If the request contained content with languages not understood by the UAS, the response MUST contain an Accept-Language header indicating the languages understood by the UAS. Beyond these checks, body handling depends on the method and type. For further information on the processing of content-specific headers see Section 7.4 as well as Section 24.11 through 24.15.

8.2.4 Applying Extensions

A UAS that wishes to apply some extension when generating the response MUST only do so if support for that extension is indicated in the Supported header in the request. If the desired extension is not supported, the server SHOULD rely only on baseline SIP and any other extensions supported by the client. To ensure that the SHOULD can be fulfilled, any specification of a new extension MUST include discussion of how to return gracefully to baseline SIP when the extension is not present. In rare circumstances, where the server cannot process the request without the extension, the server MAY send a 421 (Extension Required) response. This response indicates that the proper response cannot be generated without support of a specific extension. The needed extension(s) MUST be included in a Require header in the response. This behavior is NOT RECOMMENDED, as it will generally break interoperability.

Any extensions applied to a non-421 response MUST be listed in a Require header included in the response. Of course, the server MUST NOT apply extensions not listed in the Supported header in the request. As a result of this, the Require header in a response will only ever contain option tags defined in standards-track RFCs.

8.2.5 Processing the Request

Assuming all of the checks in the previous subsections are passed, the UAS processing becomes method-specific. Section 10 covers the REGISTER request, section 11 covers the OPTIONS request, section 13 covers the INVITE request, and section 15 covers the BYE request.

8.2.6 Generating the Response

When a UAS wishes to construct a response to a request, it follows these procedures. Additional procedures may be needed depending on the status code of the response and the circumstances of its construction. These additional procedures are documented elsewhere.

8.2.6.1 Sending a Provisional Response One largely non-method-specific guideline for the generation of responses is that UASs SHOULD NOT issue a provisional response for a non-INVITE request. Rather, UASs SHOULD generate a final response to a non-INVITE request as soon as possible.

When a 100 (Trying) response is generated, any Timestamp header present in the request MUST be copied into this 100 (Trying) response. If there is a delay in generating the response, the UAS SHOULD add a delay value into the Timestamp value in the response. This value MUST contain the difference between time of sending of the response and receipt of the request, measured in seconds.

8.2.6.2 Headers and Tags The From field of the response MUST equal the From field of the request. The Call-ID field of the response MUST equal the Call-ID field of the request. The Cseq field of the response MUST equal the Cseq field of the request. The Via headers in the response MUST equal the Via headers in the request and MUST maintain the same ordering.

If a request contained a To tag in the request, the To field in the response MUST equal that of the request. However, if the To field in the request did not contain a tag, the URI in the To field in the response MUST equal the URI in the To field in the request; additionally, the UAS MUST add a tag to the To field in the response (with the exception of the 100 (Trying) response, in which a tag MAY be present). This serves to identify the UAS that is responding, possibly resulting in a component of a dialog ID. The same tag MUST be used for all responses to that request, both final and provisional (again excepting the 100 (Trying)). Procedures for generation of tags are defined in Section 23.3.

8.2.7 Stateless UAS Behavior

A stateless UAS is a UAS that does not maintain transaction state. It replies to requests normally, but discards any state that would ordinarily be retained by a UAS after a response has been sent. If a stateless UAS receives a retransmission of a request, it regenerates the response and resends it, just as if it were replying to the first instance of the request. Stateless UASs do not use a transaction layer; they receive requests directly from the transport layer and send responses directly to the transport layer.

The stateless UAS role is needed primarily to handle unauthenticated requests for which a challenge response is issued. If unauthenticated requests were handled statefully, then malicious floods of unauthenticated requests could create massive amounts of transaction state that might slow or completely halt call processing in a UAS, effectively creating a denial of service condition; for more information see Section 22.1.5.

The most important behaviors of a stateless UAS are the following:

- A stateless UAS MUST NOT send provisional (1xx) responses.
- A stateless UAS MUST NOT retransmit responses.
- A stateless UAS MUST ignore ACK requests.
- A stateless UAS MUST ignore CANCEL requests.
- To header tags MUST be generated for responses in a stateless manner - in a manner that will generate the same tag for the same request consistently. For information on tag construction see Section 23.3.

In all other respects, a stateless UAS behaves in the same manner as a stateful UAS. A UAS can operate in either a stateful or stateless mode for each new request.

8.3 Redirect Servers

In some architectures it may be desirable to reduce the processing load on proxy servers that are responsible for routing requests, and improve signaling path robustness, by relying on redirection. Redirection allows servers to push routing information for a request back in a response to the client, thereby taking themselves out of the loop of further messaging for this transaction while still aiding in locating the target of the request. When the originator of the request receives the redirection, it will send a new request based on the URI it has received. By propagating URIs from the core of the network to its edges, redirection allows for considerable network scalability.

A redirect server is logically constituted of a server transaction layer and a transaction user that has access to a location service of some kind (see Section 10 for more on registrars and location services). This location service is effectively a database containing mappings between a single URI and a set of one or more alternative locations at which the target of that URI can be found.

A redirect server does not issue any SIP requests of its own. After receiving a request other than CANCEL, the server gathers the list of alternative locations from the location service and either returns a final response of class 3xx or it refuses the request. For well-formed CANCEL requests, it SHOULD return a 2xx response. This response ends the SIP transaction. The redirect server maintains transaction state for an entire SIP transaction. It is the responsibility of clients to detect forwarding loops between redirect servers.

When a redirect server returns a 3xx response to a request, it populates the list of (one or more) alternative locations into Contact headers. An “expires” parameter to the Contact header may also be supplied to indicate the lifetime of the Contact data.

The Contact header field contains URIs giving the new locations or user names to try, or may simply specify additional transport parameters. A 301 (Moved Permanently) or 302 (Moved Temporarily) response may also give the same location and username that was targeted by the initial request but specify additional transport parameters such as a different server or multicast address to try, or a change of SIP transport from UDP to TCP or vice versa.

However, redirect servers MUST NOT redirect a request to a URI equal to the one in the Request-URI; instead, provided that the URI does not point to itself, the redirect server SHOULD proxy the request to the destination URI.

> If a client is using an outbound proxy, and that proxy actually redirects requests, a potential arises for infinite redirection loops.

Note that the Contact header field MAY also refer to a different entity than the one originally called. For example, a SIP call connected to GSTN gateway may need to deliver a special informational announcement such as “The number you have dialed has been changed.”

A Contact response header field can contain any suitable URI indicating where the called party can be reached, not limited to SIP URIs. For example, it could contain URIs for phones, fax, or irc (if they were defined) or a mailto: (RFC 2368, [36]) URL.

The “expires” parameter of the Contact header field indicates how long the URI is valid. The value of the parameter is a number indicating seconds. If this parameter is not provided, the value of the Expires header field determines how long the URI is valid. Implementations MAY treat values larger than 2**32-1 (4294967295 seconds or 136 years) as equivalent to 2**32-1. Malformed values should be treated as equivalent to 3600.

Redirect servers MUST ignore features that are not understood (including unrecognized headers, Required extensions, or even method names) and proceed with the redirection of the session in question. If a particular extension requires that intermediate devices support it, the extension MUST be tagged in the Proxy-Require field as well (see Section 24.29).

9 Canceling a Request

The previous section has discussed general UA behavior for generating requests, and processing responses, for requests of all methods. In this section, we discuss a general purpose method, called CANCEL.

The CANCEL request, as the name implies, is used to cancel a previous request sent by a client. Specifically, it asks the UAS to cease processing the request and to generate an error response to that request. CANCEL has no effect on a request to which a UAS has already responded. Because of this, it is most useful to CANCEL requests to which can take a long time to respond. For this reason, CANCEL is most useful for INVITE requests, which can take a long time to generate a response. In that usage, a UAS that receives a CANCEL request for an INVITE, but has not yet sent a response, would "stop ringing", and then respond to the INVITE with a specific error response (a 487).

CANCEL requests can be constructed and sent by any type of client, including both proxies and user agent clients. Section 15 discusses under what conditions a UAC would CANCEL an INVITE request, and Section 16.9 discusses proxy usage of CANCEL.

Because a stateful proxy can generate its own CANCEL, a stateful proxy also responds to a CANCEL, rather than simply forwarding a response it would receive from a downstream element. For that reason, CANCEL is referred to as a "hop-by-hop" request, since it is responded to at each stateful proxy hop.

9.1 Client Behavior

A CANCEL request SHOULD NOT be sent to cancel a request other than INVITE.

> Since requests other than INVITE are responded to immediately, sending a CANCEL for a non-INVITE request would always create a race condition.

The following procedures are used to construct a CANCEL request. The Request-URI, Call-ID, To, the numeric part of CSeq and From header fields in the CANCEL request MUST be identical to those in the request being cancelled, including tags. A CANCEL constructed by a client MUST have only a single Via header, whose value matches the top Via in the request being cancelled. Using the same values for these headers allows the CANCEL to be matched with the request it cancels (Section 9.2 indicates how such matching occurs). However, the method part of the CSeq header MUST have a value of CANCEL. This allows it to be identified and processed as a transaction in its own right (See Section 17).

If the request being cancelled contains Route header fields, the CANCEL request MUST include these Route header fields.

> This is needed so that stateless proxies are able to route CANCEL requests properly.

The CANCEL request MUST NOT contain any Require or Proxy-Require header fields.

Once the CANCEL is constructed, the client SHOULD check whether any response (provisional or final) has been received for the request being cancelled (herein referred to as the "original request"). The CANCEL request MUST NOT be sent if no provisional response has been received, rather, the client MUST wait for the arrival of a provisional response before sending the request. If the original request has generated a final response, the CANCEL SHOULD NOT be sent, as it is an effective no-op, since CANCEL has no effect on requests that have already generated a final response. When the client decides to send the CANCEL, it creates a client transaction for the CANCEL and passes it the CANCEL request along with the destination address, port, and transport. The destination address, port, and transport for the CANCEL MUST be identical to those used to send the original request.

> If it was allowed to send the CANCEL before receiving a response for the previous request, the server could receive the CANCEL before the original request.

Note that both the transaction corresponding to the original request and the CANCEL transaction will complete independently. However, a UAC canceling a request cannot rely on receiving a 487 (Request Terminated) response for the original request, as an RFC 2543-compliant UAS will not generate such a response. If there is no final response for the original request in 64*T1 seconds (T1 is defined in Section 17.1.1.1), the client SHOULD then consider the original transaction cancelled and SHOULD destroy the client transaction handling the original request.

9.2 Server Behavior

The CANCEL method requests that the TU at the server side cancel a pending transaction. The transaction to be canceled is determined by taking the CANCEL request, and then assuming that the request method were anything but CANCEL, apply the transaction matching procedures of Section 17.2.3. The matching transaction is the one to be canceled.

The processing of a CANCEL request at a server depends on the type of server. A stateless proxy will forward it, a stateful proxy might respond to it and generate some CANCEL requests of its own, and a UAS will respond to it. See Section 16.9 for proxy treatment of CANCEL.

A UAS first processes the CANCEL request according to the general UAS processing described in Section 8.2. However, since CANCEL requests are hop-by-hop and cannot be resubmitted, they cannot be challenged by the server in order to get proper credentials in an Authorization header field. Note also that CANCEL requests do not contain Require header fields.

If the CANCEL did not find a matching transaction according to the procedure above, the CANCEL SHOULD be responded to with a 481 (Call Leg/Transaction Does Not Exist). If the transaction for the original request still exists, the behavior of the UAS on receiving a CANCEL request depends on whether it has already sent a final response for the original request. If it has, the CANCEL request has no effect on the processing of the original request, no effect on any session state, and no effect on the responses generated for the original request. If the UAS has not issued a final response for the original request, its behavior depends on the method of the original request. If the original request was an INVITE, the UAS SHOULD immediately respond to the INVITE with a 487 (Request Terminated). The behavior upon reception of a CANCEL request for any other method defined in this specification is effectively no-op. Extensions to this specification that define new methods MUST define the behavior of a UAS upon reception of a CANCEL for those methods.

Regardless of the method of the original request, as long as the CANCEL matched an existing transaction, the CANCEL request itself is answered with a 200 (OK) response. This response is constructed following the procedures described in Section 8.2.6 noting that the To tag of the response to the CANCEL and the To tag in the response to the original request SHOULD be the same. The response to CANCEL is passed to the server transaction for transmission.

10 Registrations

10.1 Overview

SIP offers a discovery capability. If a user wants to initiate a session with another user, SIP must discover the current host(s) at which the destination user is reachable. This discovery process is accomplished by SIP proxy servers, which are responsible for receiving a request, determining where to send it based on knowledge of the location of the user, and then sending it there. To do this, proxies consult an abstract service known as a *location service*, which provides address bindings for a particular domain. These address bindings map an incoming SIP URI, `sip:bob@Biloxi.com`, for example, to one or more SIP URIs that are somehow "closer" to the desired user, `sip:bob@engineering.Biloxi.com`, for example. Ultimately, a proxy will consult a location service that maps a received URI to the current host(s) into which a user is logged.

Registration creates bindings in a location service for a particular domain that associate an address-of-record URI with one or more contact addresses. Thus, when a proxy for that domain receives a request whose Request-URI matches the address-of-record, the proxy will forward the request to the contact addresses registered to that address-of-record. Generally, it only makes sense to register an address-of-record at a domain's location service when requests for that address-of-record would be routed to that domain. In most cases, this means that the domain of the registration will need to match the domain in the URI of the address-of-record.

There are many ways by which the contents of the location service can be established. One way is administratively. In the above example, Bob is known to be a member of the engineering department through access to a corporate database. However, SIP provides a mechanism for a UA to create a binding explicitly. This mechanism is known as registration.

Registration entails sending a REGISTER request to a special type of UAS known as a registrar. The registrar acts as a front end to the location service for a domain, reading and writing mappings based on the contents of the REGISTER requests. This location service will then be consulted by a proxy server that is responsible for routing requests for that domain.

SIP does not mandate a particular mechanism for implementing the location service. The only requirement is that a registrar for some domain MUST be able to read and write data to the location service, and a proxy for that domain MUST be capable of reading that same data. A registrar MAY be co-located with a particular SIP proxy server for the same domain.

10.2 Constructing the REGISTER Request

REGISTER requests add, remove, and query bindings. A REGISTER request may add a new binding between an address-of-record and one or more contact addresses. Registration on behalf of a particular address-of-record may be performed by a suitably authorized third party. A client may also remove previous bindings or query to determine which bindings are currently in place for an address-of-record.

Except as noted, the construction of the REGISTER request and the behavior of clients sending a REGISTER request is identical to the general UAC behavior described in Section 8.1 and Section 17.1. The following header fields MUST be included:

Request-URI: The Request-URI names the domain of the location service for which the registration is meant (for example, "sip:chicago.com"). The "userinfo" and "@" components of the SIP URI MUST NOT be present.

To: The To header field contains the address of record whose registration is to be created, queried, or modified. The To header field and the Request-URI field typically differ, as the former contains a user name. This address-of-record MUST be a SIP URI.

From: The From header field contains the address-of-record of the person responsible for the registration. The value is the same as the To header field unless the request is a third-party registration.

```
                                              bob
                                            +----+
                                            | UA |
                                            |    |
                                            +----+
                                               |
                                               |3)INVITE
                                               |   carol@chicago.com
      chicago.com        +--------+            V
      +---------+ 2)Store|Location|4)Query +-----+
      |Registrar|=======>| Service|<=======|Proxy|sip.chicago.com
      +---------+        +--------+=======>+-----+
            A                      5)Resp      |
            |                                  |
            |                                  |
  1)REGISTER|                                  |
            |                                  |
         +----+                                |
         | UA |<-------------------------------+
cube2214a|    |                            6)INVITE
         +----+                    carol@cube2214a.chicago.com
          carol
```

Figure 2: REGISTER example

Call-ID: All registrations from a UAC SHOULD use the same Call-ID header value for registrations sent to a particular registrar.

If the same client were to use different Call-ID values, a registrar could not detect whether a delayed REGISTER request might have arrived out of order.

CSeq: The CSeq value guarantees proper ordering of REGISTER requests. A UA MUST increment the CSeq value by one for each REGISTER request with the same Call-ID.

Contact: REGISTER requests contain zero or more Contact header fields, containing address bindings.

UAs MUST NOT send a new registration (that is, containing new Contact header fields, as opposed to a retransmission) until they have received a final response from the registrar for the previous one or the previous REGISTER request has timed out.

The following Contact header parameters have a special meaning in REGISTER requests:

action: The “action” parameter from RFC 2543 has been deprecated. UACs SHOULD NOT use the “action” parameter.

expires: The “expires” parameter indicates how long the UA would like the binding to be valid. The value is a number indicating seconds. If this parameter is not provided, the value of the Expires header field is used instead. Implementations MAY treat values larger than 2**32-1 (4294967295 seconds or 136 years) as equivalent to 2**32-1. Malformed values should be treated as equivalent to 3600.

10.2.1 Adding Bindings

The REGISTER request sent to a registrar includes contact addresses to which SIP requests for the address-of-record should be forwarded. The address-of-record is included in the To header field of the REGISTER request.

The Contact header fields of the request typically contain SIP URIs that identify particular SIP endpoints (for example, "sip:carol@cube2214a.chicago.com"), but they MAY use any URI scheme. A SIP UA can choose to register telephone numbers (with the tel URL, [19]) or email addresses (with a mailto URL, [36]) as Contacts for an address-of-record.

For example, Carol, with address-of-record "sip:carol@chicago.com", would register with the SIP registrar of the domain chicago.com. Her registrations would then be used by a proxy server in the chicago.com domain to route requests for Carol's address-of-record to her SIP endpoint.

Once a client has established bindings at a registrar, it MAY send subsequent registrations containing new bindings or modifications to existing bindings as necessary. The 2xx response to the REGISTER request will contain, in Contact header fields, a complete list of bindings that have been registered for this address-of-record at this registrar.

Registrations do not need to update all bindings. Typically, a UA only updates its own SIP URI as well as any non-SIP URIs.

10.2.1.1 Setting the Expiration Interval of Contact Addresses When a client sends a REGISTER request, it MAY suggest an expiration interval that indicates how long the client would like the registration to be valid. (As described in Section 10.3, the registrar selects the actual time interval based on its local policy.)

There are two ways in which a client can suggest an expiration interval for a binding: through an Expires header field or an "expires" Contact header parameter. The latter allows expiration intervals to be suggested on a per-binding basis when more than one binding is given in a single REGISTER request, whereas the former suggests an expiration interval for all Contact header fields that do not contain the "expires" parameter.

If neither mechanism for expressing a suggested expiration time is present in a REGISTER, a default suggestion of one hour is assumed.

10.2.1.2 Preferences among Contact Addresses If more than one Contact is sent in a REGISTER request, the registering UA intends to associate all of the URIs given in these Contact header fields with the address-of-record present in the To field. This list can be prioritized with the "q" parameter in the Contact header fields. The "q" parameter indicates a relative preference for the particular Contact header field compared to other bindings present in this REGISTER message or existing within the location service of the registrar. Section 16.5 describes how a proxy server uses this preference indication.

10.2.2 Removing Bindings

Registrations are soft state and expire unless refreshed, but can also be explicitly removed. A client can attempt to influence the expiration interval selected by the registrar as described in Section 10.2.1. A UA requests the immediate removal of a binding by specifying an expiration interval of "0" for that contact address in a REGISTER request. UAs SHOULD support this mechanism so that bindings can be removed before their expiration interval has passed.

The REGISTER-specific Contact header field value of "*" applies to all registrations, but it MUST only be used when the Expires header field is present with a value of "0".

> Use of the "*" Contact header field value allows a registering UA to remove all of its bindings without knowing their precise values.

If no Contact header fields are present in a REGISTER request, the list of bindings is left unchanged.

10.2.3 Fetching Bindings

A success response to any REGISTER request contains the complete list of existing bindings, regardless of whether the request contained a Contact header field.

10.2.4 Refreshing Bindings

Each UA is responsible to refresh the bindings that it has previously established. A UA SHOULD NOT refresh bindings set up by other UAs.

The 200 (OK) response from the registrar contains a list of Contact fields enumerating all current bindings. The UA compares each contact address to see if it created the contact address, using comparison rules in Section 23.1.4. If so, it updates the expiration time interval according to the expires parameter or, if absent, the Expires field value. The UA then issues a REGISTER request for each of its bindings before the expiration interval has elapsed. It MAY combine several updates into one REGISTER request.

A UA SHOULD use the same Call-ID for all registrations during a single boot cycle. Registration refreshes SHOULD be sent to the same network address as the original registration, unless redirected.

10.2.5 Setting the Internal Clock

If the response for REGISTER request contains a Date header field, the client MAY use this header field to learn the current time in order to set any internal clocks.

10.2.6 Discovering a Registrar

UAs can use three ways to determine the address to which to send registrations: by configuration, using the address-of-record, and multicast. A UA can be configured, in ways beyond the scope of this specification, with a registrar address. If there is no configured registrar address, the UA SHOULD use the host part of the address-of-record as the Request-URI and address the request there, using the normal SIP server location mechanisms [2]. For example, the UA for the user "sip:carol@chicago.com" addresses the REGISTER request to "chicago.com".

Finally, a UA can be configured to use multicast. Multicast registrations are addressed to the well-known "all SIP servers" multicast address "sip.mcast.net" (224.0.1.75 for IPv4). No well-known IPv6 multicast address has been allocated; such an allocation will be documented separately when needed. This request MUST be scoped to ensure it is not forwarded beyond the boundaries of the administrative system. This MAY be done with either TTL or administrative scopes (see [12]), depending on what is implemented in the network. SIP UAs MAY listen to that address and use it to become aware of the location of other local users (see [40]); however, they do not respond to the request.

> Multicast registration may be inappropriate in some environments, for example, if multiple businesses share the same local area network.

10.2.7 Transmitting a Request

Once the REGISTER method has been constructed, and the destination of the message identified, UACs should follow the procedures described in Section 8.1.2 to hand off the REGISTER to the transaction layer.

If the transaction layer returns a timeout error because the REGISTER yielded no response, the UAC SHOULD wait some reasonable time interval before re-attempting a registration to the same registrar; no specific interval is mandated.

10.2.8 Error Responses

If a UA receives a 423 (Registration Too Brief) response, it MAY retry the registration after making the expiration interval of all contact addresses in the REGISTER request equal to or greater than the expiration interval within the Min-Expires header field of the 423 (Registration Too Brief) response.

10.3 Processing REGISTER Requests

A registrar is a UAS that responds to REGISTER requests and maintains a list of bindings that are accessible to proxy servers within its administrative domain. A registrar handles requests according to Section 8.2 and Section 17.2, but it accepts only REGISTER requests. A registrar does not generate 6xx responses.

If a registrar listens at a multicast interface, it MAY redirect multicast REGISTER requests to its own unicast interface with a 302 (Moved Temporarily) response.

A REGISTER request MUST NOT contain Record-Route or Route header fields; registrars MUST ignore them if they appear.

A registrar must know (for example, through configuration) the set of domain(s) for which it maintains bindings. REGISTER requests MUST be processed by a registrar in the order that they are received. REGISTER requests MUST also be processed atomically, meaning that REGISTER requests are either processed completely or not at all. Each REGISTER message must be processed independently of any other registration or binding changes.

When receiving a REGISTER request, a registrar follows these steps:

1. The registrar inspects the Request-URI to determine whether it has access to bindings for the domain identified in the Request-URI. If not, and if the server also acts as a proxy server, the server SHOULD forward the request to the addressed domain, following the general behavior for proxying messages described in Section 16.

2. To guarantee that the registrar supports any necessary extensions, the registrar processes Require header fields as described for UASs in Section 8.2.2.

3. A registrar SHOULD authenticate the UAC. Mechanisms for the authentication of SIP user agents are described in Section 20; registration behavior in no way overrides the generic authentication framework for SIP. If no authentication mechanism is available, the registrar MAY take the From address as the asserted identity of the originator of the request.

4. The registrar SHOULD determine if the authenticated user is authorized to modify registrations for this address-of-record. For example, a registrar might consult a authorization database that maps user names to a list of addresses-of-record for which this identity is authorized to modify bindings. If not, the registrar returns 403 (Forbidden) and skips the remaining steps.

> In architectures that support third-party registration, one entity may be responsible for updating the registrations associated with multiple addresses-of-record.

5. The registrar extracts the address-of-record from the To header field of request. If the address-of-record is not valid for the domain in the Request-URI, the registrar sends a 404 (Not Found) response and skips the remaining steps. The URI MUST then be converted to a canonical form. To do that, all URI parameters are removed (including the user-param), and any escaped characters are converted to their unescaped form. The result serves as an index into the list of bindings.

6. The registrar checks whether the request contains any Contact header fields. If not, it skips to the last step.

   Next, the registrar checks if there is one Contact field that contains the special value "*" and a Expires field. If the request has additional Contact fields or an expiration time other than zero, the request is invalid, and the server returns 400 (Invalid Request) and skips the remaining steps. If not, the registrar checks whether the Call-ID agrees with the value stored for each binding. If not, it removes the binding. If it does agree, it only removes the binding if the CSeq in the request is higher than the value stored for that binding and leaves the binding as is otherwise. It then skips to the last step.

7. The registrar now processes each contact address in the Contact header field in turn. For each address, it determines the expiration interval as follows:

   - If the field value has an "expires" parameter, that value is used.
   - If there is no such parameter, but the request has an Expires header field, that value is used.
   - If there is neither, a locally-configured default value is used.

   The registrar MAY shorten the expiration interval. If and only if the expiration interval is greater than zero AND smaller than one hour AND less than a registrar-configured minimum, the registrar MAY reject the registration with a response of 423 (Registration Too Brief). This response MUST contain a Min-Expires header field that states the minimum expiration interval the registrar is willing to honor. It then skips the remaining steps.

   > Allowing the registrar to set the registration interval protects it against excessively frequent registration refreshes while limiting the state that it needs to maintain and decreasing the likelihood of registrations going stale. The expiration interval of a registration is frequently used in the creation of services. An example is a follow-me service, where the user may only be available at a terminal for a brief period. Therefore, registrars should accept brief registrations; a request should only be rejected if the interval is so short that the refreshes would degrade registrar performance.

   For each address, the registrar then searches the list of current bindings using the URI comparison rules. If the binding does not exist, it is tentatively added. If the binding does exist, the registrar checks the Call-ID value. If the Call-ID value in the existing binding differs from the Call-ID value in the request, the binding is removed if the expiration time is zero and updated otherwise. If they are the same, the registrar compares the CSeq value. If the value is higher than that of the existing binding, it updates or removes the binding as above. If not, the update is aborted and the request fails.

   > This algorithm ensures that out-of-order requests from the same UA are ignored.

Each binding record records the Call-ID and CSeq values from the request.

The binding updates are committed (that is, made visible to the proxy) if and only if all binding updates and additions succeed. If any one of them fails, the request fails with 500 (Server Error) response and all tentative binding updates are removed.

8. The registrar returns a 200 (OK) response. The response MUST contain Contact header fields enumerating all current bindings. Each Contact value MUST feature an "expires" parameter indicating its expiration interval chosen by the registrar. The response SHOULD include a Date header field.

11 Querying for Capabilities

The SIP method OPTIONS allows a UA to query another UA or a proxy server as to its capabilities. This allows a client to discover information about the supported methods, content types, extensions, codecs, etc. without "ringing" the other party. For example, before a client inserts a Require header field into an INVITE listing an option that it is not certain the destination UAS supports, the client can query the destination UAS with an OPTIONS to see if this option is returned in a Supported header field.

The target of the OPTIONS request is identified by the Request-URI, which could identify another UA or a SIP server. If the OPTIONS is addressed to a proxy server, the Request-URI is set without a user part, similar to the way a Request-URI is set for a REGISTER request.

Alternatively, a server receiving an OPTIONS request with a Max-Forwards header value of 0 MAY respond to the request regardless of the Request-URI.

> This behavior is common with HTTP/1.1. This behavior can be used as a "traceroute" functionality to check the capabilities of individual hop servers by sending a series of OPTIONS requests with incremented Max-Forwards values.

As is the case for general UA behavior, the transaction layer can return a timeout error if the OPTIONS yields no response. This may indicate that the target is unreachable and hence unavailable.

An OPTIONS request MAY be sent as part of an established dialog to query the peer on capabilities that may be utilized later in the dialog.

11.1 Construction of OPTIONS Request

An OPTIONS request is constructed using the standard rules for a SIP request as discussed Section 8.1.1.

A Contact header field MAY be present in an OPTIONS.

An Accept header field SHOULD be included to indicate the type of message body the UAC wishes to receive in the response. Typically, this is set to a format that is used to describe the media capabilities of a UA, such as SDP (application/sdp).

The response to an OPTIONS request is assumed to be scoped to the Request-URI in the original request. However, only when an OPTIONS is sent as part of an established dialog is it guaranteed that future requests will be received by the server which generated the OPTIONS response.

Example OPTIONS request:

```
OPTIONS sip:carol@chicago.com SIP/2.0
Via: SIP/2.0/UDP 192.0.2.4;branch=z9hG4bKhjhs8ass877
To: <sip:carol@chicago.com>
```

```
From: Alice <sip:alice@atlanta.com>;tag=1928301774
Call-ID: a84b4c76e66710
CSeq: 63104 OPTIONS
Contact: <sip:alice@192.0.2.4>
Max-Forwards: 70
Accept: application/sdp
Content-Length: 0
```

11.2 Processing of OPTIONS Request

The response to an OPTIONS is constructed using the standard rules for a SIP response as discussed in Section 8.2.6. The response code chosen is the same that would have been chosen had the request been an INVITE. That is, a 200 (OK) would be returned if the UAS is ready to accept a call, a 486 (Busy Here) would be returned if the UAS is busy, etc. This allows an OPTIONS request to be used to determine the basic state of a UAS, which can be an indication of whether the UAC will accept an INVITE request.

An OPTIONS request received within a dialog generates a 200 (OK) response that is identical to one constructed outside a dialog and does not have any impact on the dialog.

This use of OPTIONS has limitations due the differences in proxy handling of OPTIONS and INVITE requests. While a forked INVITE can result in multiple 200 (OK) responses being returned, a forked OPTIONS will only result in a single 200 (OK) response, since it is treated by proxies using the non-INVITE handling. See Section 13.2.1 for the normative details.

If the response to an OPTIONS is generated by a proxy server, the proxy returns a 200 (OK) listing the capabilities of the server. The response does not contain a message body.

Allow, Accept, Accept-Encoding, Accept-Language, and Supported header fields SHOULD be present in a 200 (OK) response to an OPTIONS request. If the response is generated by a proxy, the Allow header field SHOULD be omitted as it is ambiguous since a proxy is method agnostic. Contact header fields MAY be present in a 200 (OK) response and have the same semantics as in a redirect. That is, they may list a set of alternative names and methods of reaching the user. A Warning header field MAY be present.

A message body MAY be sent, the type of which is determined by the Accept header in the OPTIONS request (application/sdp if the Accept header was not present). If the types include one that can describe media capabilities, the UA SHOULD include a body in the response for that purpose. Details on construction of such a body in the case of application/sdp are described in [1].

Example OPTIONS response generated by a UAS (corresponding to the request in Section 11.1):

```
SIP/2.0 200 OK
Via: SIP/2.0/UDP 192.0.2.4;branch=z9hG4bKhjhs8ass877
To: <sip:carol@chicago.com>;tag=93810874
From: Alice <sip:alice@atlanta.com>;tag=1928301774
Call-ID: a84b4c76e66710@100.1.3.3
CSeq: 63104 OPTIONS
Contact: <sip:carol@chicago.com>
Contact: <mailto:carol@chicago.com>
Allow: INVITE, ACK, CANCEL, OPTIONS, BYE
Accept: application/sdp
Accept-Encoding: gzip
```

```
Accept-Language: en
Supported: foo
Content-Type: application/sdp
Content-Length: 274

(SDP not shown)
```

12 Dialogs

A key concept for a user agent is that of a dialog. A dialog represents a peer-to-peer SIP relationship between a two user agents that persists for some time. The dialog facilitates sequencing of messages between the user agents and proper routing of requests between both of them. The dialog represents a context in which to interpret SIP messages. Section 8 discussed method independent UA processing for requests and responses outside of a dialog. This section discusses how those requests and responses are used to construct a dialog, and then how subsequent requests and responses are sent within a dialog.

A dialog is identified at each UA with a dialog ID, which consists of a Call-ID value, a local URI and local tag (together called the local address), and a remote URI and remote tag (together called the remote address). The dialog ID at each UA involved in the dialog is not the same. Specifically, the local URI and local tag at one UA are identical to the remote URI and remote tag at the peer UA. The tags are opaque tokens that facilitate the generation of unique dialog IDs.

A dialog ID is also associated with all responses and with any request that contains a tag in the To field. The rules for computing the dialog ID of a message depend on whether the entity is a UAC or UAS. For a UAC, the Call-ID value of the dialog ID is set to the Call-ID of the message, the remote address is set to the To field of the message, and the local address is set to the From field of the message (these rules apply to both requests and responses). As one would expect, for a UAS, the Call-ID value of the dialog ID is set to the Call-ID of the message, the remote address is set to the From field of the message, and the local address is set to the To field of the message.

A dialog contains certain pieces of state needed for further message transmissions within the dialog. This state consists of the dialog ID, a local sequence number (used to order requests from the UA to its peer), a remote sequence number (used to order requests from its peer to the UA), the URI of the remote target, and a route set, which is an ordered list of URIs. The route set is the set of servers that need to be traversed to send a request to the peer. A dialog can also be in the “early” state, which occurs when it is created with a provisional response, and then transition to the “confirmed” state when the final response comes.

12.1 Creation of a Dialog

Dialogs are created through the generation of non-failure responses to requests with specific methods. Within this specification, only 2xx and 101-199 responses with a To tag to INVITE establish a dialog. A dialog established by a non-final response to a request is in the “early” state and it is called an early dialog. Extensions MAY define other means for creating dialogs. Section 13 gives more details that are specific to the INVITE method. Here, we describe the process for creation of dialog state that is not dependent on the method.

A dialog is identified by a dialog ID. A dialog ID consists of three components, namely a call identifier component, a local address component and a remote address component. UAs MUST assign values to these components as described below.

12.1.1 UAS behavior

When a UAS responds to a request with a response that establishes a dialog (such as a 2xx to INVITE), the UAS MUST copy all Record-Route headers from the request into the response (including the URIs, URI parameters, and any Record-Route header parameters, whether they are known or unknown to the UAS) and MUST maintain the order of those headers. The UAS MUST add a Contact header field to the response. The Contact header field contains an address where the UAS would like to be contacted for subsequent requests in the dialog (which includes the ACK for a 2xx response in the case of an INVITE). Generally, the host portion of this URI is the IP address or FQDN of the host. The URI provided in the Contact header field MUST be a SIP URI and have global scope (i.e., the same SIP URI can be used outside this dialog to contact the UAS). The same way, the scope of the SIP URI in the Contact header field of the INVITE is not limited to this dialog either. It can therefore be used to contact the UAC even outside this dialog.

The UAS then constructs the state of the dialog. This state MUST be maintained for the duration of the dialog.

The route set MUST be set to the list of URIs in the Record-Route header field from the request, taken in order and preserving all URI parameters. If no Record-Route header field is present in the request, the route set MUST be set to the empty set. This route set, even if empty, overrides any pre-existing route set for future requests in this dialog. The remote target MUST be set to the URI from the Contact header field of the request.

The remote sequence number MUST be set to the value of the sequence number in the Cseq header field of the request. The local sequence number MUST be empty. The call identifier component of the dialog ID MUST be set to the value of the Call-ID in the request. The local address component of the dialog ID MUST be set to the To field in the response to the request (which therefore includes the tag), and the remote address component of the dialog ID MUST be set to the From field in the request. A UAS MUST be prepared to receive a request without a tag in the From field, in which case the tag is considered to have a value of null.

> This is to maintain backwards compatibility with RFC 2543, which did not mandate From tags.

12.1.2 UAC behavior

When a UAC receives a response that establishes a dialog, it constructs the state of the dialog. This state MUST be maintained for the duration of the dialog.

The route set MUST be set to the list of URIs in the Record-Route header field from the response, taken in reverse order and preserving all URI parameters. If no Record-Route header field is present in the response, the route set MUST be set to the empty set. This route set, even if empty, overrides any pre-existing route set for future requests in this dialog. The remote target MUST be set to the URI from the Contact header field of the response. The local sequence number MUST be set to the value of the sequence number in the Cseq header field of the request. The remote sequence number MUST be empty (it is established when the UA sends a request within the dialog). The call identifier component of the dialog ID MUST be set to the value of the Call-ID in the request. The local address component of the dialog ID MUST be set to the From field in the request, and the remote address component of the dialog ID MUST be set to the To field of the response. A UAC MUST be prepared to receive a response without a tag in the To field, in which case the tag is considered to have a value of null.

> This is to maintain backwards compatibility with RFC 2543, which did not mandate To tags.

12.2 Requests within a Dialog

Once a dialog has been established between two UAs, either of them MAY initiate new transactions as needed within the dialog. However, a dialog imposes some restrictions on the use of simultaneous transactions.

A TU MUST NOT initiate a new regular transaction within a dialog while a regular transaction is in progress (in either direction) within that dialog. If there is a non-INVITE client or server transaction in progress the TU MUST wait until this transaction enters the completed or the terminated state to initiate the new transaction.

OPEN ISSUE #113: Should we relax the constraint on non-overlapping regular transactions?

A route refresh request sent within a dialog is defined as a request that can modify the route set of the dialog. For dialogs that have been established with an INVITE, the only route refresh request defined is re-INVITE (see Section 14). Other extensions may define different route refresh requests for dialogs established in other ways.

Note that an ACK is *NOT* a route refresh request.

12.2.1 UAC Behavior

12.2.1.1 Generating the Request A request within a dialog is constructed by using many of the components of the state stored as part of the dialog.

The To header field of the request MUST be set to the remote address, and the From header field MUST be set to the local address (both including tags, assuming the tags are not null).

The Call-ID of the request MUST be set to the Call-ID of the dialog. Requests within a dialog MUST contain strictly monotonically increasing and contiguous CSeq sequence numbers (increasing-by-one) in each direction. Therefore, if the local sequence number is not empty, the value of the local sequence number MUST be incremented by one, and this value MUST placed into the Cseq header. If the local sequence number is empty, an initial value MUST be chosen using the guidelines of Section 8.1.1.5. The method field in the Cseq header MUST match the method of the request.

With a length of 32 bits, a client could generate, within a single call, one request a second for about 136 years before needing to wrap around. The initial value of the sequence number is chosen so that subsequent requests within the same call will not wrap around. A non-zero initial value allows clients to use a time-based initial sequence number. A client could, for example, choose the 31 most significant bits of a 32-bit second clock as an initial sequence number.

The UAC uses the remote target and route set to build the Request-URI and Route header field of the request.

If the route set is empty, the UAC MUST place the remote target URI into the Request-URI. The UAC MUST NOT add a Route header field to the request.

If the route set is not empty, and the first URI in the route set contains the lr parameter (see Section 23.1.1), the UAC MUST place the remote target URI into the Request-URI and MUST a Route header field containing the route set values in order, including all parameters.

If the route set is not empty and its first URI does not contain the lr parameter, the UAC MUST place the first URI from the route set into the Request-URI, stripping any parameters that are not allowed in a Request-URI. The UAC MUST add a Route header field containing the remainder of the route set values in order, including all parameters. The UAC MUST then place the the remote target URI into the Route header field as the last value.

For example, if the remote target is sip:user@remoteua and the route set contains

```
<sip:proxy1>,<sip:proxy2>,<sip:proxy3;lr>,<sip:proxy4>
```

The request will be formed with the following Request-URI and Route header field:

```
METHOD sip:proxy1
Route: <sip:proxy2>,<sip:proxy3;lr>,<sip:proxy4>,<sip:user@remoteua>
```

> If the first URI of the route set does not contain the lr parameter, the proxy indicated does not understand the routing mechanisms described in this document and will act as specified in RFC 2543, replacing the Request-URI with the first Route header field value it receives while forwarding the message. Placing the Request-URI at the end of the Route header field preserves the information in that Request-URI across the strict router (it will be returned to the Request-URI when the request reaches a loose-router).

A UAC SHOULD include a Contact header in any route refresh requests within a dialog, and unless there is a need to change it, the URI SHOULD be the same as used in previous requests within the dialog. As discussed in Section 12.2.2, a Contact header in a route refresh request updates the remote target URI. This allows a UA to provide a new contact address, should its address change during the duration of the dialog.

However, requests that are not route refresh requests do not affect the remote target URI for the dialog.

Once the request has been constructed, the address of the server is computed and the request is sent, using the same procedures for requests outside of a dialog (Section 8.1.1).

12.2.1.2 Processing the Responses The UAC will receive responses to the request from the transaction layer. If the client transaction returns a timeout this is treated as a 408 (Request Timeout) response.

The behavior of a UAC that receives a 3xx response for a request sent within a dialog is the same as if the request had been sent outside a dialog. This behavior is described in Section 13.2.2.

> Note, however, that when the UAC tries alternative locations, it still uses the route set for the dialog to build the Route header of the request.

When a UAC recieves a 2xx response to a route refresh resquest, it MUST replace the dialog's remote target URI with the URI from the Contact header field in that response, if present.

If the response for the a request within a dialog is a 481 (Call/Transaction Does Not Exist) or a 408 (Request Timeout), the UAC SHOULD terminate the dialog. A UAC SHOULD also terminate a dialog if no response at all is received for the request (the client transaction would inform the TU about the timeout.)

> For INVITE initiated dialogs, terminating the dialog consists of sending a BYE.

12.2.2 UAS behavior

Requests sent within a dialog, as any other requests, are atomic. If a particular request is accepted by the UAS, *all* the state changes associated with it are performed. If the request is rejected, *none* of the state changes is performed.

> Note that some requests such as INVITEs affect several pieces of state.

The UAS will receive the request from the transaction layer. If the request has a tag in the To header field, the UAS core computes the dialog identifier corresponding to the request and compares it with existing dialogs. If there is a match, this is a mid-dialog request. In that case, the UAS applies the same processing rules for requests outside of a dialog, discussed in Section 8.2.

If the request has a tag in the To header field, but the dialog identifier does not match any existing dialogs, the UAS may have crashed and restarted, or it may have received a request for a different (possibly failed) UAS (the UASs can construct the To tags so that a UAS can identify that the tag was for a UAS for which it is providing recovery). Another possibility is that the incoming request has been simply missrouted. Based on the To tag, the UAS MAY either accept or reject the request. Accepting the request for acceptable To tags provides robustness, so that dialogs can persist even through crashes. UAs wishing to support this capability must take into consideration some issues such as choosing monotonically increasing CSeq sequence numbers even across reboots, reconstructing the route set, and accepting out-of-range RTP timestamps and sequence numbers.

If the UAS wishes to reject the request, because it does not wish to recreate the dialog, it MUST respond to the request with a 481 (Call/Transaction Does Not Exist) status code and pass that to the server transaction.

Requests that do not change in any way the state of a dialog may be received within a dialog (for example, an OPTIONS request). They are processed as if they had been received outside the dialog.

Requests within a dialog MAY contain Record-Route and Contact header fields. However, these requests do not cause the dialog's route set to be modified, although they may modify the remote target URI. Specifically, requests which are not refresh requests do not modify the dialog's remote target URI, and requests which are route refresh requests do. This specification only defines one route refresh request: re-INVITE (see Section 14).

> Route refresh requests only update the dialog's remote target URI, and not the route set formed from Record-Route. Updating the latter would introduce severe backwards compatibility problems with RFC 2543-compliant systems.

If the remote sequence number is empty, it MUST be set to the value of the sequence number in the Cseq header in the request. If the remote sequence number was not empty, but the sequence number of the request is lower than the remote sequence number, the request is out of order and MUST be rejected with a 500 (Server Internal Error) response. If the remote sequence number was not empty, and the sequence number of the request is greater than the remote sequence number, the request is in order. It is possible for the CSeq header to be higher than the remote sequence number by more than one. This is not an error condition, and a UAS SHOULD be prepared to receive and process requests with CSeq values more than one higher than the previous received request. The UAS MUST then set the remote sequence number to the value of the sequence number in the Cseq header in the request.

> If a proxy challenges a request generated by the UAC, the UAC has to resubmit the request with credentials. The resubmitted request will have a new Cseq number. The UAS will never see the first request, and thus, it will notice a gap in the Cseq number space. Such a gap does not represent any error condition.

12.3 Termination of a Dialog

Dialogs can end in several different ways, depending on the method. When a dialog is established with INVITE, it is terminated with a BYE. No other means to terminate a dialog are described in this specification, but extensions can define other ways.

13 Initiating a Session

13.1 Overview

When a user agent client desires to initiate a session (for example, audio, video, or a game), it formulates an INVITE request. The INVITE request asks a server to establish a session. This request is forwarded by proxies, eventually arriving at one or more UAS that can potentially accept the invitation. These UASs will frequently need to query the user about whether to accept the invitation. After some time, those UAS can accept the invitation (meaning the session is to be established) by sending a 2xx response. If the invitation is not accepted, a 3xx, 4xx, 5xx or 6xx response is sent, depending on the reason for the rejection. Before sending a final response, the UAS can also send a provisional response (1xx), either reliably or unreliably, to advise the UAC of progress in contacting the called user.

After possibly receiving one or more provisional responses, the UA will get one or more 2xx responses or one non-2xx final response. Because of the protracted amount of time it can take to receive final responses to INVITE, the reliability mechanisms for INVITE transactions differ from those of other requests (like OPTIONS). Once it receives a final response, the UAC needs to send an ACK for every final response it receives. The procedure for sending this ACK depends on the type of response. For final responses between 300 and 699, the ACK processing is done in the transaction layer and follows one set of rules (See Section 17). For 2xx responses, the ACK is generated by the UAC core.

A 2xx response to an INVITE establishes a session, and it also creates a dialog between the UA that issued the INVITE and the UA that generated the 2xx response. Therefore, when multiple 2xx responses are received from different remote UAs (because the INVITE forked), each 2xx establishes a different dialog. All these dialogs are part of the same call.

This section provides details on the establishment of a session using INVITE.

13.2 Caller Processing

13.2.1 Creating the Initial INVITE

Since the initial INVITE represents a request outside of a dialog, its construction follows the procedures of Section 8.1.1. Additional processing is required for the specific case of INVITE.

An Allow header field (Section 24.5) SHOULD be present in the INVITE. It indicates what methods can be invoked within a dialog, on the UA sending the INVITE, for the duration of the dialog. For example, a UA capable of receiving INFO requests within a dialog [39] SHOULD include an Allow header listing the INFO method.

A Supported header field (Section 24.39) SHOULD be present in the INVITE. It enumerates all the extensions understood by the UAC.

An Accept (Section 24.1) header field MAY be present in the INVITE. It indicates which content-types are acceptable to the UA, in both the response received by it, and in any subsequent requests sent to it within dialogs established by the INVITE. The Accept header is especially useful for indicating support of various session description formats.

The UA MAY add an Expires header field (Section 24.19) to limit the validity of the invitation. If the time indicated in the Expires header field is reached and no final answer for the INVITE has been received the UAC core SHOULD generate a CANCEL request for the original INVITE.

A UAC MAY also find useful to add, among others, Subject (Section 24.38), Organization (Section 24.25) and User-Agent (Section 24.43) header fields. They all contain information related to the INVITE.

The UAC MAY choose to add a message body to the INVITE. Section 8.1.1.10 deals with how to construct the header fields – Content-Type among others – needed to describe the message body.

There are special rules for message bodies that contain a session description - their corresponding Content-Disposition is "session". SIP uses an offer/answer model where one UA sends a session description, called the offer, which contains a proposed description of the session. The offer indicates the desired communications means (audio, video, games), parameters of those means (such as codec types) and addresses for receiving media from the answerer. The other UA responds with another session description, called the answer, which indicates which communications means are accepted, the parameters which apply to those means, and addresses for receiving media from the offerer. The offer/answer model defines restrictions on when offers and answers can be made. This results in restrictions on where the offers and answers can appear in SIP messages. In this specification, offers and answers can only appear in INVITE and PRACK requests and responses. The usage of offers and answers is further restricted. For the initial INVITE transaction, the rules are:

- The initial offer MUST be in either an INVITE or, if not there, in the first reliable message from the callee back to the caller. In this specification, that is either the first reliable provisional response or the final 2xx response.

- If the initial offer is in an INVITE, the answer MUST be in a reliable message from callee back to caller which is correlated to that INVITE. For this specification, that is either a reliable provisional response or the final 2xx response to that INVITE.

- If the initial offer is in the first reliable message from the callee back to caller, the answer MUST be in the acknowledgement for that message (PRACK for a reliable provisional response or ACK for a 2xx response).

- After having sent or received an answer to the first offer, the UAC MAY generate subsequent offers in requests (PRACK alone for this specification), but only if it has received answers to any previous offers, and has not send any offers to which it hasn't gotten an answer.

- Once the UAS has sent or received an answer to the initial offer, it MUST NOT generate subsequent offers in any responses to the INVITE. Since only the UAC can send PRACK, this means the a UAS based on this specification alone can never generate subsequent offers.

Extensions to SIP which define new methods MAY specify whether offers and answers can appear in requests of that method or its responses. However, those extensions MUST adhere to the protocol rules specified in [2], and MUST adhere to the additional constraints in the list above.

Concretely, the above rules specify two exchanges for UAs which don't support reliable provisional responses - the offer is in the INVITE, and the answer in the 2xx, or the offer is in the 2xx, and the answer is in the ACK. When reliable provisional responses is supported, several more flows are possible. One possibility is to have the offer in the INVITE, and the answer in a reliable provisional response, with no further SDP exchanges.

All user agents that support INVITE and/or PRACK MUST support all exchanges that are possible based on the above rules and on their support for PRACK.

The Session Description Protocol (SDP) [11] MUST be supported by all user agents as a means to describe sessions, and its usage for constructing offers and answers MUST follow the procedures defined in [1].

The restrictions of the offer-answer model just described only apply to bodies whose Content-Disposition header field is "session". Therefore, it is possible that both the INVITE and the ACK contain a body message (e.g., the INVITE carries a photo (Content-Disposition: render) and the ACK a session description (Content-Disposition: session)).

> If the Content-Disposition header field is missing, bodies of Content-Type `application/sdp` imply the disposition "session", while other content types imply "render".

Once the INVITE has been created, the UAC follows the procedures defined for sending requests outside of a dialog (Section 8). This results in the construction of a client transaction that will ultimately send the request and deliver responses to the UAC.

13.2.2 Processing INVITE Responses

Once the INVITE has been passed to the INVITE client transaction, the UAC waits for responses for the INVITE. Responses are matched to their corresponding INVITE because they have the same Call-ID, the same From header field, the same To header field, excluding the tag, and the same CSeq. Rules for comparisons of these headers are described in Section 24. If the INVITE client transaction returns a timeout rather than a response the TU acts as if a 408 (Request Timeout) response had been received.

13.2.2.1 1xx responses Zero, one or multiple provisional responses may arrive before one or more final responses are received. Provisional responses for an INVITE request can create “early dialogs”. If a provisional response has a tag in the To field, and if the dialog ID of the response does not match an existing dialog, one is constructed using the procedures defined in Section 12.1.2.

The early dialog will only be needed if the UAC needs to send a request to its peer within the dialog before the initial INVITE transaction completes. This will be the case for all reliable provisional responses, which require transmission of PRACK. Header fields present in a provisional response are applicable as long as the dialog is in the early state (e.g., an Allow header field in a provisional response contains the methods that can be used in the dialog while this is in the early state).

If the 1xx is reliable and contains a session description, the UAC MUST generate an answer if the description is an offer. If the description is an answer, the session SHOULD be established based on the parameters of the offer and answer.

13.2.2.2 3xx responses A 3xx response may contain a Contact header field providing new addresses where the callee might be reachable. Depending on the status code of the 3xx response (see Section 25.3) the UAC MAY choose to try those new addresses.

13.2.2.3 4xx, 5xx and 6xx responses A single non-2xx final response may be received for the INVITE. 4xx, 5xx and 6xx responses may contain a Contact header field indicating the location where additional information about the error can be found.

All early dialogs are considered terminated upon reception of the non-2xx final response.

After having received the non-2xx final response the UAC core considers the INVITE transaction completed. The INVITE client transaction handles generation of ACKs for the response (see Section 17).

13.2.2.4 2xx responses Multiple 2xx responses may arrive at the UAC for a single INVITE request due to a forking proxy. Each response is distinguished by the tag parameter in the To header field, and each represents a distinct dialog, with a distinct dialog identifier.

If the dialog identifier in the 2xx response matches the dialog identifier of an existing dialog, the dialog MUST be transitioned to the “confirmed” state, and the route set for the dialog MUST be recomputed based on the 2xx response using the procedures of Section 12.1.2. Otherwise, a new dialog in the “confirmed” state is constructed in the same fashion.

> The route set only is recomputed for backwards compatibility. RFC 2543 did not mandate mirroring of Record-Route headers in a 1xx, only 2xx. However, we cannot update the entire state of the dialog, since mid-dialog requests may have been sent within the early call leg, modifying the sequence numbers, for example.

The UAC core MUST generate an ACK request for each 2xx received from the transaction layer. The header fields of the ACK are constructed in the same way as for any request sent within a dialog (see Section

12) with the exception of the CSeq and the header fields related to authentication. The sequence number of the CSeq header field MUST be the same as the INVITE being acknowledged, but the CSeq method MUST be ACK. The ACK MUST contain the same credentials as the INVITE. If the 2xx contains an offer (based on the rules above), the ACK MUST carry an answer in its body. If the offer in the 2xx response is not acceptable, the UAC core MUST generate a valid answer in the ACK and then send a BYE immediately.

Once the ACK has been constructed, the procedures of [2] are used to determine the destination address, port and transport. However, the request is passed to the transport layer directly for transmission, rather than a client transaction. This is because the UAC core handles retransmissions of the ACK, not the transaction layer. The ACK MUST be passed to the client transport every time a retransmission of the 2xx final response that triggered the ACK arrives.

The UAC core considers the INVITE transaction completed 64*T1 seconds after the reception of the first 2xx response. At this point all the early dialogs that have not transitioned to established dialogs are terminated. Once the INVITE transaction is considered completed by the UAC core, no more new 2xx responses are expected to arrive.

If, after acknowledging any 2xx response to an INVITE, the caller does not want to continue with that dialog, then the caller MUST terminate the dialog by sending a BYE request as described in Section 15.

13.3 Callee Processing

13.3.1 Processing of the INVITE

The UAS core will receive INVITE requests from the transaction layer. It first performs the request processing procedures of Section 8.2, which are applied for both requests inside and outside of a dialog.

Assuming these processing states complete without generating a response, the UAS core performs the additional processing steps:

1. If the request is an INVITE that contains an Expires header field the UAS core inspects this header field. If the INVITE has already expired a 487 (Request Terminated) response SHOULD be generated. In any case, if the INVITE expires before the UAS has generated a final response a 487 (Request Terminated) response SHOULD be generated.

2. If the request is a mid-dialog request, the method-independent processing described in Section 12.2.2 is first applied. It might also modify the session; Section 14 provides details.

3. If the request has a tag in the To header field but the dialog identifier does not match any of the existing dialogs, the UAS may have crashed and restarted, or may have received a request for a different (possibly failed) UAS. Section 12.2.2 provides guidelines to achieve a robust behaviour under such a situation.

Processing from here forward assumes that the INVITE is outside of a dialog, and is thus for the purposes of establishing a new session.

The INVITE may contain a session description, in which case the UAS is being presented with an offer for that session. It is possible that the user is already a participant in that session, even though the INVITE is outside of a dialog. This can happen when a user is invited to the same multicast conference by multiple other participants. If desired, the UAS MAY use identifiers within the session description to detect this duplication. For example, SDP contains a session id and version number in the origin (o) field. If the user is already a member of the session, and the session parameters contained in the session description have not changed, the UAS MAY silently accept the INVITE (that is, send a 2xx response without prompting the user).

The INVITE may not contain a session description at all, in which case the UAS is being asked to participate in a session, but the UAC has asked that the UAS provide the offer of the session. It MUST provide the offer in its first reliable message back to the UAC.

The callee can indicate progress, accept, redirect, or reject the invitation. In all of these cases, it formulates a response using the procedures described in Section 8.2.6.

13.3.1.1 Progress The UAS may not be able to answer the invitation immediately, and might choose to indicate some kind of progress to the caller (for example, an indication that a phone is ringing). This is accomplished with a provisional response between 101 and 199. These provisional responses establish early dialogs and therefore follow the procedures of Section 12.1.1 in addition to those of Section 8.2.6. A UAS MAY send as many provisional responses as it likes. Each of these MUST indicate the same dialog ID. However, these will not be delivered reliably unless reliable provisional responses are used.

If the INVITE contained an offer, the UAS MAY generate an answer in a reliable provisional response (assuming these are supported by the UAC). That results in the establishment of the session before completion of the call. Similarly, if a reliable provisional response is the first reliable message sent back to the caller, and the INVITE did not contain an offer, one MUST appear in that reliable provisional response.

If the UAS will require an extended period of time to answer the INVITE, it will need to ask for an “extension” in order to prevent proxies from cancelling the transaction. A proxy has the option of canceling a transaction when there is a gap of 3 minutes between messages in a transaction. To prevent cancellation, the UAS MUST send a non-100 provisional response at least that often. This response SHOULD be sent reliably, if supported by the UAC. If not, the UAS SHOULD send provisional responses every minute, to handle the possibility of lost provisional responses.

> An INVITE transaction can go on for extended durations when the user is placed on hold, or when interworking with PSTN systems which allow communications to take place without answering the call. The latter is common in Interactive Voice Response (IVR) systems.

13.3.1.2 The INVITE is redirected If the UAS decides to redirect the call, a 3xx response is sent. A 300 (Multiple Choices), 301 (Moved Permanently) or 302 (Moved Temporarily) response SHOULD contain a Contact header field containing URIs of new addresses to be tried. The response is passed to the INVITE server transaction, which will deal with its retransmissions.

13.3.1.3 The INVITE is rejected A common scenario occurs when the callee is currently not willing or able to take additional calls at this end system. A 486 (Busy Here) SHOULD be returned in such scenario. If the UAS knows that no other end system will be able to accept this call a 600 (Busy Everywhere) response SHOULD be sent instead. However, it is unlikely that a UAS will be able to know this in general, and thus this response will not usually be used. The response is passed to the INVITE server transaction, which will deal with its retransmissions.

A UAS rejecting an offer contained in an INVITE SHOULD return a 488 (Not Acceptable Here) response. Such a response SHOULD include a Warning header field explaining why the offer was rejected.

13.3.1.4 The INVITE is accepted The UAS core generates a 2xx response. This response establishes a dialog, and therefore follows the procedures of Section 12.1.1 in addition to those of Section 8.2.6.

If the UAS had placed a session description in any reliable provisional response that is unacknowledged when the INVITE is accepted, the UAS MUST delay sending the 2xx until the provisional response is acknowledged. Otherwise, the reliability of the 1xx cannot be guaranteed.

A 2xx response to an INVITE SHOULD contain the Allow header field and the Supported header field, and MAY contain the Accept header field. Including these header fields allows the UAC to determine the features and extensions supported by the UAS for the duration of the call, without probing.

If the INVITE request contained an offer, and the UAS had not yet sent an answer, the 2xx MUST contain an answer. If the INVITE did not contain an offer, the 2xx MUST contain an offer if the UAS had not yet sent an offer.

Once the response has been constructed it is passed to the INVITE server transaction. Note, however, that the INVITE server transaction will be destroyed as soon as it receives this final response. Therefore, it is necessary to pass periodically the response to the transport until the ACK arrives. The 2xx response is passed to the transport with an interval that starts at T1 seconds and doubles for each retransmission until it reaches T2 seconds (T1 and T2 are defined in Section 17). Response retransmissions cease when an ACK request is received with the same dialog ID as the response. This is independent of whatever transport protocols are used to send the response.

> Since 2xx is retransmitted end-to-end, there may be hops between UAS and UAC which are UDP. To ensure reliable delivery across these hops, the response is retransmitted periodically even if the transport at the UAS is reliable.

If the server retransmits the 2xx response for 64*T1 seconds without receiving an ACK, it considers the dialog completed, the session terminated, and therefore it SHOULD send a BYE.

14 Modifying an Existing Session

A successful INVITE request (see Section 13) establishes both a dialog between two user agents and a session (using the offer/answer model). Section 12 explains how to modify an existing dialog using a route refresh request (for example, changing the remote target URI of the dialog). This section describes how to modify the actual session. This modification can involve changing addresses or ports, adding a media stream, deleting a media stream, and so on. This is accomplished by sending a new INVITE request within the same dialog that established the session. An INVITE request sent within an existing dialog is known as a re-INVITE.

> Note that a single re-INVITE can modify the dialog and the parameters of the session at the same time.

Either the caller or callee can modify an existing session.

The behavior of a UA on detection of media failure is a matter of local policy. However, automated generation of re-INVITE or BYE is NOT RECOMMENDED to avoid flooding the network with traffic when there is congestion. In any case, if these messages are sent automatically, they SHOULD be sent after some randomized interval.

> Note that the paragraph above refers to automatically generated BYEs and re-INVITEs. If the user hangs up upon media failure the UA would send a BYE request as usual.

14.1 UAC Behavior

The same offer-answer model that applies to session descriptions in INVITEs (Section 13.2.1) applies to re-INVITEs. As a result, a UAC that wants to add a media stream, for example, will create a new offer that contains this media stream, and send that in an INVITE request to its peer. It is important to note that the full description of the session, not just the change, is sent. This supports stateless session processing in various elements, and supports failover and recovery capabilities. Of course, a UAC MAY send a re-INVITE with no session description, in which case the first reliable response to the re-INVITE will contain the offer.

If the session description format has the capability for version numbers, the offerer SHOULD indicate that the version of the session description has changed.

The To, From, Call-ID, CSeq, and Request-URI of a re-INVITE are set following the same rules as for regular requests within an existing dialog, described in Section 12.

A UAC MAY choose not to add Alert-Info header fields or bodies with Content-Disposition "alert" to re-INVITEs because UASs do not typically alert the user upon reception of a re-INVITE.

Note that, as opposed to initial INVITEs (see Section 13), re-INVITEs contain tags in the To header field and are sent using the route set for the dialog. Therefore, a single final (2xx or non-2xx) response is received for re-INVITEs.

Note that a UAC MUST NOT initiate a new INVITE transaction within a dialog while another transaction (INVITE or non-INVITE) is in progress in either direction.

1. If there is an ongoing INVITE client transaction, the TU MUST wait until the transaction reaches the *completed* or *terminated* state before initiating the new INVITE.

2. If there is an ongoing INVITE server transaction, the TU MUST wait until the transaction reaches the *confirmed* or *terminated* state before initiating the new INVITE.

3. If there is an ongoing non-INVITE client or server transaction, the TU MUST wait until the transaction reaches the *completed* or *terminated* state before initiating the new INVITE.

However, a UA MAY initiate a regular transaction while an INVITE transaction is in progress.

If a UA receives a non-2xx final response to a re-INVITE, the session parameters MUST remain unchanged, as if no re-INVITE had been issued. Note that, as stated in Section 12.2.1.2, if the non-2xx final response is a 481 (Call/Transaction Does Not Exist), or a 408 (Request Timeout), or no response at all is received for the re-INVITE (that is, a timeout is returned by the INVITE client transaction), the UAC will terminate the dialog.

The rules for transmitting a re-INVITE and for generating an ACK for a 2xx response to re-INVITE are the same as for an INVITE (Section 13.2.1).

14.2 UAS Behavior

Section 13.3.1 describes the steps to follow in order to distinguish incoming re-INVITEs from incoming initial INVITEs. This section describes the procedures to follow upon reception of a re-INVITE for an existing dialog.

A UAS that receives a second INVITE before it sends the final response to a first INVITE with a lower CSeq sequence number on the same dialog MUST return a 500 (Server Internal Error) response to the second INVITE and MUST include a Retry-After header field with a randomly chosen value of between 0 and 10 seconds.

A UAS that receives an INVITE on a dialog while an INVITE it had sent on that dialog is in progress MUST return a 491 (Request Pending) response to the received INVITE and MUST include a Retry-After header field with a value chosen as follows:

1. If the UAS is the owner of the Call-ID of the dialog ID, the Retry-After header field has a randomly chosen value of between 2.1 and 4 seconds in units of 10 ms.

2. If the UAS is *not* the owner of the Call-ID of the dialog ID, the Retry-After header field has a randomly chosen value of between 0 and 2 seconds in units of 10 ms.

If a UA receives a re-INVITE for an existing dialog, it MUST check any version identifiers in the session description or, if there are no version identifiers, the content of the session description to see if it has changed. If the session description has changed, the UAS MUST adjust the session parameters accordingly, possibly after asking the user for confirmation.

Versioning of the session description can be used to accommodate the capabilities of new arrivals to a conference, add or delete media or change from a unicast to a multicast conference.

If the new session

description is not acceptable, the UAS can reject it by returning a 488 (Not Acceptable Here) response for the re-INVITE. This response SHOULD include a Warning header field.

If a UAS generates a 2xx response and never receives an ACK, it SHOULD generate a BYE to terminate the dialog.

A UAS MAY choose not to generate 180 (Ringing) responses for a re-INVITE because UACs do not typically render this information to the user. For the same reason, UASs MAY choose not to use Alert-Info header fields or bodies with Content-Disposition "alert" in responses to a re-INVITE.

A UAS providing an offer in a 2xx (because the INVITE did not contain an offer) SHOULD construct the offer as if the UAS were making a brand new call, subject to the constraints of sending an offer which updates an existing session, as described in [1] in the case of SDP. Specifically, this means that it SHOULD include as many media formats and media types that the UA is willing to support. The UAS MUST ensure that the session description overlaps with its previous session description in media formats, transports, or other parameters that require support from the peer. This is to avoid the need for the peer to reject the session description. If, however, it is unacceptable to the UAC, the UAC SHOULD generate an answer with a valid session description, and then send a BYE to terminate the session.

15 Terminating a Session

This section describes the procedures for terminating a SIP dialog. For two-party sessions that are otherwise unbound in time, the termination of the dialog implies the termination of the session. Other types of sessions, such as multicast sessions, are not terminated when a participant terminates the SIP dialog that he used to join the session. However, the SIP dialog SHOULD be terminated even though its termination does not imply the termination of the session. A UA joining a multicast session MAY terminate the SIP dialog immediately after the INVITE transaction used to join the session has completed.

Either the caller or callee may terminate a dialog for any reason. A caller terminates a dialog either with BYE or CANCEL depending on the state of the dialog. A callee uses BYE to terminate a confirmed dialog.

If the callee wants to terminate an early dialog, it just returns a non-2xx final response for the INVITE.

Sections 13 and 12 document some cases where dialog termination is normative behavior. If a UA decides to terminate the dialog, it MUST follow the procedures here to initiate signaling action to convey that.

When a UAC sends an INVITE request to create a session, if a 1xx response with a tag in the To field is received, an early dialog is created. When a 2xx response is received, the dialog becomes confirmed. For a confirmed dialog, if the UAC desires to terminate the session, the UAC SHOULD follow the procedures described in Section 15.1.1 to terminate the session. If the callee for a new session wishes to terminate the dialog, it uses the procedures of Section 15.1.1, but MUST NOT do so until it has received an ACK or until the server transaction times out.

> This does not mean a user cannot hang up right away; it just means that the software in his phone needs to maintain state for a short while in order to clean up properly.

If the UAC desires to end the session before a confirmed dialog has been created, it SHOULD send a CANCEL for the INVITE request that requested establishment of the session that is to be terminated. The UAC constructs and sends the CANCEL following the procedures described in Section 9. This CANCEL will normally result in a 487 (Request Terminated) response to be returned to the INVITE, indicating successful cancellation. However, it is possible that the CANCEL and a 2xx response to the INVITE “pass on the wire”. In this case, the UAC will receive a 2xx to the INVITE. It SHOULD then terminate the call by following the procedures described in Section 15.1.1.

A UAC can terminate a specific early dialog by following the procedures described in Section 15.1.1. This would only terminate one particular early dialog.

15.1 Terminating a Dialog with a BYE Request

15.1.1 UAC Behavior

A user agent client uses the BYE request, sent within a dialog, to indicate to the server that it wishes to terminate the session. This will also terminate the dialog. A BYE request MAY be issued by either caller or callee. A BYE request SHOULD NOT be sent before the creation of a dialog (either early or confirmed). In that case the UAC SHOULD follow the procedures described in Section 9 instead.

> Proxies ensure that a CANCEL request is routed in the same way as the INVITE was. However, a proxy performing load balancing may route a BYE without a Route header field in a different way than the INVITE, since both requests have different CSeq sequence numbers.

The To, From, Call-ID, CSeq, and Request-URI of a BYE are set following the same rules as for regular requests sent within a dialog, described in Section 12.

Once the BYE is constructed, it creates a new non-INVITE client transaction, and passes it the BYE request. The UA SHOULD stop sending media as soon as the BYE request is passed to the client transaction. If the response for the BYE is a 481 (Call/Transaction Does Not Exist) or a 408 (Request Timeout) or no response at all is received for the BYE (that is, a timeout is returned by the client transaction), the UAC considers the dialog down.

15.1.2 UAS Behavior

A UAS first processes the BYE request according to the general UAS processing described in Section 8.2. A UAS core receiving a BYE request checks if it matches an existing dialog. If the BYE does not match an existing dialog, the UAS core SHOULD generate a 481 (Call/Transaction Does Not Exist) response and pass that to the server transaction.

> This rule means that a BYE sent without tags by a UAC will be rejected. This is a change from RFC 2543, which allowed BYE without tags.

A UAS core receiving a BYE request for an existing dialog MUST follow the procedures of Section 12.2.2 to process the request. Once done, the UAS MUST cease transmitting media streams for the session being terminated. The UAS core MUST generate a 2xx response to the BYE, and MUST pass that to the server transaction for transmission.

The UAS MUST still respond to any pending requests received for that dialog, (which can only be an INVITE). It is RECOMMENDED that a 487 (Request Terminated) response is generated to those pending requests.

16 Proxy Behavior

16.1 Overview

SIP proxies are elements that route SIP requests to user agent servers and SIP responses to user agent clients. A request may traverse several proxies on its way to a UAS. Each will make routing decisions, modifying the request before forwarding it to the next element. Responses will route through the same set of proxies traversed by the request in the reverse order.

Being a proxy is a logical role for a SIP element. When a request arrives, an element that can play the role of a proxy must first decide if it needs to respond to the request on its own. For instance, the request could be malformed or the element may need credentials from the client before acting as a proxy. The element MAY respond with any appropriate error code. When responding directly to a request, the element is playing the role of a UAS and MUST behave as described in Section 8.2.

A proxy can operate in either a stateful or stateless mode for each new request. When stateless, a proxy acts as a simple forwarding element. It forwards each request downstream to a single element determined by making a routing decision based on the request. It simply forwards every response it receives upstream. A stateless proxy discards information about a message once it has been forwarded.

On the other hand, a stateful proxy remembers information (specifically, transaction state) about each incoming request and any requests it sends as a result of processing the incoming request. It uses this information to affect the processing of future messages associated with that request. A stateful proxy MAY chose to "fork" a request, routing it to multiple destinations. Any request that is forwarded to more than one location MUST be handled statefully.

In some circumstances, a proxy MAY forward requests using stateful transports (such as TCP) without being transaction stateful. For instance, a proxy MAY forward a request from one TCP connection to another transaction statelessly as long as it places enough information in the message to be able to forward the response down the same connection the request arrived on. Requests forwarded between different types of transports where the proxy's TU must take an active role in ensuring reliable delivery on one of the transports MUST be forwarded transaction statefully.

A stateful proxy MAY transition to stateless operation at any time during the processing of a request, so long as it did not do anything that would otherwise prevent it from being stateless initially (forking, for example, or generation of a 100 response). When performing such a transition, all state is simply discarded. The proxy SHOULD NOT send a CANCEL.

Much of the processing involved when acting statelessly or statefully for a request is identical. The next several subsections are written from the point of view of a stateful proxy. The last section calls out those places where a stateless proxy behaves differently.

16.2 Stateful Proxy

When stateful, a proxy is purely a SIP transaction processing engine. Its behavior is modeled here in terms of the Server and Client Transactions defined in Section 17. A stateful proxy has a server transaction associated with one or more client transactions by a higher layer proxy processing component (see figure 3), known as a proxy core. An incoming request is processed by a server transaction. Requests from the server transaction are passed to a proxy core. The proxy core determines where to route the request, choosing one or more next-hop locations. An outgoing request for each next-hop location is processed by its own associated client transaction. The proxy core collects the responses from the client transactions and uses them to send responses to the server transaction.

A stateful proxy creates a new server transaction for each new request received. Any retransmissions of the request will then be handled by that server transaction per Section 17.

This is a model of proxy behavior, not of software. An implementation is free to take any approach that replicates the external behavior this model defines.

For all new requests, including any with unknown methods, an element intending to proxy the request MUST:

1. Validate the request (Section 16.3)
2. Make a routing decision (Section 16.4)
3. Forward the request to each chosen destination (Section 16.5)
4. Process all responses (Section 16.6)

16.3 Request Validation

Before an element can proxy a request, it MUST verify the message's validity. A valid message must pass the following checks:

1. Reasonable Syntax
2. Max-Forwards
3. (Optional) Loop Detection
4. Proxy-Require
5. Proxy-Authorization

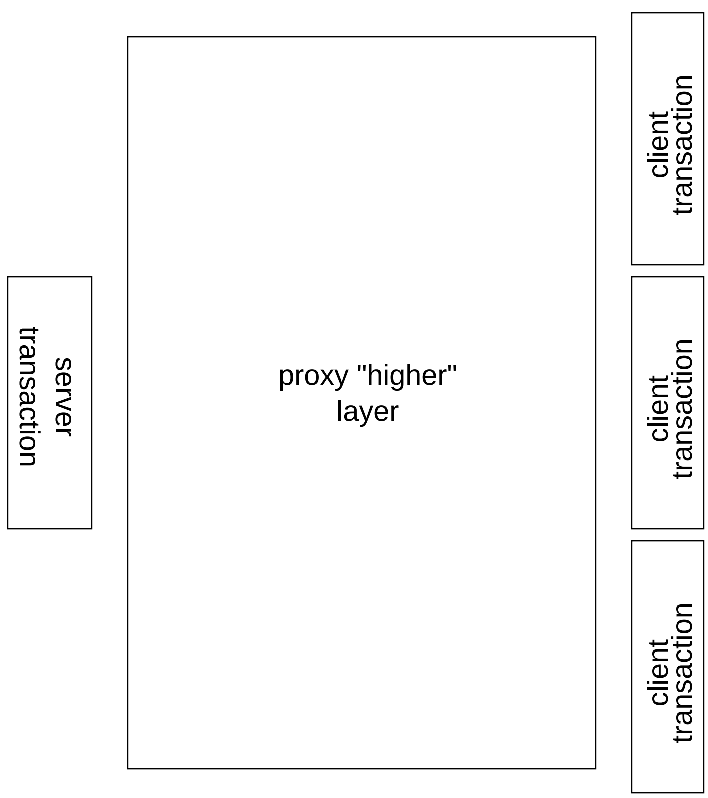
If any of these checks fail, the element MUST behave as a user agent server (see Section 8.2) and respond with an error code.

Notice that a proxy is not required to detect merged requests and MUST NOT treat merged requests as an error condition. The endpoints receiving the requests will resolve the merge as described in Section 8.2.2.2.

1. Reasonable Syntax check

   The request MUST be well-formed enough to be handled with a server transaction. Any components involved in the remainder of these Request Validation steps or the Request Processing section MUST be well-formed. Any other components, well-formed or not, SHOULD be ignored and remain unchanged when the message is forwarded. For instance, an element SHOULD NOT reject a request because of a malformed Date header field. Likewise, a proxy SHOULD NOT remove a malformed Date header field before forwarding a request.

   This protocol is designed to be extended. Future extensions may define new methods and header fields at any time. An element MUST NOT refuse to proxy a request because it contains a method or header field it does not know about.


server transaction
proxy "higher" layer
client transaction
client transaction
client transaction

2. Max-Forwards check

   The Max-Forwards header field (Section 24.22) is used to limit the number of elements a SIP request can traverse.

   If the request does not contain a Max-Forwards header field, this check is passed.

   If the request contains a Max-Forwards header field with a field value greater than zero, the check is passed.

   If the request contains a Max-Forwards header field with a field value of zero (0), the element MUST NOT forward the request. If the request was for OPTIONS, the element MAY act as the final recipient and respond per Section 11. Otherwise, the element MUST return a 483 (Too many hops) response.

3. Optional Loop Detection check

   An element MAY check for forwarding loops before forwarding a request. If the request contains a Via header field with a sent-by value that equals a value placed into previous requests by the proxy, the request has been forwarded by this element before. The request has either looped or is legitimately spiraling through the element. To determine if the request has looped, the element MAY perform the branch parameter calculation described in Step 3 of Section 16.5 on this message and compare it to the parameter received in that Via header field. If the parameters match, the request has looped. If they differ, the request is spiraling, and processing continues. If a loop is detected, the element MAY return a 482 (Loop Detected) response.

   > In earlier versions of this memo, loop detection was REQUIRED. This requirement has been relaxed in favor of the Max-Forwards mechanism.

4. Proxy-Require check

   Future extensions to this protocol may introduce features that require special handling by proxies. Endpoints will include a Proxy-Require header field in requests that use these features, telling the proxy it should not process the request unless the feature is understood.

   If the request contains a Proxy-Require header field (Section 24.29) with one or more option-tags this element does not understand, the element MUST return a 420 (Bad Extension) response. The response MUST include an Unsupported (Section 24.42) header field listing those option-tags the element did not understand.

5. Proxy-Authorization check

   If an element requires credentials before forwarding a request, the request MUST be inspected as described in Section 20.3. That section also defines what the element must do if the inspection fails.

16.4 Making a Routing Decision

At this point, the proxy must decide where to forward the request. This can be modeled as computing a set of destinations for the request. This set will either be predetermined by the contents of the request or will be obtained from an abstract location service. Each destination is represented as a URI, and is is referred to as a “next-hop location”.

First, the proxy MUST inspect the Request-URI of the request. If the Request-URI of the request contains a value this proxy previously placed into a Record-Route header field (see Section 16.5 item 6), the proxy MUST replace the Request-URI in the request with the last value from the Route header field, and remove that value from the Route header field. The proxy MUST then proceed as if it received this modified request.

> This will only happen when the element sending the request to the proxy (which may have been an endpoint) is a strict router. This rewrite on receive is necessary to enable backwards compatibility with those elements. It also allows elements following this specification to preserve the Request-URI through strict-routing proxies (see Section refsec:dialog:uac:generate).

> This requirement does not obligate a proxy to keep state in order to detect URIs it previously placed in Record-Route header fields. Instead, a proxy need only place enough information in those URIs to recognize them as values it provided when they later appear.

If the Request-URI has a URI whose scheme is not understood by the proxy, the proxy SHOULD reject the request with a 416 (Unsupported URI Scheme) response. If the Request-URI contains an maddr parameter, the proxy MUST check to see if its value is in the set of addresses or domains the proxy is configured to be responsible for. If the Request-URI has an maddr parameter with a value the proxy is responsible for, and the request was received using the port and transport indicated (explicitly or by default) in the Request-URI, the proxy MUST strip the maddr and any non-default port or transport parameter and continue processing as if those values had not been present in the request. Otherwise, if the Request-URI contains an maddr parameter, the Request-URI MUST be placed into the destination set as the only next hop URI, and the proxy MUST proceed to Section 16.5.

> A request may arrive with an maddr matching the proxy, but on a port or transport different from that indicated in the URI. Such a request needs to be forwarded to the proxy using the indicated port and transport.

If the domain of the Request-URI indicates a domain this element is not responsible for, it SHOULD set the next hop URI to the Request-URI. That next hop MUST be placed into the destination set as the only next hop, and the element MUST proceed to the task of Request Processing (Section 16.5).

> There are many circumstances in which a proxy might receive a request for a domain it is not responsible for. A firewall proxy handling outgoing calls (the way HTTP proxies handle outgoing requests) is an example of where this is likely to occur.

If the destination set for the request has not been predetermined as described above, this implies that the element is responsible for the domain in the Request-URI, and the element MAY use whatever mechanism it desires to determine where to send the request. However, if the request contains a Route header, the proxy MUST only choose a single destination for the request. Any of these mechanisms can be modeled as accessing an abstract Location Service. This may consist of obtaining information from a location service created by a SIP Registrar, reading a database, consulting a presence server, utilizing other protocols, or simply performing an algorithmic substitution on the Request-URI. When accessing the location service constructed by the registrar, the Request-URI MUST first be canonicalized as described in Section 10.3 before being used as an index. The output of these mechanisms is used to construct the destination set.

If the Request-URI does not provide sufficient information for the proxy to determine the destination set, it SHOULD return a 485 (Ambiguous) response. This response SHOULD contain a Contact header field containing URIs of new addresses to be tried. For example, an INVITE to sip:John.Smith@company.com may be ambiguous at a proxy whose location service has multiple John Smiths listed. See Section 25.4.23 for details.

Any information in or about the request or the current environment of the element MAY be used in the construction of the destination set. For instance, different sets may be constructed depending on contents or the presence of header fields and bodies, the time of day of the request's arrival, the interface on which the request arrived, failure of previous requests, or even the element's current level of utilization.

As potential destinations are located through these services, their next hops are added to the destination set (although, as pointed out above, the destination set MUST NOT ever contain more than one destination if the request contains a Route header). Next-hop locations may only be placed in the destination set once. If a next-hop location is already present in the set (based on the definition of equality for the URI type), it MUST NOT be added again.

If the received request contained no Route header fields, a proxy MAY continue to add destinations to the set after beginning Request Processing. It MAY use any information obtained during that processing to determine new locations. For instance, a proxy may choose to incorporate contacts obtained in a redirect response (3xx) into the destination set. If a proxy uses a dynamic source of information while building the destination set (for instance, if it consults a SIP Registrar), it SHOULD monitor that source for the duration of processing the request. New locations SHOULD be added to the destination set as they become available. As above, any given URI MUST NOT be added to the set more than once.

> Allowing a URI to be added to the set only once reduces unnecessary network traffic, and in the case of incorporating contacts from redirect requests prevents infinite recursion.

For example, a trivial location service is a "no-op", where the destination URI is equal to the incoming request URI. The request is sent to a specific next hop proxy for further processing. During request processing of Section 16.5, Item 5, the identity of that next hop, expressed as a SIP URI, is inserted as the top most Route header into the request.

If the Request-URI indicates a resource at this proxy that does not exist, the proxy MUST return a 404 (Not Found) response.

If the destination set remains empty after applying all of the above, the proxy MUST return an error response, which SHOULD be the 480 (Temporarily Unavailable) response.

16.5 Request Processing

As soon as the destination set is non-empty, a proxy MAY begin forwarding the request. A stateful proxy MAY process the set in any order. It MAY process multiple destinations serially, allowing each client transaction to complete before starting the next. It MAY start client transactions with every destination in parallel. It also MAY arbitrarily divide the set into groups, processing the groups serially and processing the destinations in each group in parallel.

A common ordering mechanism is to use the qvalue parameter of destinations obtained from Contact header fields (see Section 24.10). Destinations are processed from highest qvalue to lowest. Destinations with equal qvalues may be processed in parallel.

A stateful proxy must have a mechanism to maintain the destination set as responses are received and associate the responses to each forwarded request with the original request. For the purposes of this model, this mechanism is a "response context" created by the proxy layer before forwarding the first request.

For each destination, the proxy forwards the request following these steps:

1. Make a copy of the received request

2. Update the Request-URI

3. Add a Via header field

4. Update the Max-Forwards header field
5. Update the Route header field if present
6. Optionally add a Record-route header field value
7. Optionally add additional header fields
8. send the new request
9. Set timer C

Each of these steps is detailed below:

1. Copy request

   The proxy starts with a copy of the received request. The copy MUST initially contain all of the header fields from the received request. Only those fields detailed in the processing described below may be removed. The copy SHOULD maintain the ordering of the header fields as in the received request. The proxy MUST NOT reorder field values with a common field name (See Section 7.3.1).

   > An actual implementation need not perform a copy; the primary requirement is that the processing of each next hop begin with the same request.

2. Request-URI

   The Request-URI in the copy's start line MUST be replaced with the URI for this destination. If the URI contains any parameters not allowed in a Request-URI, they MUST be removed.

   This is the essence of a proxy's role. This is the mechanism through which a proxy routes a request toward its destination.

   In some circumstances, the received Request-URI is placed into the destination set without being modified. For that destination, the replacement above is effectively a no-op.

3. Via

   The proxy MUST insert a Via header field into the copy before the existing Via header fields. The construction of this header field follows the same guidelines of Section 8.1.1.7. This implies that the proxy will compute its own branch parameter, which will be globally unique for that branch, and contain the requisite magic cookie.

   Proxies choosing to detect loops have an additional constraint in the value they use for construction of the branch parameter. A proxy choosing to detect loops SHOULD create a branch parameter separable into two parts by the implementation. The first part MUST satisfy the constraints of Section 8.1.1.7 as described above. The second is used to perform loop detection and distinguish loops from spirals.

   Loop detection is performed by verifying that, when a request returns to a proxy, those fields having an impact on the processing of the request have not changed. The value placed in this part of the branch parameter SHOULD reflect all of those fields (including any Route, Proxy-Require and Proxy-Authorization header fields). This is to ensure that if the request is routed back to the proxy and one of those fields changes, it is treated as a spiral and not a loop (Section 16.3 item 3) A common way to create this value is to compute a cryptographic hash of the To, From, Call-ID header fields, the Request-URI of the request received (before translation) and the sequence number from the CSeq header field, in addition to any Proxy-Require and Proxy-Authorization header fields that may be present. The algorithm used to compute the hash is implementation-dependent, but MD5 [31], expressed in hexadecimal, is a reasonable choice. (Base64 is not permissible for a token.)

> If a proxy wishes to detect loops, the "branch" parameter it supplies MUST depend on all information affecting processing of a request, including the incoming Request-URI and any header fields affecting the request's admission or routing. This is necessary to distinguish looped requests from requests whose routing parameters have changed before returning to this server.

The request method MUST NOT be included in the calculation of the branch parameter. In particular, CANCEL and ACK requests (for non-2xx responses) MUST have the same branch value as the corresponding request they cancel or acknowledge. The branch parameter is used in correlating those requests at the server handling them (see Section 17.2.3 and 9.2).

4. Max-Forwards

If the copy does not contain a Max-Forwards header field, the proxy MUST add one with a field value which SHOULD be 70.

> Some existing UAs will not provide a Max-Forwards header field in a request.

If the copy contains a Max-Forwards header field, the proxy must decrement its value by one (1).

5. Route

A proxy MAY have a local policy that mandates that a request visit a specific set of proxies before being delivered to the destination. A proxy MUST ensure that all such proxies are loose routers. Generally, this can only be known with certainty if the proxies are within the same administrative domain. This set of proxies is represented by a set of URIs (each of which contains the lr parameter). This set MUST be pushed into the Route header field ahead of any existing values, if present. If the Route header field is empty, it MUST be added, containing that list of URIs.

If the proxy has a local policy that mandates that the request visit one specific proxy, an alternative to pushing a Route value into the Route header field is to bypass the forwarding logic of item 8 below, and instead just send the request to the address, port and transport for that specific proxy. If the request has Route headers, this alternative MUST NOT be used unless it known that next hop proxy is a loose router. Otherwise, this approach MAY be used, but the Route insertion mechanism above is preferred for its robustness, flexibility, generality and consistency of operation.

In absence of a policy for forwarding a request through specific next hops, the proxy MUST inspect the topmost Route header field value. If that value indicates this proxy, the proxy MUST remove the value from the copy (removing the Route header field if that was the only value).

If a Route header field remains after the previous step, the proxy MUST inspect the URI in its first value. If that URI does not contain a lr parameter, the proxy MUST modify the request as follows:

- The proxy MUST place the Request-URI into the Route header field as the last value.
- The proxy MUST then place the first Route header field value into the Request-URI and remove that value from the Route header field.

Appending the Request-URI to the Route header field is part of a mechanism used to pass the information in that Request-URI through strict-routing elements. ”Popping” the first Route header field value into the Request-URI formats the message the way a strict-routing element expects to receive it (with its own URI in the Request-URI and the next location to visit in the first Route header field value).

6. Record-Route

If this proxy wishes to remain on the path of future requests in a dialog created by this request, it MUST insert a Record-Route header field into the copy before any existing Record-Route header field, even if a Route header field is already present.

Requests establishing a dialog may contain preloaded Route header fields.

If this request is already part of a dialog, the proxy SHOULD insert a Record-Route header field value if it wishes to remain on the path of future requests in the dialog. In normal endpoint operation as described in Section 12 these Record-Route header field values will not have any effect on the route sets used by the endpoints.

The proxy will remain on the path if it choses to not insert a Record-Route header field value into requests that are already part of a dialog. However, it would be removed from the path when an endpoint that has failed reconstitutes the dialog.

A proxy MAY insert a Record-Route header field into any request. If the request does not initiate a dialog, the endpoints will ignore the value. See Section 12 for details on how endpoints use the Record-Route header field values to construct Route header fields.

Each proxy in the path of a request chooses whether to add a Record-Route header field independently - the presence of a Record-Route header field in a request does not obligate this proxy to add a value.

The URI placed in the Record-Route header field value MUST be a SIP URI. This URI MUST contain an lr parameter (see Section 23.1.1). This URI MAY be different for each destination the request is forwarded to. The URI SHOULD NOT contain the transport parameter unless the proxy has knowledge (such as in a private network) that the next downstream element that will be in the path of subsequent requests supports that transport.

The URI this proxy provides will be used by some other element to make a routing decision. This proxy, in general, has no way to know what the capabilities of that element are, so it must restrict itself to the mandatory elements of a SIP implementation: SIP URIs and either the TCP or UDP transports.

The URI placed in the Record-Route header field MUST resolve to this element when the server location procedures of [2] are applied to it. This ensures subsequent requests are routed back to this element.

If the URI placed in the Record-Route header field needs to be be rewritten when it passes back through in a response, the URI MUST be distinct enough to locate at that time. (The request may spiral through this proxy, resulting in more than one Record-Route header field value being added). Item 8 of Section 16.6 recommends a mechanism to make the URI sufficiently distinct.

The proxy MAY include Record-Route header field parameters in the value it provides. These will be returned in some responses to the request (200 (OK) responses to INVITE for example) and may be useful for pushing state into the message.

If a proxy needs to be in the path of any type of dialog (such as one straddling a firewall), it SHOULD add a Record-Route header field to every request with a method it does not understand since that method may have dialog semantics.

The URI a proxy places into a Record-Route header field is only valid for the lifetime of any dialog created by the transaction in which it occurs. A dialog-stateful proxy, for example, MAY refuse to accept future requests with that value in the Request-URI after the dialog has terminated. Non-dialog-stateful proxies, of course, have no concept of when the dialog has terminated, but they MAY encode enough information in the value to compare it against the dialog identifier of future requests and MAY reject requests not matching that information. Endpoints MUST NOT use a URI obtained from a Record-Route header field outside the dialog in which it was provided. See Section 12 for more information on an endpoint's use of Record-Route header fields.

Generally, the choice about whether to record-route or not is a tradeoff of features vs. performance. Faster request processing and higher scalability is achieved when proxies do not record route. However, provision of certain services may require a proxy to observe all messages in a dialog. It is RECOMMENDED that proxies do not automatically record route. They should do so only if specifically required.

The Record-Route process is designed to work for any SIP request that initiates a dialog. The only such request in this specification is INVITE. Extensions to the protocol MAY define others, and the mechanisms described here will apply.

7. Adding Additional Header Fields

The proxy MAY add any other appropriate header fields to the copy at this point.

8. Forward Request

A stateful proxy creates a new client transaction for this request as described in Section 17.1. The proxy MAY have a local policy to send the request to a specific IP address, port, and transport, independent of the values of the Route and Request-URI. Such a policy MUST NOT be used if the proxy is not certain that the IP address, port, and transport correspond to a server that is a loose router. However, this mechanism for sending the request through a specific next hop is NOT RECOMMENDED; instead a Route header field should be used for that purpose as described above.

In the absence of such an overriding mechanism, the proxy applies the procedures listed in [2] as follows to determine where to send the request. If the proxy has reformatted the request to send to a strict-routing element as described in Section 5, the proxy MUST apply those proceedures to the Request-URI of the request. Otherwise, the proxy MUST apply the proceedures to the first value in the Route header field, if present, else the Request-URI. The proceedures will produce an ordered set of addresses. As described in [2], the proxy MUST attempt to contact the first address by instructing the client transaction to send the request there. If the client transaction reports failure to send the request or a timeout from its state machine, the stateful proxy continues to the next address in that ordered set. Each attempt is a new client transaction, and therefore represents a new branch, so that the processing described above for each branch would need to be repeated. This results in a requirement to use a different branch ID parameter for each attempt. If the ordered set is exhausted, the request cannot be forwarded to this element in the destination set. The proxy does not need to place anything in the response context, but otherwise acts as if this element of the destination set returned a 408 (Request Timeout) final response.

9. Set timer C

   In order to handle the case where an INVITE request never generates a final response, a transaction timeout value is used. This is accomplished through a timer, called timer C, which MUST be set for each client transaction when an INVITE request is proxied. The timer MUST be larger than 3 minutes. Section 16.6 bullet 2 discusses how this timer is updated with provisional responses, and Section 16.7 discusses processing when it fires.

16.6 Response Processing

When a response is received by an element, it first tries to locate a client transaction (Section 17.1.3) matching the response. If none is found, the element MUST process the response (even if it is an informational response) as a stateless proxy (described below). If a match is found, the response is handed to the client transaction.

> Forwarding responses for which a client transaction (or more generally any knowledge of having sent an associated request) is not found improves robustness. In particular, it ensures that "late" 2xx responses to INVITE requests are forwarded properly.

As client transactions pass responses to the proxy layer, the following processing MUST take place:

1. Find the appropriate response context
2. Update timer C for provisional responses
3. Remove the topmost Via
4. Add the response to the response context
5. Check to see if this response should be forwarded

The following processing MUST be performed on each response that is forwarded. It is likely that more than one response to each request will be forwarded: at least each provisional and one final response.

1. Aggregate authorization header fields if necessary;
2. forward the response;
3. generate any necessary CANCEL requests.

If no final response has been forwarded after every client transaction associated with the response context has been terminated, the proxy must choose and forward the "best" response from those it has seen so far.

Each of the above steps are detailed below:

1. Find Context

   The proxy locates the "response context" it created before forwarding the original request using the key described in Section 16.5. The remaining processing steps take place in this context.

2. Update timer C for provisional responses

   For an INVITE transaction, if the response is a provisional response with status codes 101 to 199 inclusive (i.e., anything but 100), the proxy MUST reset timer C for that client transaction. The timer MAY be reset to a different value, but this value MUST be greater than 3 minutes.

3. Via

The proxy removes the topmost Via header field from the response.

If no Via header fields remain in the response, the response was meant for this element and MUST NOT be forwarded. The remainder of the processing described in this section is not performed on this message, the UAC processing rules described in Section 8.1.3 are followed instead (transport layer processing has already occurred).

This will happen, for instance, when the element generates CANCEL requests as described in Section 10.

4. Add response to context ;

Final responses received are stored in the response context until a final response is generated on the server transaction associated with this context. The response may be a candidate for the best final response to be returned on that server transaction. Information from this response may be needed in forming the best response even if this response is not chosen.

If the proxy chooses to recurse on any contacts in a 3xx response by adding them to the destination set, it MUST remove them from the response before adding the response to the response context. If the proxy recurses on all of the contacts in a 3xx response, the proxy SHOULD NOT add the resulting contactless response to the response context.

> Removing the contact before adding the response to the response contact prevents the next element upstream from retrying a location this proxy has already attempted.
>
> 3xx responses may contain a mixture of SIP and non-SIP URIs. A proxy may choose to recurse on the SIP URIs and place the remainder into the response context to be returned potentially in the final response.

If a proxy receives a 416 (Unsupported URI Scheme) response to a request whose Request-URI scheme was not SIP, but the scheme in the original received request was SIP (that is, the proxy changed the scheme from SIP to something else when it proxied a request), the proxy SHOULD add a new URI to the destination set. This URI SHOULD be a SIP URI version of the non-SIP URI that was just tried. In the case of the tel URL, this is accomplished by placing the telephone-subscriber part of the tel URL into the user part of the SIP URI, and setting the hostpart to the domain where the prior request was sent.

As with a 3xx response, if a proxy “recurses” on the 416 by trying a SIP URI instead, the 416 response SHOULD NOT be added to the response context.

5. Check response for forwarding

Until a final response has been sent on the server transaction, the following responses MUST be forwarded immediately:

- Any provisional response other than 100 (Trying)
- Any 2xx response

If a 6xx response is received, it is not immediately forwarded, but the stateful proxy SHOULD cancel all pending transactions as described in Section 10.

> This is a change from RFC 2543, which mandated that the proxy was to forward the 6xx response immediately. For an INVITE transaction, this approach had the problem that a 2xx response could arrive on another branch, in which case the proxy would have to forward the 2xx. The result was that the UAC could receive a 6xx response followed by a 2xx response, which should never be allowed to happen. Under the new rules, upon receiving a 6xx, a proxy will issue a CANCEL request, which will generally result in 487 responses from all outstanding client transactions, and then at that point the 6xx is forwarded upstream.

After a final response has been sent on the server transaction, the following responses MUST be forwarded immediately:

- Any 2xx response to an INVITE request

A stateful proxy MUST NOT immediately forward any other responses. In particular, a stateful proxy MUST NOT forward any 100 (Trying) response. Those responses that are candidates for forwarding later as the “best” response have been gathered as described in step “Add Response to Context”.

Any response chosen for immediate forwarding MUST be processed as described in steps “Aggregate Authorization Header Fields” through “Record-Route”.

This step, combined with the next, ensures that a stateful proxy will forward exactly one final response to a non-INVITE request, and either exactly one non-2xx response or one or more 2xx responses to an INVITE request.

6. Choosing the best response

A stateful proxy MUST send a final response to a response context’s server transaction if no final responses have been immediately forwarded by the above rules and all client transactions in this response context have been terminated.

The stateful proxy MUST choose the “best” final response among those received and stored in the response context.

If there are no final responses in the context, the proxy MUST send a 408 (Request Timeout) response to the server transaction.

Otherwise, the proxy MUST forward one of the responses from the lowest response class stored in the response context. The proxy MAY select any response within that lowest class. The proxy SHOULD give preference to responses that provide information affecting resubmission of this request, such as 401, 407, 415, 420, and 484.

A proxy which receives a 503 (Service Unavailable) response SHOULD NOT forward it upstream unless it can determine that any subsequent requests it might proxy will also generate a 503. In other words, forwarding a 503 means that the proxy knows it cannot service any requests, not just the one for the Request-URI in the request which generated the 503.

The forwarded response MUST be processed as described in steps “Aggregate authorization Header Fields” through “Record-Route”.

For example, if a proxy forwarded a request to 4 locations, and received 503, 407, 501, and 404 responses, it may choose to forward the 407 (Proxy Authentication Required) response.

1xx and 2xx responses may be involved in the establishment dialogs. When a request does not contain a To tag, the To tag in the response is used by the UAC to distinguish multiple responses to a dialog creating request. A proxy MUST NOT insert a tag into the To header field of a 1xx or 2xx response if the request did not contain one. A proxy MUST NOT modify the tag in the To header field of a 1xx or 2xx response.

Since a proxy may not insert a tag into the To header field of a 1xx response to a request that did not contain one, it cannot issue non-100 provisional responses on its own. However, it can branch the request to a UAS sharing the same element as the proxy. This UAS can return its own provisional responses, entering into an early dialog with the initator of the request. The UAS does not have to be a discreet process from the proxy. It could be a virtual UAS implemented in the same code space as the proxy.

3-6xx responses are delivered hop-hop. When issuing a 3-6xx response, the element is effectivly acting as a UAS, issuing its own response, usually based on the responses received from downstream elements. An element SHOULD preserve the To tag when simply forwarding a 3-6xx response to a request that did not contain a To tag.

A proxy MUST NOT modify the To tag in any forwarded response to a request that contains a To tag.

> While it makes no difference to the upstream elements if the proxy replaced the To tag in a forwarded 3-6xx response, preserving the original tag may assist with debugging.
>
> When the proxy is aggregating information from several responses, choosing a To tag from among them is arbitrary, and generating a new To tag may make debugging easier. This happens, for instance, when combining 401 (Unauthorized) and 407 (Proxy Authentication Required) challenges, or combining Contact values from unencrypted and unauthenticated 3xx responses.

7. Aggregate Authorization Header Fields

If the selected response is a 401 (Unauthorized) or 407 (Proxy Authentication Required), the proxy MUST collect any WWW-Authenticate and Proxy-Authenticate header fields from all other 401 (Unauthorized) and 407 (Proxy Authentication Required) responses received so far in this response context and add them to this response before forwarding. Each WWW-Authenticate and Proxy-Authenticate header field added to the response MUST preserve that header field value. The resulting 401 (Unauthorized) or 407 (Proxy Authenication Required) response may have several WWW-Authenticate AND Proxy-Authenticate header fields.

This is necessary because any or all of the destinations the request was forwarded to may have requested credentials. The client must receive all of those challenges and supply credentials for each of them when it retries the request. Motivation for this behavior is provided in Section 22.

8. Record-Route

If the selected response contains a Record-Route header field value originally provided by this proxy, the proxy MAY chose to rewrite the value before forwarding the response. This allows the proxy to provide different URIs for itself to the next upstream and downstream elements. A proxy may choose to use this mechanism for any reason. For instance, it is useful for multi-homed hosts.

The new URI provided by the proxy MUST satisfy the same constraints on URIs placed in Record-Route header fields in requests (see Step 6 of Section 16.5) with the following modifications:

The URI SHOULD NOT contain the transport parameter unless the proxy has knowledge that the next upstream (as opposed to downstream) element that will be in the path of subsequent requests supports that transport.

When a proxy does decide to modify the Record-Route header field in the response, one of the operations it must perform is to locate the Record-Route that it had inserted. If the request spiraled, and the proxy inserted a Record-Route in each iteration of the spiral, locating the correct header field in the response (which must be the proper iteration in the reverse direction) is tricky. The rules above recommend that a proxy wishing to rewrite Record-Route header field values insert sufficiently distinct URIs into the Record-Route header field so that the right one may be selected for rewriting. A RECOMMENDED mechanism to achieve this is for the proxy to append a unique identifier for the proxy instance to to the user portion of the URI. When the response arrives, the proxy modifies the first Record-Route whose identifier matches the proxy instance. The modification results in a URI without this piece of data appended to the user portion of the URI. Upon the next iteration, the same algorithm (find the topmost Record-Route header field with the parameter) will correctly extract the next Record-Route header field inserted by that proxy.

9. Forward response

After performing the processing described in steps “Aggregate Authorization Header Fields” through “Record-Route”, the proxy may perform any feature specific manipulations on the selected response. Unless otherwise specified, the proxy MUST NOT remove the message body or any header fields other than the Via header field discussed in Section 3. In particular, the proxy MUST NOT remove any “received” parameter it may have added to the next Via header field while processing the request associated with this response. The proxy MUST pass the response to the server transaction associated with the response context. This will result in the response being sent to the location now indicated in the topmost Via header field value. If the server transaction is no longer available to handle the transmission, the element MUST forward the response statelessly by sending it to the server transport. The server transaction may indicate failure to send the response or signal a timeout in its state machine. These errors should be logged for diagnostic purposes as appropriate, but the protocol requires no remedial action from the proxy.

The proxy MUST maintain the response context until all of its associated transactions have been terminated, even after forwarding a final response.

10. Generate CANCELs

If the forwarded response was a final response, the proxy MUST generate a CANCEL request for all pending client transactions associated with this response context. A proxy SHOULD also generate a CANCEL request for all pending client transactions associated with this response context when it receives a 6xx response. A pending client transaction is one that has received a provisional response, but no final response and has not had an associated CANCEL generated for it. Generating CANCEL requests is described in Section 9.1.

The requirement to CANCEL pending client transactions upon forwarding a final response does not guarantee that an endpoint will not receive multiple 200 (OK) responses to an INVITE. 200 (OK) responses on more than one branch may be generated before the CANCEL requests can be sent and processed. Further, it is reasonable to expect that a future extension may override this requirement to issue CANCEL requests.

16.7 Processing Timer C

If timer C should fire, the proxy MUST either reset the timer with any value it chooses, or generate a CANCEL for that particular request.

16.8 Handling Transport Errors

If the transport layer notifies a proxy of an error when it tries to forward a request (see Section 19.4), the proxy MUST behave as if the forwarded request received a 400 (Bad Request) response.

If the proxy is notified of an error when forwarding a response, it drops the response. The proxy SHOULD NOT cancel any outstanding client transactions associated with this response context due to this notification.

> If a proxy cancels its outstanding client transactions, a single malicious or misbehaving client can cause all transactions to fail through its Via header field.

16.9 CANCEL Processing

A stateful proxy may generate a CANCEL to any other request it has generated at any time (subject to receiving a provisional response to that request as described in section 9.1). A proxy MUST cancel any pending client transactions associated with a response context when it receives a matching CANCEL request.

A stateful proxy MAY generate CANCEL requests for pending INVITE client transactions based on the period specified in the INVITE's Expires header field elapsing. However, this is generally unnecessary since the endpoints involved will take care of signaling the end of the transaction.

While a CANCEL request is handled in a stateful proxy by its own server transaction, a new response context is not created for it. Instead, the proxy layer searches its existing response contexts for the server transaction handling the request associated with this CANCEL. If a matching response context is found, the element MUST immediately return a 200 (OK) response to the CANCEL request. In this case, the element is acting as a user agent server as defined in Section 8.2. Furthermore, the element MUST generate CANCEL requests for all pending client transactions in the context as described in Section 10.

If a response context is not found, the element does not have any knowledge of the request to apply the CANCEL to. It MUST forward the CANCEL request (it may have statelessly forwarded the associated request previously).

16.10 Stateless Proxy

When acting statelessly, a proxy is a simple message forwarder. Much of the processing performed when acting statelessly is the same as when behaving statefully. The differences are detailed here.

A stateless proxy does not have any notion of a transaction, or of the response context used to describe stateful proxy behavior. Instead, the stateless proxy takes messages, both requests and responses, directly from the transport layer (See section 19). As a result, stateless proxies do not retransmit messages on their own. They do, however, forward all retransmission they receive (they do not have the ability to distinguish a retransmission from the original message). Furthermore, when handling a request statelessly, an element MUST NOT generate its own 100 (Trying) or any other provisional response.

A stateless proxy must validate a request as described in Section 16.3

A stateless proxy must make a routing decision as described in Section 16.4 with the following exception:

- A stateless proxy MUST choose one and only one destination from the destination set. This choice MUST only rely on fields in the message and time-invariant properties of the server. In particular, a retransmitted request MUST be forwarded to the same destination each time it is processed. Furthermore, CANCEL and non-Routed ACK requests MUST generate the same choice as their associated INVITE.

A stateless proxy must process the request before forwarding as described in Section 16.5 with the following exceptions:

- The requirement for unique branch IDs across time applies to stateless proxies as well. However, a stateless proxy cannot simply use a random number generator to compute the first component of the branch ID, as described in Section 16.5 bullet 3. This is because retransmissions of a request need to have the same value, and a stateless proxy cannot tell a retransmission from the original request. Therefore, the component of the branch parameter that makes it unique MUST be the same each time a retransmitted request is forwarded. Thus for a stateless proxy, the branch parameter MUST be computed as a combinatoric function of message parameters which are invariant on retransmission.

- The stateless proxy MAY use any technique it likes to guarantee uniqueness of its branch IDs across transactions. However, the following procedure is RECOMMENDED. The proxy examines the branch ID of the received request. If it begins with the magic cookie, the first component of the branch ID of the outgoing request is computed as a hash of the received branch ID. Otherwise, the first component of the branch ID is computed as a hash of the topmost Via, the To header field, the From header field, the Call-ID header field, the CSeq number (but not method), and the Request-URI from the received request. One of these fields will always vary across two different transactions.

- The request is sent directly to the transport layer instead of through a client transaction. If the next-hop destination parameters don't provide an explicit destination, the element applies the procedures of [2] to the Request-URI to determine where to send the request.

  Since a stateless proxy must forward retransmitted requests to the same destination and add identical branch parameters to each of them, it can only use information from the message itself and time-invariant configuration data for those calculations. If the configuration state is not time-invariant (for example, if a routing table is updated) any requests that could be affected by the change may not be forwarded statelessly during an interval equal to the transaction timeout window before or after the change. The method of processing the affected requests in that interval is an implementation decision. A common solution is to forward them transaction statefully.

Stateless proxies MUST NOT perform special processing for CANCEL requests. They are processed by the above rules as any other requests. In particular, a stateless proxy applies the same Route header field processing to CANCEL requests that it applies to any other request.

Response processing as described in Section 16.6 does not apply to a proxy behaving statelessly. When a response arrives at a stateless proxy, the proxy inspects the sent-by value in the first (topmost) Via header field. If that address matches the proxy (it equals a value this proxy has inserted into previous requests) the proxy MUST remove that value from the response and forward the result to the location indicated in the next Via header field. Unless specified otherwise, the proxy MUST NOT remove any other header fields or the message body. If the address does not match the proxy, the message MUST be silently discarded.

16.11 Summary of Proxy Route Processing

In the absence of local policy to the contrary, the processing a proxy performs on a request containing a route header can be summarized in the following steps.

- 1 The proxy will inspect the Request-URI. If it indicates a resource owned by this proxy, the proxy will replace it with the results of running a location service. Otherwise, the proxy will not change the Request-URI.
- 2 The proxy will inspect the URI in the topmost Route header field value. If it indicates this proxy, the proxy removes it from the Route header field (this route node has been reached).
- 3 The proxy will forward the request to the resource indicated by the URI in the topmost Route header field value or in the Request-URI if no Route header field is present. The proxy determines the address, port and transport to use when forwarding the request by applying the proceedures in [2] to that URI.

If no strict-routing elements are encountered on the path of the request, the Request-URI will always indicate the target of the request.

16.11.1 Examples

16.11.1.1 Basic SIP Trapezoid This scenario is the basic sip trapeziod, U1 -> P1 -> P2 -> U2, with both proxies record-routing. Here is the flow.

U1 sends:

```
INVITE sip:callee@domain.com SIP/2.0
Contact: sip:caller@u1.example.com
```

to P1. P1 is an outbound proxy. P1 is not responsible for domain.com, so it looks it up in DNS and sends it there. It also adds a Record-Route header field value:

```
INVITE sip:callee@domain.com SIP/2.0
Contact: sip:caller@u1.example.com
Record-Route: <sip:p1.example.com;lr>
```

P2 gets this. It is responsible for domain.com so it runs a location service and rewrites the Request-URI. There are no Route headers, so it sends to the result of the location lookup. It also adds a Record-Route header field value:

```
INVITE sip:callee@u2.domain.com SIP/2.0
Contact: sip:caller@u1.example.com
Record-Route: <sip:p2.domain.com;lr>
Record-Route: <sip:p1.example.com;lr>
```

The callee at u2.domain.com gets this and responds with a 200 OK:

```
SIP/2.0 200 OK
Contact: sip:callee@u2.domain.com
Record-Route: <sip:p2.domain.com;lr>
Record-Route: <sip:p1.example.com;lr>
```

The callee at u2 also sets its dialog state's remote target URI to sip:caller@u1.example.com and its route set to

```
(<sip:p2.domain.com;lr>,<sip:p1.example.com;lr>)
```

This is forwarded by P2 to P1 to U1 as normal. Now, U1 sets its dialog state's remote target URI to sip:callee@u2.domain.com and its route set to

```
(<sip:p1.example.com;lr>,<sip:p2.domain.com;lr>)
```

Since all the route set elements contain the lr parameter, U1 constructs the following for the BYE:

```
BYE sip:callee@u2.domain.com SIP/2.0
Route: <sip:p1.example.com;lr>,<sip:p2.domain.com;lr>
```

As any other element (including proxies) would do, it sends this request to the location obtained by looking up the topmost Route header field value in DNS. This goes to P1. P1 notices that it is not responsible for the resource indicated in the Request-URI so it doesn't change it. It does see that it is the first value in the Route header field, so it removes that value, and forwards the request to P2:

```
BYE sip:callee@u2.domain.com SIP/2.0
Route: <sip:p2.domain.com;lr>
```

P2 also notices it is not responsible for the resource indicated by the Request-URI (it is responsible for domain.com, not u2.domain.com), so it doesn't change it. It does see itself in the first Route header field value, so it removes it and forwards the following to u2.domain.com based on a DNS lookup against the Request-URI:

```
BYE sip:callee@u2.domain.com SIP/2.0
```

16.11.1.2 Traversing a strict-routing proxy In this scanario, a dialog is established across three proxies, each of which adds Record-Route header field values. The second proxy implements the strict-routing proceedures specified in RFC2543 and the bis drafts up to bis-05.

```
U1->P1->P2->P3->U2
```

The INVITE arriving at U2 contains

```
INVITE sip:callee@u2.domain.com SIP/2.0
Contact: sip:caller@u1.example.com
Record-Route: <sip:p3.domain.com;lr>
Record-Route: <sip:p2.middle.com>
Record-Route: <sip:p1.example.com;lr>
```

Which U2 responds to with a 200 OK. Later, U2 sends the following BYE to P3 based on the first Route header field value.

```
BYE sip:caller@u1.example.com SIP/2.0
Route: <sip:p3.domain.com;lr>
Route: <sip:p2.middle.com>
Route: <sip:p1.example.com;lr>
```

P3 is not responsible for the resource indicated in the Request-URI so it will leave it alone. It notices that it is the element in the first Route header field value so it removes it. It then prepares to send the request based on the now first Route header field value of sip:p2.middle.com, but it notices that this URI does not contain the lr parameter, so before sending, it reformats the request to be:

```
BYE sip:p2.middle.com SIP/2.0
Route: <sip:p1.example.com;lr>
Route: <sip:caller@u1.example.com>
```

P2 is a strict router, so it forwards the following to P1:

```
BYE sip:p1.example.com;lr SIP/2.0
Route: <sip:caller@u1.example.com>
```

P1 sees the request-URI is a value it placed into a Record-Route header field, so before further processing, it rewrites the request to be

```
BYE sip:caller@u1.example.com SIP/2.0
```

Since P1 is not responsible for u1.example.com and there is no Route header field, P1 will forward the request to u1.example.com based on the Request-URI:

```
BYE sip:caller@u1.example.com SIP/2.0
```

16.11.1.3 Rewriting Record-Route header field values In this scenario, U1 and U2 are in different private namespaces and they enter a dialog through a proxy P1 which acts as a gateway between the namespaces.

```
U1->P1->U2
```

U1 receives:

```
INVITE sip:callee@gateway.leftprivatespace.com SIP/2.0
Contact: <sip:caller@u1.leftprivatespace.com>
```

P1 its location service and sends the following to U2:

```
INVITE sip:callee@rightprivatespace.com SIP/2.0
Contact: <sip:caller@u1.leftprivatespace.com>
Record-Route: <sip:gateway.rightprivatespace.com;lr>
```

U2 sends this 200 OK back to the gateway:

```
SIP/2.0 200 OK
Contact: <sip:callee@u2.rightprivatespace.com>
Record-Route: <sip:gateway.rightprivatespace.com;lr>
```

P1 rewrites its Record-Route header parameter to provide a value that U1 will find useful, and sends the following to U1:

```
SIP/2.0 200 OK
Contact: <sip:callee@u2.rightprivatespace.com>
Record-Route: <sip:gateway.leftprivatespace.com;lr>
```

Later, U1 sends the following BYE to P1:

```
BYE sip:callee@u2.rightprivatespace.com SIP/2.0
Route: <sip:gateway.leftprivatespace.com;lr>
```

which P1 forwards to U2 as

```
BYE sip:callee@u2.rightprivatespace.com SIP/2.0
```

17 Transactions

SIP is a transactional protocol: interactions between components take place in a series of independent message exchanges. Specifically, a SIP transaction consists of a single request, and any responses to that request (which include zero or more provisional responses and one or more final responses). In the case of a transaction where the request was an INVITE (known as an INVITE transaction), the transaction also includes the ACK only if the final response was not a 2xx response. If the response was a 2xx, the ACK is not considered part of the transaction.

> The reason for this separation is rooted in the importance of delivering all 200 (OK) responses to an INVITE to the UAC. To deliver them all to the UAC, the UAS alone takes responsibility for retransmitting them (see Section 13.3.1.4) , and the UAC alone takes responsibility for acknowledging them with ACK (see Section 13.2.2.4). Since this ACK is retransmitted only by the UAC, it is effectively considered its own transaction.

Transactions have a client side and a server side. The client side is known as a client transaction, and the server side, as a server transaction. The client transaction sends the request, and the server transaction sends the response. The client and server transactions are logical functions that are embedded in any number of elements. Specifically, they exist within user agents and stateful proxy servers. Consider the example of Section 4. In this example, the UAC executes the client transaction, and its outbound proxy executes the server transaction. The outbound proxy also executes a client transaction, which sends the request to a server transaction in the inbound proxy. That proxy also executes a client transaction, which in turn, sends the request to a server transaction in the UAS. This is shown pictorially in Figure 4.

```
+---------+        +---------+        +---------+        +---------+
|      +-+|Request |+-+   +-+|Request |+-+   +-+|Request |+-+      |
|      |C||------->||S|   |C||------->||S|   |C||------->||S|      |
|      |l||        ||e|   |l||        ||e|   |l||        ||e|      |
|      |i||        ||r|   |i||        ||r|   |i||        ||r|      |
|      |e||        ||v|   |e||        ||v|   |e||        ||v|      |
|      |n||        ||e|   |n||        ||e|   |n||        ||e|      |
|      |t||        ||r|   |t||        ||r|   |t||        ||r|      |
|      | ||        || |   | ||        || |   | ||        || |      |
|      |T||        ||T|   |T||        ||T|   |T||        ||T|      |
|      |r||        ||r|   |r||        ||r|   |r||        ||r|      |
|      |a||        ||a|   |a||        ||a|   |a||        ||a|      |
|      |n||        ||n|   |n||        ||n|   |n||        ||n|      |
|      |s||Response||s|   |s||Response||s|   |s||Response||s|      |
|      +-+|<-------|+-+   +-+|<-------|+-+   +-+|<-------|+-+      |
+---------+        +---------+        +---------+        +---------+
   UAC              Outbound           Inbound              UAS
                    Proxy               Proxy
```

Figure 4: Transaction relationships

A stateless proxy does not contain a client or server transaction. The transaction exists between the UA or stateful proxy on one side of the stateless proxy, and the UA or stateful proxy on the other side. As far as SIP transactions are concerned, stateless proxies are effectively transparent. The purpose of the client transaction is to receive a request from the element the client is embedded in (call this element the “Transaction User” or TU; it can be a UA or a stateful proxy), and reliably deliver the request to that server transaction. The client transaction is also responsible for receiving responses, and delivering them to the TU, filtering out any retransmissions or disallowed responses (such as a response to ACK). In the case of an INVITE transaction, that includes generation of the ACK request for any final response excepting a 2xx response.

Similarly, the purpose of the server transaction is to receive requests from the transport layer, and deliver them to the TU. The server transaction filters any request retransmissions from the network. The server transaction accepts responses from the TU, and delivers them to the transport layer for transmission over the network. In the case of an INVITE transaction, it absorbs the ACK request for any final response excepting a 2xx response.

The 2xx response, and the ACK for it, have special treatment. This response is retransmitted only by a UAS, and its ACK generated only by the UAC. This end-to-end treatment is needed so that a caller knows the entire set of users that have accepted the call. Because of this special handling, retransmissions of the 2xx response are handled by the UA core, not the transaction layer. Similarly, generation of the ACK for the 2xx is handled by the UA core. Each proxy along the path merely forwards each 2xx response to INVITE, and its corresponding ACK.

A reliable provisional response, and the PRACK for it, also have special treatment. Reliable provisional responses are also only retransmitted by the UAS core, and the PRACK generated by the UAC core. Unlike ACK, however, PRACK is a normal non-INVITE transaction, which means that it will generate its own final response. The reason for this seemingly inexplicable difference between PRACK and ACK is that reliability of provisional responses was added on later as an extra feature, and therefore needed to be done within the confines of SIP extensibility. SIP extensibility only allowed the additions of new methods which behaved like any other non-INVITE method.

17.1 Client Transaction

The client transaction provides its functionality through the maintenance of a state machine.

The TU communicates with the client transaction through a simple interface. When the TU wishes to initiate a new transaction, it creates a client transaction, and passes it the SIP request to send, and an IP address, port, and transport to send it to. The client transaction begins execution of its state machine. Valid responses are passed up to the TU from the client transaction.

There are two types of client transaction state machines, depending on the method of the request passed by the TU. One handles client transactions for INVITE request. This type of machine is referred to as an INVITE client transaction. Another type handles client transactions for all requests except INVITE and ACK. This is referred to as a non-INVITE client transaction. There is no client transaction for ACK. If the TU wishes to send an ACK, it passes one directly to the transport layer for transmission.

The INVITE transaction is different from those of other methods because of its extended duration. Normally, human input is required in order to respond to an INVITE. The long delays expected for sending a response argue for a three way handshake. Requests of other methods, on the other hand, are expected to complete rapidly. In fact, because of its reliance on just a two way handshake, TUs SHOULD respond immediately to non-INVITE requests. Protocol extensions which require longer durations for generation of a response (such as a new method that does require human interaction) SHOULD instead use two transactions - one to send the request, and another in the reverse direction to convey the result of the request.

17.1.1 INVITE Client Transaction

17.1.1.1 Overview of INVITE Transaction The INVITE transaction consists of a three-way handshake. The client transaction sends an INVITE, the server transaction sends responses, and the client transaction sends an ACK. For unreliable transports (such as UDP), the client transaction will retransmit requests at an interval that starts at T1 seconds and doubles after every retransmission. T1 is an estimate of the RTT, and it defaults to 500 ms. Nearly all of the transaction timers described here scale with T1, and changing T1 is how their values are adjusted. The request is not retransmitted over reliable transports. After receiving a 1xx response, any retransmissions cease altogether, and the client waits for further responses. The server transaction can send additional 1xx responses, which are not transmitted reliably by the server transaction. If the provisional response needs to be sent reliably, this is handled by the TU. Eventually, the server transaction decides to send a final response. For unreliable transports, that response is retransmitted periodically, and for reliable transports, it is sent once. For each final response that is received at the client transaction, the client transaction sends an ACK, the purpose of which is to quench retransmissions of the response.

17.1.1.2 Formal Description The state machine for the INVITE client transaction is shown in Figure 5. The initial state, "calling", MUST be entered when the TU initiates a new client transaction with an INVITE request. The client transaction MUST pass the request to the transport layer for transmission (see Section

```
                               |INVITE from TU
             Timer A fires     |INVITE sent
             Reset A,          V                      Timer B fires
             INVITE sent +-----------+                or Transport Err.
               +---------|           |---------------+inform TU
               |         |  Calling  |               |
               +-------->|           |-------------->|
                         +-----------+ 2xx           |
                            |  |       2xx to TU     |
                            |  |1xx                  |
    300-699 +---------------+  |1xx to TU            |
   ACK sent |                  |                     |
resp. to TU |  1xx             V                     |
            |  1xx to TU  -----------+               |
            |  +---------|           |               |
            |  |         |Proceeding |-------------->|
            |  +-------->|           | 2xx           |
            |            +-----------+ 2xx to TU     |
            |       300-699    |                     |
            |       ACK sent,  |                     |
            |       resp. to TU|                     |
            |                  |                     |      NOTE:
            |  300-699         V                     |
            |  ACK sent  +-----------+Transport Err. |  transitions
            |  +---------|           |Inform TU      |  labeled with
            |  |         | Completed |-------------->|  the event
            |  +-------->|           |               |  over the action
            |            +-----------+               |  to take
            |              ^   |                     |
            |              |   | Timer D fires       |
            +--------------+   | -                   |
                               |                     |
                               V                     |
                         +-----------+               |
                         |           |               |
                         | Terminated|<--------------+
                         |           |
                         +-----------+
```

Figure 5: INVITE client transaction

19). If an unreliable transport is being used, the client transaction SHOULD start timer A with a value of T1, and SHOULD NOT start timer A when a reliable transport is being used (Timer A controls request retransmissions). For any transport, the client transaction MUST start timer B with a value of 64*T1 seconds (Timer B controls transaction timeouts).

When timer A fires, the client transaction SHOULD retransmit the request by passing it to the transport layer, and SHOULD reset the timer with a value of 2*T1. The formal definition of *retransmit* within the context of the transaction layer, is to take the message previously sent to the transport layer, and pass it to the transport layer once more.

When timer A fires 2*T1 seconds later, the request SHOULD be retransmitted again (assuming the client transaction is still in this state). This process SHOULD continue, so that the request is retransmitted with intervals that double after each transmission. These retransmissions SHOULD only be done while the client transaction is in the "calling" state.

The default value for T1 is 500 ms. T1 is an estimate of the RTT between the client and server transactions. The optional RTT estimation procedure of Section 17.3 MAY be followed, in which case the resulting estimate MAY be used instead of 500 ms. If no RTT estimation is used, other values MAY be used in private networks where it is known that RTT has a different value. On the public Internet, T1 MAY be chosen larger, but SHOULD NOT be smaller.

If the client transaction is still in the "calling"state when timer B fires, the client transaction SHOULD inform the TU that a timeout has occurred. The client transaction MUST NOT generate an ACK. The value of 64*T1 is equal to the amount of time required to send seven requests in the case of an unreliable transport.

If the client transaction receives a provisional response while in the "calling" state, it transitions to the "proceeding" state. In the "proceeding" state, the client transaction SHOULD NOT retransmit the request any longer. Furthermore, the provisional response MUST be passed to the TU. Any further provisional responses MUST be passed up to the TU while in the "proceeding" state. Passing of all provisional responses is necessary since the TU will handle reliability of these messages, and therefore even retransmissions of a provisional response must be passed upwards.

When in either the "calling" or "proceeding" states, reception of a response with status code from 300-699 MUST cause the client transaction to transition to "completed". The client transaction MUST pass the received response up to the TU, and the client transaction MUST generate an ACK request, even if the transport is reliable (guidelines for constructing the ACK from the response are given in Section 17.1.1.3) and then pass the ACK to the transport layer for transmission. The ACK MUST be sent to the same address, port and transport that the original request was sent to. The client transaction SHOULD start timer D when it enters the "completed" state, with a value of at least 32 seconds for unreliable transports, and a value of zero seconds for reliable transports. Timer D is a reflection of the amount of time that the server transaction can remain in the "completed" state when unreliable transports are used. This is equal to Timer H in the INVITE server transaction, whose default is 64*T1. However, the client transaction does not know the value of T1 in use by the server transaction, so an absolute minimum of 32s is used instead of basing Timer D on T1.

Any retransmissions of the final response that are received while in the "completed" state SHOULD cause the ACK to be re-passed to the transport layer for retransmission, but the newly received response MUST NOT be passed up to the TU. A retransmission of the response is defined as any response which would match the same client transaction, based on the rules of Section 17.1.3.

If timer D fires while the client transaction is in the "completed" state, the client transaction MUST move to the terminated state, and it MUST inform the TU of the timeout.

When in either the "calling" or "proceeding" states, reception of a 2xx response MUST cause the client transaction to enter the terminated state, and the response MUST be passed up to the TU. The handling of this response depends on whether the TU is a proxy core or a UAC core. A UAC core will handle generation of the ACK for this response, while a proxy core will always forward the 200 (OK) upstream. The differing treatment of 200 (OK) between proxy and UAC is the reason that handling of it does not take place in the transaction layer.

The client transaction MUST be destroyed the instant it enters the terminated state. This is actually necessary to guarantee correct operation. The reason is that 2xx responses to an INVITE are treated differently;

each one is forwarded by proxies, and the ACK handling in a UAC is different. Thus, each 2xx needs to be passed to a proxy core (so that it can be forwarded) and to a UAC core (so it can be acknowledged). No transaction layer processing takes place. Whenever a response is received by the transport, if the transport layer finds no matching client transaction (using the rules of Section 17.1.3), the response is passed directly to the core. Since the matching client transaction is destroyed by the first 2xx, subsequent 2xx will find no match and therefore be passed to the core.

17.1.1.3 Construction of the ACK Request The ACK request constructed by the client transaction MUST contain values for the Call-ID, From, and Request-URI which are equal to the values of those header fields in the request passed to the transport by the client transaction (call this the "original request"). The To header field in the ACK MUST equal the To header field in the response being acknowledged, and will therefore usually differ from the To header field in the original request by the addition of the tag parameter. The ACK MUST contain a single Via header field, and this MUST be equal to the top Via header field of the original request. The ACK request MUST contain the same Route header fields as the request whose response it is acknowledging. The CSeq header field in the ACK MUST contain the same value for the sequence number as was present in the original request, but the method parameter MUST be equal to "ACK".

If the INVITE request whose response is being acknowledged had Route header fields, those header fields MUST appear in the ACK. This is to ensure that the ACK can be routed properly through any downstream stateless proxies.

Although any request MAY contain a body, a body in an ACK is special since the request cannot be rejected if the body is not understood. Therefore, placement of bodies in ACK for non-2xx is NOT RECOMMENDED, but if done, the body types are restricted to any that appeared in the INVITE, assuming that that the response to the INVITE was not 415. If it was, the body in the ACK MAY be any type listed in the Accept header field in the 415.

These rules for construction of ACK only apply to the client transaction. A UAC core which generates an ACK for 2xx MUST instead follow the rules described in Section 13. For example, consider the following request:

```
INVITE sip:bob@biloxi.com SIP/2.0
Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKkjshdyff
To: Bob <sip:bob@biloxi.com>
From: Alice <sip:alice@atlanta.com>;tag=88sja8x
Max-Forwards: 70
Call-ID: 987asjd97y7atg
CSeq: 986759 INVITE
```

The ACK request for a non-2xx final response to this request would look like this:

```
ACK sip:bob@biloxi.com SIP/2.0
Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKkjshdyff
To: Bob <sip:bob@biloxi.com>;tag=99sa0xk
From: Alice <sip:alice@atlanta.com>;tag=88sja8x
Max-Forwards: 70
Call-ID: 987asjd97y7atg
CSeq: 986759 ACK
```

17.1.2 non-INVITE Client Transaction

17.1.2.1 Overview of the non-INVITE Transaction Non-INVITE transactions do not make use of ACK. They are a simple request-response interaction. For unreliable transports, requests are retransmitted at an interval which starts at T1, and doubles until it hits T2. If a provisional response is received, retransmissions continue for unreliable transports, but at an interval of T2. The server transaction retransmits the last response it sent (which can be a provisional or final response) only when a retransmission of the request is received. This is why request retransmissions need to continue even after a provisional response, they are what ensure reliable delivery of the final response.

Unlike an INVITE transaction, a non-INVITE transaction has no special handling for the 2xx response. The result is that only a single 2xx response to a non-INVITE is ever delivered to a UAC.

17.1.2.2 Formal Description The state machine for the non-INVITE client transaction is shown in Figure 6. It is very similar to the state machine for INVITE.

The "Trying" state is entered when the TU initiates a new client transaction with a request. When entering this state, the client transaction SHOULD set timer F to fire in 64*T1 seconds. The request MUST be passed to the transport layer for transmission. If an unreliable transport is in use, the client transaction MUST set timer E to fire in T1 seconds. If timer E fires while still in this state, the timer is reset, but this time with a value of MIN(2*T1, T2). When the timer fires again, it is reset to a MIN(4*T1, T2). This process continues, so that retransmissions occur with an exponentially increasing inverval that caps at T2. The default value of T2 is 4s, and it represents the amount of time a non-INVITE server transaction will take to respond to a request, if it does not respond immediately. For the default values of T1 and T2, this results in intervals of 500 ms, 1 s, 2 s, 4 s, 4 s, 4 s, etc.

If Timer F fires while the client transaction is still in the "Trying" state, the client transaction SHOULD inform the TU about the timeout, and then it SHOULD enter the "Terminated" state. If a provisional response is received while in the "Trying" state, the response MUST be passed to the TU, and then the client transaction SHOULD move to the "Proceeding" state. If a final response (status codes 200-699) is received while in the "Trying" state, the response MUST be passed to the TU, and the client transaction MUST transition to the "Completed" state.

If Timer E fires while in the "Proceeding" state, the request MUST be passed to the transport layer for retransmission, and Timer E MUST be reset with a value of T2 seconds. If timer F fires while in the "Proceeding" state, the TU MUST be informed of a timeout, and the client transaction MUST transition to the terminated state. If a final response (status codes 200-699) is received while in the "Proceeding" state, the response MUST be passed to the TU, and the client transaction MUST transition to the "Completed" state.

Once the client transaction enters the "Completed" state, it MUST set Timer K to fire in T4 seconds for unreliable transports, and zero seconds for reliable transports. The "Completed" state exists to buffer any additional response retransmissions that may be received (which is why the client transaction remains there only for unreliable transports). T4 represents the amount of time the network will take to clear messages between client and server transactions. The default value of T4 is 5s. A response is a retransmission when it matches the same transaction, using the rules specified in Section 17.1.3. If Timer K fires while in this state, the client transaction MUST transition to the "Terminated" state.

Once the transaction is in the terminated state, it MUST be destroyed. As with client transactions, this is needed to ensure reliability of the 2xx responses to INVITE.

```
                                   |Request from app
                                   |send request
               Timer E             V
               send request  +-----------+
                   +---------|           |-------------------+
                   |         |  Trying   |  Timer F          |
                   +-------->|           |  or Transport Err.|
                             +-----------+  inform TU        |
                200-699         |  |                         |
                resp. to TU     |  |1xx                      |
                +---------------+  |resp. to TU              |
                |                  |                         |
                |   Timer E        V       Timer F           |
                |   send req +-----------+ or Transport Err. |
                |  +---------|           | inform TU         |
                |  |         |Proceeding |------------------>|
                |  +-------->|           |-----+             |
                |            +-----------+     |1xx          |
                |              |      ^        |resp to TU   |
                | 200-699      |      +--------+             |
                | resp. to TU  |                             |
                |              |                             |
                |              V                             |
                |            +-----------+                   |
                |            |           |                   |
                |            | Completed |                   |
                |            |           |                   |
                |            +-----------+                   |
                |              ^   |                         |
                |              |   | Timer K                 |
                +--------------+   | -                       |
                                   |                         |
                                   V                         |
             NOTE:           +-----------+                   |
                             |           |                   |
         transitions         | Terminated|<------------------+
         labeled with        |           |
         the event           +-----------+
         over the action
         to take
```

Figure 6: non-INVITE client transaction

17.1.3 Matching Responses to Client Transactions

When the transport layer in the client receives a response, it has to figure out which client transaction will handle the response, so that the processing of Sections 17.1.1 and 17.1.2 can take place.

The branch parameter in the top Via header field is used for this purpose. A response matches a client transaction under two conditions. First, if the response has the same value of the branch parameter in the top Via header field as the branch parameter in the top Via header field of the request that created the transaction. Second, if the method parameter in the CSeq header field matches the method of the request that created the transaction. The method is needed since a CANCEL request constitutes a different transaction, but shares the same value of the branch parameter.

A response which matches a transaction matched by a previous response is considered a retransmission of that response.

17.1.4 Handling Transport Errors

When the client transaction sends a request to the transport layer to be sent, the following procedures are followed if the transport layer indicates a failure.

The client transaction SHOULD inform the TU that a transport failure has occurred, and the client transaction SHOULD transition directly to the terminated state.

17.2 Server Transaction

The server transaction is responsible for the delivery of requests to the TU, and the reliable transmission of responses. It accomplishes this through a state machine. Server transactions are created by the core when a request is received, and transaction handling is desired for that request (this won't always be the case).

As with the client transactions, the state machine depends on whether the received request is an INVITE request or not.

17.2.1 INVITE Server Transaction

The state diagram for the INVITE server transaction is shown in Figure 7.

When a server transaction is constructed with a request, it enters the "Proceeding" state. The server transaction MUST generate a 100 response (not any status code – the specific value of 100) unless it knows that the TU will generate a provisional or final response within 200 ms, in which case it MAY generate a 100 (Trying) response. This provisional response is needed to rapidly quench request retransmissions in order to avoid network congestion. The 100 response is constructed according to the procedures in Section 8.2.6, except that insertion of tags in the To header field of the response (when none was present in the request), is downgraded from MAY to SHOULD NOT. The request MUST be passed to the TU.

The TU passes any number of provisional responses to the server transaction. So long as the server transaction is in the "Proceeding" state, each of these MUST be passed to the transport layer for transmission. They are not sent reliably by the transaction layer (they are not retransmitted by it), and do not cause a change in the state of the server transaction. When provisional responses need to be delivered reliably, it is handled by the TU, which will retransmit the provisional responses itself, and pass downwards each retransmission to the server transaction. If a request retransmission is received while in the "Proceeding" state, the most recent provisional response that was received from the TU MUST be passed to the transport layer for retransmission. A request is a retransmission if it matches the same server transaction based on the rules of Section 17.2.3.

If, while in the "proceeding" state, the TU passes a 2xx Response to the server transaction, the server transaction MUST pass this response to the transport layer for transmission. It is not retransmitted by the server transaction; retransmissions of 2xx responses are handled by the TU. The server transaction MUST then transition to the "terminated" state.

```
                   |INVITE
                   |pass INV to TU
INVITE             V send 100 if TU won't in 200ms
send response+-----------+
    +--------|           |--------+101-199 from TU
    |        | Proceeding|        |send response
    +------->|           |<-------+
             |           |          Transport Err.
             |           |          Inform TU
             |           |--------------->+
             +-----------+                |
300-699 from TU |     |2xx from TU        |
send response   |     |send response      |
                |     +------------------>+
                |                         |
INVITE          V          Timer G fires  |
send response+-----------+ send response  |
    +--------|           |--------+       |
    |        | Completed |        |       |
    +------->|           |<-------+       |
             +-----------+                |
                |     |                   |
            ACK |     |                   |
            -   |     +------------------>+
                |        Timer H fires    |
                V        or Transport Err.|
             +-----------+  Inform TU     |
             |           |                |
             | Confirmed |                |
             |           |                |
             +-----------+                |
                   |                      |
                   |Timer I fires         |
                   |-                     |
                   |                      |
                   V                      |
             +-----------+                |
             |           |                |
             | Terminated|<---------------+
             |           |
             +-----------+
```

Figure 7: INVITE server transaction

While in the "Proceeding" state, if the TU passes a response with status code from 300 to 699 to the server transaction, the response MUST be passed to the transport layer for transmission, and the state machine MUST enter the "Completed" state. For unreliable transports, timer G is set to fire in T1 seconds, and is not set to fire for reliable transports.

This is a change from RFC 2543, where responses were always retransmitted, even over reliable transports.

When the "Completed" state is entered, timer H MUST be set to fire in 64*T1 seconds, for all transports. Timer H determines when the server transaction gives up retransmitting the response. Its value is chosen to equal Timer B, the amount of time a client transaction will continue to retry sending a request. If timer G fires, the response is passed to the transport layer once more for retransmission, and timer G is set to fire in MIN(2*T1, T2) seconds. From then on, when timer G fires, the response is passed to the transport again for transmission, and timer G is reset with a value that doubles, unless that value exceeds T2, in which case it is reset with the value of T2. This is identical to the retransmit behavior for requests in the "Trying" state of the non- INVITE client transaction. Furthermore, while in the "completed" state, if a request retransmission is received, the server SHOULD pass the response to the transport for retransmission.

If an ACK is received while the server transaction is in the "Completed" state, the server transaction MUST transition to the "confirmed" state. As Timer G is ignored in this state, any retransmissions of the response will cease.

If timer H fires while in the "Completed" state, it implies that the ACK was never received. In this case, the server transaction MUST transition to the terminated state, and MUST indicate to the TU that a transaction failure has occurred.

The purpose of the "confirmed" state is to absorb any additional ACK messages that arrive, triggered from retransmissions of the final response. When this state is entered, timer I is set to fire in T4 seconds for unreliable transports, and zero seconds for reliable transports. Once timer I fires, the server MUST transition to the "Terminated" state.

Once the transaction is in the terminated state, it MUST be destroyed. As with client transactions, this is needed to ensure reliability of the 2xx responses to INVITE.

17.2.2 non-INVITE Server Transaction

The state machine for the non-INVITE server transaction is shown in Figure 8.

The state machine is initialized in the "Trying" state, and is passed a request other than INVITE or ACK when initialized. This request is passed up to the TU. Once in the "Trying" state, any further request retransmissions are discarded. A request is a retransmission if it matches the same server transaction, using the rules specified in Section 17.2.3.

While in the "Trying" state, if the TU passes a provisional response to the server transaction, the server transaction MUST enter the "Proceeding" state. The response MUST be passed to the transport layer for transmission. Any further provisional responses that are received from the TU while in the "Proceeding" state MUST be passed to the transport layer for transmission. If a retransmission of the request is received while in the "Proceeding" state, the most recently sent provisional response MUST be passed to the transport layer for retransmission. If the TU passes a final response (status codes 200-699) to the server while in the "Proceeding" state, the transaction MUST enter the "Completed" state, and the response MUST be passed to the transport layer for transmission.

When the server transaction enters the "Completed" state, it MUST set Timer J to fire in 64*T1 seconds for unreliable transports, and zero seconds for reliable transports. While in the "Completed" state, the server transaction MUST pass the final response to the transport layer for retransmission whenever a retransmission

```
                      |Request received
                      |pass to TU
                      V
                +-----------+
                |           |
                | Trying    |-------------+
                |           |             |
                +-----------+             |200-699 from TU
                      |                   |send response
                      |1xx from TU        |
                      |send response      |
                      |                   |
   Request            V      1xx from TU  |
   send response+-----------+send response|
       +--------|           |--------+    |
       |        | Proceeding|        |    |
       +------->|           |<-------+    |
+<--------------|           |             |
|Trnsprt Err    +-----------+             |
|Inform TU            |                   |
|                     |                   |
|                     |200-699 from TU    |
|                     |send response      |
|  Request            V                   |
|  send response+-----------+             |
|      +--------|           |             |
|      |        | Completed |-------------+
|      +------->|           |
+<--------------|           |
|Trnsprt Err    +-----------+
|Inform TU            |
|                     |Timer J fires
|                     |-
|                     |
|                     V
|               +-----------+
|               |           |
+-------------->| Terminated|
                |           |
                +-----------+
```

Figure 8: non-INVITE server transaction

of the request is received. Any other final responses passed by the TU to the server transaction MUST be discarded while in the "Completed" state. The server transaction remains in this state until Timer J fires, at which point it MUST transition to the "Terminated" state.

The server transaction MUST be destroyed the instant it enters the "Terminated" state.

17.2.3 Matching Requests to Server Transactions

When a request is received from the network by the server, it has to be matched to an existing transaction. This is accomplished in the following manner.

The branch parameter in the topmost Via header field the request is examined. If it is present, and begins with the magic cookie "z9hG4bK", the request was generated by a client transaction compliant to this specification. Therefore, the branch parameter will be unique across all transactions sent by that client. The request matches a transaction if the branch parameter in the request is equal to the one in the top Via header field of the request that created the transaction, the source address and port of the request are the same as the source address and port of the the request that created the transaction, and in the case of a CANCEL request, the method of the request that created the transaction was also CANCEL. This matching rule applies to both INVITE and non-INVITE transactions alike.

> Source address and port are used as part of the matching process because there could be duplication of branch parameters from different clients; uniqueness in time is mandated for construction of the parameter, but not uniqueness in space.

If the branch parameter in the top Via header field is not present, or does not contain the magic cookie, the following procedures are used. These exist to handle backwards compatibility with RFC 2543 compliant implementations.

The INVITE request matches a transaction if the Request-URI, To, From, Call-ID, CSeq, and top Via header field match those of the INVITE request which created the transaction. In this case, the INVITE is a retransmission of the original one that created the transaction. The ACK request matches a transaction if the Request-URI, From, Call-ID, CSeq number (not the method), and top Via header field match those of the INVITE request which created the transaction, and the To header field of the ACK matches the To header field of the response sent by the server transaction (which then includes the tag). Matching is done based on the matching rules defined for each of those header fields. The usage of the tag in the To header field helps disambiguate ACK for 2xx from ACK for other responses at a proxy which may have forwarded both responses (which can occur in unusual conditions). An ACK request that matches an INVITE transaction matched by a previous ACK is considered a retransmission of that previous ACK.

For all other request methods, a request is matched to a transaction if the Request-URI, To, From, Call-ID and Cseq (including the method) and top Via header field match those of the request which created the transaction. Matching is done based on the matching rules defined for each of those header fields. When a non-INVITE request matches an existing transaction, it is a retransmission of the request which created that transaction.

Because the matching rules include the Request-URI, the server cannot match a response to a transaction. When the TU passes a response to the server transaction, it must pass it to the specific server transaction for which the response is targeted.

17.2.4 Handling Transport Errors

When the server transaction sends a response to the transport layer to be sent, the following procedures are followed if the transport layer indicates a failure.

First, the procedures in [2] are followed, which attempt to deliver the response to a backup. If those should all fail, such that all elements generate ICMP errors, or no SRV records are present, the server transaction SHOULD inform the TU that a failure has occurred, and SHOULD transition to the terminated state.

17.3 RTT Estimation

Most of the timeouts used in the transaction state machines derive from T1, which is an estimate of the RTT between the client and server transactions. This subsection defines optional procedures that a client can use to build up estimates of the RTT to a particular IP address. To perform this procedure, the client MUST maintain a table of variables for each destination IP address to which an RTT estimate is being made.

If a client wishes to measure RTT for a particular IP address, it MUST include a Timestamp header field into a request containing the time when the request is initially created and passed to a new client transaction, which transmits the request. If a 100 (Trying) response (not any 1xx, only the 100 (Trying) response) is received before the client transaction generates a retransmission, an RTT estimate is made. This is consistent with the RFC 2988 requirements on TCP for using Karn's algorithm in RTT estimation.

The estimate, called R, is made by computing the difference between the current time and the value of Timestamp header field in the 100 response, and then subtracting the value of the delay field of the Timestamp header in the response, if present. The value of R is applied to the estimation of RTO as described in Section 2 of RFC 2988 [26], with the following differences. First, the initial value of RTO is 500 ms for SIP, not 3 s as is used for TCP. Second, there is no minimum value for the RTO, as there is for TCP, if SIP is being run on a private network. When run on the public Internet, the minimum is 500 ms, as opposed to 1 s for TCP. This difference is because of the expected usage of SIP in private networks where rapid call setup times are service critical. Once RTO is computed, the timer T1 is set to the value of RTO, and all other timers scale proportionally as described above.

This value of T1 would be used for scaling all of the client and server transaction timers described above, when a request or response, respectively, is sent to that IP address.

If the IP address is that of a stateless proxy, the actual round trip time that is measured will be the average to all transaction stateful proxies or UAs that are reached through the stateless proxy. This estimate may therefore be too low or too high for a specific transactional element being communicated with through the stateless proxy.

18 Reliability of Provisional Responses

Normally, provisional responses are not transmitted reliably. The TU generates a single provisional response and passes it to the server transaction, which sends it once. RFC 2543 provided no means for reliable transmission of these messages.

It was later observed that reliability was important in several cases, including interoperability scenarios with the PSTN. Therefore, an optional capability was added in this specification to support reliable transmission of provisional responses.

The reliability mechanism works by mirroring the current reliability mechanisms for 2xx final responses to INVITE. Those requests are transmitted periodically by the TU until a separate transaction, ACK, is received that indicates reception of the 2xx by the UAC. The reliability for the 2xx responses to INVITE and ACK messages are end-to-end. In order to achieve reliability for provisional responses, we do nearly the same thing. Reliable provisional responses are retransmitted by the TU with an exponential backoff.

Those retransmissions cease when a PRACK message is received. The PRACK request plays the same role as ACK, but for provisional responses. There is an important difference, however. PRACK is a normal SIP message, like BYE. As such, its own reliability is ensured hop-by-hop through each stateful proxy. Similarly, PRACK has its own response. If this were not the case, the PRACK message could not traverse existing proxy servers.

Each provisional response is given a sequence number, carried in the RSeq header field in the response. The PRACK messages contain an RAck header field, which indicates the sequence number of the provisional response that is being acknowledged. The acknowledgements are not cumulative, and the specifications recommend a single outstanding provisional response at a time, for purposes of congestion control.

18.1 UAS Behavior

A UAS MAYsend any non-100 provisional response to INVITE reliably, so long as the initial INVITE request (the request whose provisional response is being sent reliably) contained a Supported header field with the option tag `100rel`. While this specification does not allow reliable provisional responses for any method but INVITE, extensions that define new methods that can establish dialogs may make use of the mechanism.

The UAS MUST send any non-100 provisional response reliably if the initial request contained a Require header field with the option tag `100rel`. If the UAS is unwilling to do so, it MUST reject the initial request with a 420 (Bad Extension) and include a Unsupported header field containing the option tag `100rel`.

A UAS MUST NOT attempt to send a 100 (Trying) response reliably. Only provisional responses numbered 101 to 199 may be sent reliably. If the request did not include either a Supported or Require header field indicating this feature, the UAS MUST NOT send the provisional response reliably.

> 100 (Trying) responses are hop-by-hop only. For this reason, the reliability mechanisms described here, which are end-to-end, cannot be used.

An element that can act as a proxy can also send reliable provisional Responses. In this case, it acts as a UAS for purposes of that transaction. However, it MUST NOT attempt to do so for any request that contains a tag in the To field. That is, a proxy cannot generate reliable provisional responses to requests sent within the context of a dialog. Of course, unlike a UAS, when the proxy element receives a PRACK that does not match any outstanding reliable provisional response, the PRACK MUST be proxied.

The rest of this discussion assumes that the initial request contained a Supported or Require header field listing `100rel`, and that there is a provisional response to be sent reliably.

The provisional response to be sent reliably is constructed by the UAS core according to the procedures of Section 8.2.6 and Section 12. Specifically, the provisional response MUST establish a dialog if one is not yet created. In addition, it MUSTcontain a Require header field containing the option tag `100rel`, and MUSTinclude an RSeq header field. The value of the header field for the first reliable provisional response in a transaction MUST be between 1 and 2**31 - 1. It is RECOMMENDED that it be chosen uniformly in this range. The RSeq numbering space is within a single transaction. This means that provisional responses for different requests MAY use the same values for the RSeq number.

The reliable provisional response is passed to the transaction layer periodically with an interval that starts at T1 seconds and doubles for each retransmission (T1 is defined in Section 17). Once passed to the server transaction, it is added to an internal list of unacknowledged reliable provisional responses.

> This differs from retransmissions of 2xx responses, which cap at T2 seconds. This is because retransmissions of ACK are triggered on receipt of a 2xx, but retransmissions of PRACK take place independently of reception of 1xx.

Retransmissions cease when a matching PRACK is received. PRACK is like any other request within a dialog, and the UAS core processes it according to the procedures of Sections 8.2 and 12.2.2. A matching PRACK is defined as one within the same dialog as the response, and whose method, CSeq-num, and response-num in the RAck header field match, respectively, the method and sequence number from the CSeq and sequence number from the RSeq of the reliable provisional response.

If a PRACK request is received that does not match any unacknowledged reliable provisional response, the UAS MUST respond to the PRACK with a 481 response. If the PRACK does match an unacknowledged reliable provisional response, it MUST be responded to with a 2xx response. The UAS can be certain at this point that the provisional response has been received in order. It SHOULD cease retransmissions of the reliable provisional response, and MUST remove it from the list of unacknowledged provisional responses.

If a reliable provisional response is retransmitted for 64*T1 seconds without reception of a corresponding PRACK, the UAS SHOULD reject the original request with a 5xx response.

If the PRACK contained a body, the body is treated in the same way a body in an ACK is treated.

After the first reliable provisional response for a request has been acknowledged, the UAS MAY send additional reliable provisional responses. The UAS MUST NOT send a second reliable provisional response until the first is acknowledged. After the first, it is RECOMMENDED that the UAS not send an additional reliable provisional response until the previous is acknowledged. The first reliable provisional response receives special treatment because it conveys the initial sequence number. If additional reliable provisional responses were sent before the first was acknowledged, the UAS could not be certain these were received in order.

The value of the RSeq in each subsequent reliable provisional response for the same request MUSTbe greater by exactly one. RSeq numbers MUST NOT wrap around. Because the initial one is chosen to be less than 2**31 - 1, but the maximum is 2**32 - 1, there can be up to 2**31 reliable provisional responses per request, which is more than sufficient.

Note that the UAS MAY send a final response to the initial request before having received PRACKs for all unacknowledged reliable provisional responses. In that case, it SHOULD NOT continue to retransmit the unacknowledged reliable provisional responses, but it MUST be prepared to process PRACK requests for those outstanding responses. A UAS MUST NOT send new reliable provisional responses (as opposed to retransmissions of unacknowledged ones) after sending a final response to a request.

18.2 UAC Behavior

If a provisional response is received for the initial request, and that response contains a Require header field containing the option tag `100rel`, the response is to be sent reliably. If the response is a 100 (Trying) (as opposed to 101 to 199), this option tag MUST be ignored, and the procedures below MUST NOT be used.

Assuming the response is to be transmitted reliably, the UAC MUST create a new request with method PRACK. This request is sent within the dialog associated with the provisional response (indeed, the provisional response may have created the dialog). PRACK requests MAY contain bodies, which are interpreted according to their type and disposition.

Note that the PRACK is like any other non-INVITE request within a dialog. In particular, a UAC SHOULD NOT retransmit the PRACK request when it receives a retransmission of the provisional response being acknowledged, although doing so does not create a protocol error.

Once a reliable provisional response is received, retransmissions of that response MUST be discarded. A response is a retransmission when its dialog ID, CSeq, and RSeq match the original response. The UAC MUST maintain a sequence number that indicates the most recently received in-order reliable provisional response for the initial request. This sequence number MUST be maintained until a final response is received for the initial request. Its value MUST be initialized to the RSeq header field in the first reliable provisional response received for the initial request.

Handling of subsequent reliable provisional responses for the same initial request follows the same rules as above, with the following difference: reliable provisional responses are guaranteed to be in order. As a result, if the UAC receives another reliable provisional response to the same request, and its RSeq value is not one higher than the value of the sequence number, that response MUST NOT be acknowledged with a PRACK, and MUST NOT be processed further by the TU. An implementation MAY discard the response, or MAY cache the response in the hopes of receiving the missing responses.

The UAC MAY acknowledge reliable provisional responses received after the final response or MAY discard them.

19 Transport

The transport layer is responsible for the actual transmission of requests and responses over network transports. This includes determination of the connection to use for a request or response, in the case of connection oriented transports.

The transport layer is responsible for managing any persistent connections (for transports like TCP, TLS and SCTP) including ones it opened, as well as ones opened to it. This includes connections opened by the client or server transports, so that connections are shared between client and server transport functions. These connections are indexed by the [address, port, transport] at the far end of the connection. When a connection is opened by the transport layer, this index is set to the destination IP, port and transport. When the connection is accepted by the transport layer, this index is set to the source IP, port and transport. Note that, because the source port is often ephemeral, connections accepted by the transport layer will frequently not be reused. The result is that two proxies in a “peering” relationship using a connection oriented transport will frequently have two connections in use, one for transactions initiated in each direction.

It is RECOMMENDED that connections be kept open for some implementation defined duration after the last message was sent or received over that connection. This duration SHOULD at least equal the longest amount of time the element would need in order to bring a transaction from instantiation to the terminated state. This is to insure that transactions complete over the same connection they are initiated on (i.e., request, response, and in the case of INVITE, ACK for non-2xx responses)). This usually means at least the maximum of T3 and 64*T1. However, it could be larger in an element that has a TU that is using a large value for timer C, for example.

All SIP elements MUST implement UDP and TCP. Other transports MAY be implemented by any entity.

> Making TCP mandatory for UA is a substantial change from RFC 2543. It has arisen out of the need to handle larger messages, which MUST use TCP, as discussed below. Thus, even if an element never sends large messages, it may receive one, and needs to be able to do that.

19.1 Clients

19.1.1 Sending Requests

The client side of the transport layer is responsible for sending the request and receiving responses. The user of the transport layer passes the client transport the request, an IP address, port, transport, and possibly TTL for multicast destinations.

If a request is within 500 bytes of the path MTU, or if it is larger than 1000 bytes when the path MTU is unknown, it MUST be sent using TCP. This is to prevent fragmentation of messages over UDP, and to provide congestion control for larger messages. However, implementations MUST be able to handle messages up to the maximum datagram packet size. For UDP, this size is 65,535 bytes, including header fields.

> The 500 byte "buffer" between the message size and the MTU accomodates the fact that the response in SIP can be larger than the request. This happens due to the addition of Record-Route header fields to the responses to INVITE, for example. With the extra buffer, the response can be 500 bytes larger than the request, and still not be fragmented. 1000 is chosen when path MTU is not known, based on the assumption of a 1500 byte ethernet MTU.

A client that sends a request to a multicast address MUST add the "maddr" parameter to its Via header field, and SHOULD add the "ttl" parameter. (In that case, the maddr parameter SHOULD contain the destination multicast address, although under exceptional circumstances it MAY contain a unicast address.) Requests sent to multicast groups SHOULD be scoped to ensure that they are not forwarded beyond the administrative domain to which they were targeted. This scoping MAY be done with either TTL or administrative scopes [12], depending on what is implemented in the network.

It is important to note that the layers above the transport layer do not operate differently for multicast as opposed to unicast requests. This means that SIP treats multicast more like anycast, assuming that there is a single recipient generating responses to requests. If this is not the case, the first response will end up "winning", based on the client transaction rules. Any other responses from different UA will appear as retransmissions and be discarded. This limits the utility of multicast to cases where an anycast type of function is desired, such as registrations.

Before a request is sent, the client transport MUST insert a value of the sent-by field into the Via header field. This field contains an IP address or host name, and port. The usage of an FQDN is RECOMMENDED. This field is used for sending responses under certain conditions.

For reliable transports, the response is normally sent on the connection the request was received on. Therefore, the client transport MUST be prepared to receive the response on the same connection used to send the request. Under error conditions, the server may attempt to open a new connection to send the response. To handle this case, the transport layer MUST also be prepared to receive an incoming connection on the source IP address that the request was sent from, and port number in the sent-by field. It also MUST be prepared to receiving incoming connections on any address and port which would be selected by a server based on the procedures described in Section 5 of [2].

For unreliable unicast transports, the client transport MUST be prepared to receive responses on the source IP address that the request is sent from (as responses are sent back to the source address), but the port number in the sent-by field. Furthermore, as with reliable transports, in certain cases the response will be sent elsewhere. The client MUST be prepared to receive responses on any address and port which would be selected by a server based on the procedures described in Section 5 of [2].

For multicast, the client transport MUST be prepared to receive responses on the same multicast group and port that the request is sent to (e.g., it needs to be a member of the multicast group it sent the request to.)

If a request is destined to an IP address, port, and transport to which an existing connection is open, it is RECOMMENDED that this connection be used to send the request, but another connection MAY be opened and used.

If a request is sent using multicast, it is sent to the group address, port, and TTL provided by the transport user. If a request is sent using unicast unreliable transports, it is sent to the IP address and port provided by the transport user.

19.1.2 Receiving Responses

When a response is received, the client transport examines the top Via header field. If the value of the sent-by parameter in that header field does not correspond to a value that the client transport is configured to insert into requests, the response MUST be rejected.

If there are any client transactions in existence, the client transport uses the matching procedures of Section 17.1.3 to attempt to match the response to an existing transaction. If there is a match, the response MUST be passed to that transaction. Otherwise, the response MUST be passed to the core (whether it be stateless proxy, stateful proxy, or UA) for further processing. Handling of these "stray" responses is dependent on the core (a stateless proxy will forward all responses, for example).

19.2 Servers

19.2.1 Receiving Requests

When the server transport receives a request over any transport, it MUST examine the value of the sent-by parameter in the top Via header field. If the host portion of the sent-by parameter contains a domain name, or if it contains an IP address that differs from the packet source address, the server MUST add a "received" attribute to that Via header field. This attribute MUST contain the source address that the packet was received from. This is to assist the server transport layer in sending the response, since it must be sent to the source IP address that the request came from.

Consider a request received by the server transport which looks like, in part:

```
INVITE sip:bob@Biloxi.com SIP/2.0
Via: SIP/2.0/UDP bobspc.biloxi.com:5060
```

The request is received with a source IP address of 1.2.3.4. Before passing the request up, the transport would add a received parameter, so that the request would look like, in part:

```
INVITE sip:bob@Biloxi.com SIP/2.0
Via: SIP/2.0/UDP bobspc.biloxi.com:5060;received=1.2.3.4
```

Next, the server transport attempts to match the request to the server transaction. It does so using the matching rules described in Section 17.2.3. If a matching server transaction is found, the request is passed to that transaction for processing. If no match is found, the request is passed to the core, which may decide to construct a new server transaction for that request. Note that when a UAS core sends a 2xx response to INVITE, the server transaction is destroyed. This means that when the ACK arrives, there will be no matching server transaction, and based on this rule, the ACK is passed to the UAS core, where it is processed.

19.2.2 Sending Responses

The server transport uses the value of the top Via header field in order to determine where to send a response. It MUST follow the following process:

- If the "sent-protocol" is a reliable transport protocol such as TCP, TLS or SCTP, the response MUST be sent using the existing connection to the source of the original request that created the transaction, if that connection is still open. This does require the server transport to maintain an association between server transactions and transport connections. If that connection is no longer open, the server MAY open a connection to the IP address in the received parameter, if present, using the port in the sent-by value, or the default port for that transport, if no port is specified (5060 for UDP and TCP, 5061 for TLS and SSL). If that connection attempt fails, the server SHOULD use the procedures in [2] for servers in order to determine the IP address and port to open the connection and send the response to.

- Otherwise, if the Via header field contains a “maddr” parameter, forward the response to the address listed there, using the port indicated in “sent-by”, or port 5060 if none is present. If the address is a multicast address, the response SHOULD be sent using the TTL indicated in the “ttl” parameter, or with a TTL of 1 if that parameter is not present.

- Otherwise (for unreliable unicast transports), if the top Via has a received parameter, send the response to the address in the “received” parameter, using the port indicated in the “sent-by” value, or using port 5060 if none is specified explicitly. If this fails, e.g., elicits an ICMP “port unreachable” response, send the response to the address in the “sent-by” parameter. The address to send to is determined by following the procedures defined in Section 5 of [2].

- Otherwise, if it is not receiver-tagged, send the response to the address indicated by the “sent-by” value, using the procedures in Section 5 of [2].

19.3 Framing

In the case of message oriented transports (such as UDP), if the message has a Content-Length header field, the message body is assumed to contain that many bytes. If there are additional bytes in the transport packet below the end of the body, they MUST be discarded. If the transport packet ends before the end of the message body, this is considered an error. If the message is a response, it MUST be discarded. If its a request, the element SHOULD generate a 400 class response. If the message has no Content-Length header field, the message body is assumed to end at the end of the transport packet.

In the case of stream oriented transports (such as TCP), the Content-Length header field indicates the size of the body. The Content-Length header field MUST be used with stream oriented transports.

19.4 Error Handling

Error handling is independent of whether the message was a request or response.

If the transport user asks for a message to be sent over an unreliable transport, and the result is an ICMP error, the behavior depends on the type of ICMP error. A host, network, port or protocol unreachable errors, or parameter problem errors SHOULD cause the transport layer to inform the transport user of a failure in sending. Source quench and TTL exceeded ICMP errors SHOULD be ignored.

If the transport user asks for a request to be sent over a reliable transport, and the result is a connection failure, the transport layer SHOULD inform the transport user of a failure in sending.

20 Usage of HTTP Authentication

SIP provides a stateless, challenge-based mechanism for authentication that is based on authentication in HTTP. Any time that a proxy server or UA receives a request (with the exceptions given in Section 20.1), it

MAY challenge the initiator of the request to provide assurance of its identity. Once the originator has been identified, the recipient of the request SHOULD ascertain whether or not this user is authorized to make the request in question. No authorization systems are recommended or discussed in this document.

The “Digest” authentication mechanism described in this section provides message authentication and replay protection only, without message integrity or confidentiality. Protective measures above and beyond those provided by Digest need to be taken to prevent active attackers from modifying SIP requests and responses.

Note that due to its weak security, the usage of “Basic” authentication has been deprecated. Servers MUST NOT accept credentials using the “Basic” authorization scheme, and servers also MUST NOT challenge with “Basic”. This is a change from RFC 2543.

20.1 Framework

The framework for SIP authentication closely parallels that of HTTP (RFC 2617 [16]). In particular, the BNF for auth-scheme, auth-param, challenge, realm, realm-value, and credentials is identical (although the usage of “Basic” as a scheme is not permitted). In SIP, a UAS uses the 401 (Unauthorized) response to challenge the identity of a UAC. Additionally, registrars and redirect servers MAY make use of 401 (Unauthorized) responses for authentication, but proxies MUST NOT, and instead MAY use the 407 (Proxy Authentication Required) response. The requirements for inclusion of the Proxy-Authenticate, Proxy-Authorization, WWW-Authenticate, and Authorization in the various messages are identical to those described in RFC 2617 [16].

Since SIP does not have the concept of a canonical root URL, the notion of protection spaces is interpreted differently in SIP. The realm string alone defines the protection domain. This is a change from RFC 2543, in which the Request-URI and the realm together defined the protection domain.

> This previous definition of protection domain caused some amount of confusion since the Request-URI sent by the UAC and the Request-URI received by the challenging server might be different, and indeed the final form of the Request-URI might not be known to the UAC. Also, the previous definition depended on the presence of a SIP URI in the Request-URI and seemed to rule out alternative URI schemes (for example, the tel URL).

Operators of user agents or proxy servers that will authenticate received requests MUST adhere to the following guidelines for creation of a realm string for their server:

- Realm strings MUST be globally unique. It is RECOMMENDED that a realm string contain a hostname or domain name, following the recommendation in Section 3.2.1 of RFC 2617 [16].

- Realm strings SHOULD present a human-readable identifier that can be rendered to a user.

For example:

```
INVITE sip:bob@biloxi.com SIP/2.0
WWW-Authenticate:  Digest realm="biloxi.com", <...>
```

Generally, SIP authentication is meaningful for a specific realm, a protection domain. Thus, for Digest authentication, each such protection domain has its own set of usernames and passwords. If a server does not require authentication for a particular request, it MAY accept a default username, “anonymous”, which has no password (password of “”). Similarly, UACs representing many users, such as PSTN gateways, MAY have their own device-specific username and password, rather than accounts for particular users, for their realm.

While a server can legitimately challenge most SIP requests, there are two requests defined by the SIP standard today that require special handling for authentication: ACK and CANCEL.

Under an authentication scheme that uses responses to carry values used to compute nonces (such as Digest), some problems come up for any requests that take no response, including ACK. For this reason, any credentials in the INVITE that were accepted by a server MUST be accepted by that server for the ACK. UACs creating an ACK message should duplicate all of the Authorization and Proxy-Authorization header fields that appeared in the INVITE to which the ACK corresponds. Servers MUST NOT attempt to challenge an ACK.

Although the CANCEL method does take a response (a 2xx), servers MUST NOT attempt to challenge CANCEL requests since these requests cannot be resubmitted. Generally, a CANCEL request SHOULD be accepted by a server if it comes from the same host that sent the request being canceled (provided that some sort of transport or network layer security association, as described in Section 22.2.1, is in place).

When a UAC receives a challenge, it SHOULD render to the user the contents of the "realm" parameter in the challenge (which appears in either a WWW-Authenticate header field or Proxy-Authenticate header field) if the UAC device does not already know of a credential for the realm in question. A service provider that pre-configures UAs with credentials for its realm should be aware that users will not have the opportunity to present their own credentials for this realm when challenged at a pre-configured device.

Finally, note that even if a UAC can locate credentials that are associated with the proper realm, the potential exists that these credentials may no longer be valid or that the challenging server will not accept these credentials for whatever reason (especially when "anonymous" with no password is submitted). In this instance a server may repeat its challenge, or it may respond with a 403 Forbidden. A UAC MUST NOT re-attempt requests with the credentials that have just been rejected (unless the request was rejected because of a stale nonce).

20.2 User-to-User Authentication

When a UAS receives a request from a UAC, the UAS MAY authenticate the originator before the request is processed. If no credentials (in the Authorization header field) are provided in the request, the UAS can challenge the originator to provide credentials by rejecting the request with a 401 (Unauthorized) status code.

The WWW-Authenticate response-header field MUST be included in 401 (Unauthorized) response messages. The field value consists of at least one challenge that indicates the authentication scheme(s) and parameters applicable to the Request-URI. See [H14.47] for a definition of the syntax.

An example of the WWW-Authenticate header field in a 401 challenge is:

```
WWW-Authenticate: Digest
        realm="biloxi.com",
        qop="auth,auth-int",
        nonce="dcd98b7102dd2f0e8b11d0f600bfb0c093",
        opaque="5ccc069c403ebaf9f0171e9517f40e41"
```

When the originating UAC receives the 401 (Unauthorized), it SHOULD, if it is able, re-originate the request with the proper credentials. The UAC may require input from the originating user before proceeding.

Once authentication credentials have been supplied (either directly by the user, or discovered in an internal keyring), UAs SHOULD cache the credentials for a given value of the To header field and "realm" and attempt to re-use these values on the next request for that destination. UAs MAY cache credentials in any way they would like.

If no credentials for a realm can be located, UACs MAY attempt to retry the request with a username of "anonymous" and no password (a password of "").

Once credentials have been located, any UA that wishes to authenticate itself with a UAS or registrar – usually, but not necessarily, after receiving a 401 (Unauthorized) response – MAY do so by including an Authorization header field with the request. The Authorization field value consists of credentials containing the authentication information of the UA for the realm of the resource being requested as well as parameters required in support of authentication and replay protection.

An example of the Authorization header field is:

```
Authorization: Digest username="bob",
        realm="biloxi.com",
        nonce="dcd98b7102dd2f0e8b11d0f600bfb0c093",
        uri=sip:alice@atlanta.com,
        qop=auth,
        nc=00000001,
        cnonce="0a4f113b",
        response="6629fae49393a05397450978507c4ef1",
        opaque="5ccc069c403ebaf9f0171e9517f40e41"
```

When a UAC resubmits a request with its credentials after receiving a 401 (Unauthorized) or 407 (Proxy Authentication Required) response, it MUST increment the CSeq header field as it would normally when sending an updated request.

20.3 Proxy-to-User Authentication

Similarly, when a UAC sends a request to a proxy server, the proxy server MAY authenticate the originator before the request is processed. If no credentials (in the Proxy-Authorization header field) are provided in the request, the UAS can challenge the originator to provide credentials by rejecting the request with a 407 (Proxy Authentication Required) status code. The proxy MUST populate the 407 (Proxy Authentication Required) message with a Proxy-Authenticate header field applicable to the proxy for the requested resource.

The use of Proxy-Authentication and Proxy-Authorization parallel that described in [16, Section 3.6], with one difference. Proxies MUST NOT add the Proxy-Authorization header field. 407 (Proxy Authentication Required) responses MUST be forwarded upstream toward the UAC following the procedures for any other response. It is the UAC's responsibility to add the Proxy-Authorization header field containing credentials for the realm of the proxy that has asked for authentication.

> If a proxy were to resubmit a request with a Proxy-Authorization header field, it would need to increment the CSeq in the new request. However, this would cause the UAC that submitted the original request to discard a response from the UAS, as the CSeq value would be different.

When the originating UAC receives the 407 (Proxy Authentication Required) it SHOULD, if it is able, re-originate the request with the proper credentials. It should follow the same procedures for the display of the "realm" parameter that are given above for responding to 401. If no credentials for a realm can be located, UACs MAY attempt to retry the request with a username of "anonymous" and no password (a password of ""). The UAC SHOULD also cache the credentials used in the re-originated request.

The following rule is RECOMMENDED for proxy credential caching:

If a UA receives a Proxy-Authenticate header field in a 401/407 response to a request with a particular Call-ID, it should incorporate credentials for that realm in all subsequent requests that contain the same Call-ID. These credentials MUST NOT be cached across dialogs; however, if a UA is configured with the realm of its local outbound proxy, when one exists, then the UA MAY cache credentials for that realm across dialogs. Note that this does mean a future request in a dialog could contain credentials that are not needed by any proxy along the Route header path.

Any UA that wishes to authenticate itself to a proxy server – usually, but not necessarily, after receiving a 407 (Proxy Authentication Required) response – MAY do so by including a Proxy-Authorization header field with the request. The Proxy-Authorization request-header field allows the client to identify itself (or its user) to a proxy that requires authentication. The Proxy-Authorization header field value consists of credentials containing the authentication information of the UA for the proxy and/or realm of the resource being requested.

A Proxy-Authorization header field applies only to the proxy whose realm is identified in the "realm" parameter (this proxy may previously have demanded authentication using the Proxy-Authenticate field). When multiple proxies are used in a chain, the Proxy-Authorization header field MUST NOT be consumed by any proxy whose realm does not match the "realm" parameter specified in the Proxy-Authorization header field.

Note that if an authentication scheme that does not support realms is used in the Proxy-Authorization header field, a proxy server MUST attempt to parse all Proxy-Authorization header fields to determine whether one of them has what the proxy server considers to be valid credentials. Because this is potentially very time-consuming in large networks, proxy servers SHOULD use an authentication scheme that supports realms in the Proxy-Authorization header field.

If a request is forked (as described in Section 16.6), various proxy servers and/or UAs may wish to challenge the UAC. In this case, the forking proxy server is responsible for aggregating these challenges into a single response. Each WWW-Authenticate and Proxy-Authenticate received in responses to the forked request MUST be placed into the single response that is sent by the forking proxy to the UA; the ordering of these header fields is not significant.

> When a proxy server issues a challenge in response to a request, it will not proxy the request until the UAC has provided valid credentials. A forking proxy may forward a request simultaneously to multiple proxy servers that require authentication, each of which in turn will not forward the request until the originating UAC has authenticated itself in their respective realm. If the UAC does not provide credentials for each challenge, then the proxy servers that issued the challenges will not forward requests to the UA where the destination user might be located, and therefore, the virtues of forking are largely lost.

If at least one UAS responds to a forked request with a challenge, then a 401 (Unauthorized) MUST be sent as the aggregated response by the forking proxy to the UAC; otherwise, if only proxy servers respond, a 407 MUST be used.

When resubmitting its request in response to a 401 (Unauthorized) or 407 (Proxy Authentication Required) that contains multiple challenges, a UAC MAY include an Authorization for each WWW-Authenticate and Proxy-Authorization for each Proxy-Authenticate for which the UAC wishes to supply a credential. As noted above, multiple credentials in a request SHOULD be differentiated by the "realm" parameter.

It is possible for multiple challenges associated with the same realm to appear in the same 401 (Unauthorized) or 407 (Proxy Authentication Required). This can occur, for example, when multiple proxies within the same administrative domain, which use a common realm, are reached by a forking request.

See [H14.34] for a definition of the syntax of Proxy-Authentication and Proxy-Authorization.

20.4 The Digest Authentication Scheme

This section describes the modifications and clarifications required to apply the HTTP Digest authentication scheme to SIP. The SIP scheme usage is almost completely identical to that for HTTP [16].

Since RFC 2543 is based on HTTP Digest as defined in RFC 2069 [27], SIP servers supporting RFC 2617 MUST ensure they are backwards compatible with RFC 2069. Procedures for this backwards compatibility are specified in RFC 2617. Note, however, that servers MUST NOT accept or request Basic authentication.

20.4.0.1 HTTP Digest The rules for Digest authentication follow those defined in [16, Section 3], with "HTTP 1.1" replaced by "SIP/2.0" in addition to the following differences:

1. The URI included in the challenge has the following BNF:

   URI = SIP-URI

2. The BNF in RFC 2617 has an error in that the 'uri' parameter of the Authorization header field for HTTP Digest authentication is not enclosed in quotation marks. (The example in Section 3.5 of RFC 2617 is correct.) For SIP, the 'uri' MUST be enclosed in quotation marks.

3. The BNF for digest-uri-value is:

   digest-uri-value = Request-URI ; as defined in Section 27

4. The example procedure for choosing a nonce based on Etag does not work for SIP.

5. The text in RFC 2617 [16] regarding cache operation does not apply to SIP.

6. RFC 2617 [16] requires that a server check that the URI in the request line and the URI included in the Authorization header field point to the same resource. In a SIP context, these two URIs may refer to different users, due to forwarding at some proxy. Therefore, in SIP, a server MAY check that the Request-URI in the Authorization header field corresponds to a user for whom that the server is willing to accept forwarded or direct requests.

7. As a clarification to the calculation of the A2 value for message integrity assurance in the Digest authentication scheme, implementers should assume, when the entity-body is empty (that is, when SIP messages have no body) that the hash of the entity-body resolves to the MD5 hash of an empty string, or:

   H(entity-body) = MD5("") = "d41d8cd98f00b204e9800998ecf8427e"

8. RFC 2617 notes that a cnonce value MUST NOT be sent in an Authorization (and by extension Proxy-Authorization) header field if no qop directive has been sent. Therefore, any algorithms that have a dependency on the cnonce (including "MD5-Sess") require that the qop directive be sent. Use of the "qop" parameter is optional in RFC 2617 for the purposes of backwards compatibility with RFC 2069; since RFC 2543 was based on RFC 2069, the "qop" parameter must unfortunately remain optional for clients and servers to receive. However, servers MUST always send a "qop" parameter in WWW-Authenticate and Proxy-Authenticate header fields. If a client receives a "qop" parameter in a challenge header field, it MUST send the "qop" parameter in any resulting authorization header field.

RFC 2543 did not allow usage of the Authentication-Info header field (it effectively used RFC 2069). However, we now allow usage of this header field, since it provides integrity checks over the bodies and provides mutual authentication. RFC 2617 [16] defines mechanisms for backwards compatibility using the qop attribute in the request. These mechanisms MUST be used by a server to determine if the client supports the new mechanisms in RFC 2617 that were not specified in RFC 2069.

21 S/MIME

SIP messages carry MIME bodies and the MIME standard includes mechanisms for securing MIME contents to ensure both integrity and confidentiality (including the 'multipart/signed' and 'application/pkcs7-mime' MIME types, see RFC 1847 [7], RFC 2630 [17] and RFC 2633 [18]). Implementers should note, however, that there may be rare network intermediaries (not typical proxy servers) that rely on viewing or modifying the bodies of SIP messages (especially SDP), and that secure MIME may prevent these sorts of intermediaries from functioning.

This applies particularly to certain types of firewalls.

The PGP mechanism for encrypting the headers and bodies of SIP messages described in RFC 2543 has been deprecated.

21.1 S/MIME Certificates

The certificates that are used to identify an end-user for the purposes of S/MIME differ from those used by servers in one important respect - rather than asserting that the identity of the holder corresponds to a particular hostname, these certificates assert that the holder is identified by an end-user address. This address is composed of the concatenation of the "userinfo" "@" and "domainname" portions of a SIP URI (in other words, an email address of the form "bob@biloxi.com"), most commonly corresponding to a user's address of record.

These certificates are used to sign or encrypt bodies of SIP messages. Bodies are signed with the private key of the sender (who may include their public key with the message as appropriate), but bodies are encrypted with the public key of the intended recipient. Obviously, senders must have foreknowledge of the public key of recipients in order to encrypt message bodies. Public keys can be stored within a UA on a virtual keyring.

Each user agent that supports S/MIME MUST contain a keyring specifically for end-users' certificates. This keyring should map between addresses of record and corresponding certificates, including any associated with the owner or operator of the UA, when appropriate. Over time, users SHOULD use the same certificate when they populate the originating URI of signaling (the From header field) with the same address of record.

Any mechanisms depending on the existence of end-user certificates, is seriously limited in that there is virtually no consolidated authority today that provides certificates for end-user applications. However, users SHOULD acquire certificates from known public certificate authorities. As an alternative, users MAY create self-signed certificates. The implications of self-signed certificates are explored further in Section 22.4.2.

Above and beyond the problem of acquiring an end-user certificate, there are few well-known centralized directories that distribute end-user certificates. However, the holder of a certificate SHOULD publish their certificate in any public directories as appropriate. Similarly, UACs SHOULD support a mechanism for importing (manually or automatically) certificates discovered in public directories corresponding to the target URIs of SIP requests.

21.2 S/MIME Key Exchange

SIP itself can also be used as a means to distribute public keys in the following manner.

Whenever the CMS SignedData message is used in S/MIME for SIP, it MUST contain the certificate bearing the public key necessary to verify the signature.

When a UAC sends a request containing an S/MIME body that initiates a dialog, or sends a non-INVITE request outside the context of a dialog, the UAC SHOULD structure the body as an S/MIME 'multipart/signed' CMS SignedData body. If the desired CMS service is EnvelopedData, the UAC SHOULD send the EnvelopedData message encapsulated within a SignedData message.

When a UAS receives a request containing an S/MIME CMS body that includes a certificate, the UAS SHOULD first verify the certificate, if possible, with any available certificate authority. The UAS SHOULD also determine the subject of the certificate and compare this value to the From field of the request. If the certificate cannot be verified, because it is self-signed, or signed by no known authority, the UAS MUST notify the user of the status of the certificate (including the subject of the certificate, its signer, and any key fingerprint information) and request explicit permission before proceeding. If the certificate was successfully verified and the subject of the certificate corresponds to the From header field of the SIP request, or if the user (after notification) explicitly authorizes the use of the certificate, the UAS SHOULD add this certificate to a local keyring, indexed by the address of record of the holder of the certificate.

When a UAS sends a response containing an S/MIME body that answers the first request in a dialog, or a response to a non-INVITE request outside the context of a dialog, the UAS SHOULD structure the body as a S/MIME 'multipart/signed' CMS SignedData body. If the desired CMS service is EnvelopedData, the UAS SHOULD send the EnvelopedData message encapsulated within a SignedData message. If the S/MIME body received by the UAS was encrypted with a public key recognized by the UAS, it MAY opt not to sign its response when appropriate.

When a UAC receives a response containing an S/MIME CMS body which includes a certificate, the UAC SHOULD first verify the certificate, if possible, with any available certificate authority. The UAC SHOULD also determine the subject of the certificate and compare this value to the To field of the response; although the two may very well be different, and this is not necessarily indicative of a security breach. If the certificate cannot be verified because it is self-signed, or signed by no known authority, the UAC MUST notify the user of the status of the certificate (including the subject of the certificate, its signator, and any key fingerprint information) and request explicit permission before proceeding. If the certificate was successfully verified, and the subject of the certificate corresponds to the To header in the response, or if the user (after notification) explicitly authorizes the use of the certificate, the UAC SHOULD add this certificate to a local keyring, indexed by the address of record of the holder of the certificate. If the UAC had not transmitted its own certificate to the UAS in any previous transaction, it SHOULD use a CMS SignedData body for its next request or response.

On future occasions, when the UA receives requests or responses that contain a From header field corresponding to a value in its keyring, the UA SHOULD compare the certificate offered in these messages with the existing certificate in its keyring. If there is a discrepancy, the UA MUST notify the user of a change of the certificate (preferably in terms that indicate that this is a potential security breach) and acquire the user's permission before continuing to process the signaling. If the user authorizes this certificate, it MUST be added to the keyring alongside any previous value(s) for this address of record.

Note well however, that this key exchange mechanism does not guarantee the secure exchange of keys when self-signed certificates, or certificates signed by an obscure authority, are used - it is vulnerable to well-known attacks. In the opinion of the authors, however, the security it provides is proverbially better than nothing; it is in fact comparable to the widely used SSH application. These limitations are explored in greater detail in Section 22.4.2.

If a UA receives an S/MIME body that has been encrypted with a public key unknown to the recipient, it MUST reject the request with a 493 (Undecipherable) response. This response SHOULD contain a valid certificate for the respondent (corresponding, if possible, to any address of record given in the To header of the rejected request) within a MIME body with a 'certs-only' "smime-type" parameter. A 493 (Undecipherable) sent without any certificate indicates that the respondent cannot or will not utilize S/MIME encrypted messages, though they may still support S/MIME signatures

Note that a user agent that receives a request containing an S/MIME body that is not optional (with a Content-Disposition header "handling" parameter of "required") MUST reject the request with a 415 Unsupported Media Type response if the MIME type is not understood. A user agent that receives such a response when S/MIME is sent SHOULD notify its user that the remote device does not support S/MIME, and it MAY subsequently resend the request without S/MIME, if appropriate.

If a user agent sends an S/MIME body in a request, but receives a response that contains a MIME body that is not secured, the user agent SHOULD notify the end user that the session could not be secured. However, if a user agent that supports S/MIME receives a request with an unsecured body, it SHOULD NOT respond with a secured body.

Finally, if during the course of a dialog a UA receives a certificate in a CMS SignedData message that does not correspond with the certificates previously exchanged during a dialog, the UA MUST notify its user of the change, preferably in terms that indicate that this is a potential security breach.

21.3 Securing MIME bodies

There are two types of secure MIME bodies that are of interest to SIP: 'multipart/signed' and 'application/pkcs7-mime'. The procedures for the use of these bodies should follow the S/MIME specification ([18]) with a few variations.

- UAs that support S/MIME MUST support the 'signed-data' and 'certs-only' "smime-types". UAs MAY support the 'enveloped-data' "smime-type".

- "multipart/signed" MUST be used only with CMS detached signatures.

  This allows backwards compatibility with non-S/MIME-compliant recipients.

- S/MIME bodies SHOULD have a Content-Disposition header field, and the value of the "handling" parameter SHOULD be "required."

- If a UAC has no certificate on its keyring associated with the address of record to which it wants to send a request, it cannot send an encrypted 'application/pkcs7-mime' MIME message. UACs MAY send an initial request such as an OPTIONS message with a CMS detached signature in order to solicit the certificate of the remote side (the signature SHOULD be over a 'message/sip' body of the type described in Section 21.4).
- Senders of S/MIME bodies SHOULD use the 'SMIMECapabilities' (see Section 2.5.2 of [18]) attribute to express their capabilities and preferences for further communications. Note especially that senders MAY use the 'preferSignedData' capability to encourage receivers to respond with CMS SignedData messages (for example, when sending an OPTIONS request as described above).
- S/MIME implementations MUST at a minimum support SHA1 as a digital signature algorithm, and 3DES as an encryption algorithm. All other signature and encryption algorithms MAY be supported. Implementations can negotiate support for these algorithms with the 'SMIMECapabilities' attribute.
- Each S/MIME body in a SIP message SHOULD be signed with only one certificate. If a UA receives a message with multiple signatures, the outermost signature should be treated as the single certificate for this body.

21.4 Tunneling SIP in MIME

As a means of providing some degree of end-to-end authentication, integrity or confidentiality for SIP headers, S/MIME can encapsulate entire SIP messages within MIME bodies of type “message/sip” and then apply MIME security to these bodies in the same manner as typical SIP bodies. These encapsulated SIP requests and responses do not constitute a separate dialog or transaction, they are a copy of the “outer” message that is used to verify integrity or to supply additional information.

If a UAS receives a request that contains a tunneled “message/sip” S/MIME body, it SHOULD include a tunneled “message/sip” body in the response with the same smime-type.

Any traditional MIME bodies (such as SDP) SHOULD be attached to the ‘inner” message so that they can also benefit from S/MIME security. Note that “message/sip” bodies can be sent as a part of a MIME “multipart/mixed” body if any unsecured MIME types should also be transmitted in a request.

21.4.1 Integrity and Confidentiality Properties of SIP Headers

When the S/MIME integrity or confidentiality mechanisms are used, there may be discrepancies between the values in the “inner” message and values in the “outer” message. The rules for handling any such differences for all of the headers described in this document are given in this section.

21.4.1.1 Integrity Headers that can be legitimately modified by proxy servers are: Request-URI, Via, Record-Route, Route, Max-Forwards, and Proxy-Authorization. If these headers are not intact end-to-end, implementations SHOULD NOT consider this a breach of security. Changes to any other headers constitute an integrity violation; users MUST be notified of a discrepancy.

21.4.1.2 Confidentiality When messages are encrypted, headers may be included in the encrypted body that are not present in the “outer” message.

Some headers must always have a plaintext version because they are required headers in requests and responses - these include: To, From, Call-ID, CSeq, Contact. While it is probably not useful to provide an encrypted alternative for the Call-ID, Cseq, or Contact, providing an alternative to the information in the "outer" To or From is permitted. Note that the values in an encrypted body are not used for the purposes of identifying transactions or dialogs - they are merely informational. If the From header in an encrypted body differs from the value in the "outer" message, the value within the encrypted body SHOULD be displayed to the user, but MUST NOT be used in the "outer" headers of any future messages.

Primarily, a user agent will want to encrypt headers that have an end-to-end semantic, including: Subject, Reply-To, Organization, Accept, Accept-Encoding, Accept-Language, Alert-Info, Error-Info, Authentication-Info, Expires, In-Reply-To, Require, Supported, Unsupported, Retry-After, User-Agent, Server, and Warning. If any of these headers are present in an encrypted body, they should be used instead of any "outer" headers, whether this entails displaying the header field values to users or setting internal states in the UA.

Since MIME bodies are attached to the "inner" message, implementations will usually encrypt MIME-specific headers, including: MIME-Version, Content-Type, Content-Length, Content-Language, Content-Encoding and Content-Disposition. The "outer" message will have the proper MIME headers for S/MIME bodies. These headers (and any MIME bodies they preface) should be treated as normal MIME headers and bodies received in a SIP message.

It is not particularly useful to encrypt the following headers: Date, Min-Expires, RAck, RSeq, Timestamp, Authorization, Priority, and WWW-Authenticate. This category also includes those headers that can be changed by proxy servers (described in the preceding section). UAs SHOULD never include these in an "inner" message if they are not included in the "outer" message. UAs that receive any of these headers in an encrypted body SHOULD ignore the encrypted values.

Note that extensions to SIP may define additional headers; the authors of these extensions should describe the integrity and confidentiality properties of such headers. If a SIP UA encounters an unknown header with an integrity violation, it MUST ignore the header.

21.4.2 Tunneling Integrity and Authentication

Tunneling SIP messages within S/MIME bodies can provide integrity for SIP headers if the headers which the sender wishes to secure are replicated in a "message/sip" MIME body signed with a CMS detached signature.

Provided that the "message/sip" body contains at least the fundamental dialog identifiers (To, From, Call-ID, CSeq), then a signed MIME body can provide limited authentication. At the very least, if the certificate used to sign the body is unknown to the recipient and cannot be verified, the signature can be used to ascertain that a later request in a dialog was transmitted by the same certificate-holder that initiated the dialog. If the recipient of the signed MIME body has some stronger incentive to trust the certificate (they were able to verify it, acquire it from a trusted repository, or they have used it frequently) then the signature can be taken as a stronger assertion of the identity of the subject of the certificate.

In order to eliminate possible confusions about the addition or subtraction of entire headers, senders SHOULD replicate all headers from the request within the signed body. Any message bodies that require integrity protection SHOULD be attached to the "inner" message.

If an integrity violation in a message is detected by its recipient, the message MAY be rejected with a 403 (Forbidden) response if it is a request, or any existing dialog MAY be terminated. UAs SHOULD notify users of this circumstance and request explicit guidance on how to proceed.

The following is an example of the use of a tunneled "message/sip" body:

```
INVITE sip:bob@biloxi.com SIP/2.0
Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
To: Bob <bob@biloxi.com>
From: Alice <alice@atlanta.com>;tag=1928301774
Call-ID: a84b4c76e66710
CSeq: 314159 INVITE
Max-Forwards: 70
Contact: <sip:alice@pc33.atlanta.com>
Content-Type: multipart/signed;
  protocol="application/pkcs7-signature";
  micalg=sha1; boundary=boundary42

--boundary42
Content-Type: message/sip

INVITE sip:bob@biloxi.com SIP/2.0
Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
To: Bob <bob@biloxi.com>
From: Alice <alice@atlanta.com>;tag=1928301774
Call-ID: a84b4c76e66710
CSeq: 314159 INVITE
Max-Forwards: 70
Contact: <sip:alice@pc33.atlanta.com>
Content-Type: application/sdp
Content-Length: 147

v=0
o=UserA 2890844526 2890844526 IN IP4 here.com
s=Session SDP
c=IN IP4 pc33.atlanta.com
t=0 0
m=audio 49172 RTP/AVP 0
a=rtpmap:0 PCMU/8000

--boundary42
Content-Type: application/pkcs7-signature; name=smime.p7s
Content-Transfer-Encoding: base64
Content-Disposition: attachment; filename=smime.p7s;
   handling=required

ghyHhHUujhJhjH77n8HHGTrfvbnj756tbB9HG4VQpfyF467GhIGfHfYT6
4VQpfyF467GhIGfHfYT6jH77n8HHGghyHhHUujhJh756tbB9HGTrfvbnj
n8HHGTrfvhJhjH776tbB9HG4VQbnj7567GhIGfHfYT6ghyHhHUujpfyF4
7GhIGfHfYT64VQbnj756
```

```
--boundary42-
```

21.4.3 Tunneling Encryption

It may also be desirable to use this mechanism to encrypt a “message/sip” MIME body within a CMS EnvelopedData message S/MIME body, but in practice, most headers are of at least some use to the network; the general use of encryption with S/MIME is to secure message bodies like SDP rather than message headers. Some informational headers, such as the Subject or Organization could perhaps warrant end-to-end security. Headers defined by future SIP applications might also require obfuscation.

Another possible application of encrypting headers is selective anonymity. A request could be constructed with a From header field that contains no personal information (for example, sip:anonymous@anonymizer.com). However, a second From header field containing the genuine address of record of the originator could be encrypted within a “message/sip” MIME body where it will only be visible to the endpoints of a dialog.

In order to guarantee end-to-end integrity, encrypted “message/sip” MIME bodies SHOULD be signed by the sender.

In the following example, the text boxed in asterisks (“*”) is encrypted (note that this example is unsigned):

```
     INVITE sip:bob@biloxi.com SIP/2.0
     Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
     To: Bob <bob@biloxi.com>
     From: Alice <alice@atlanta.com>;tag=1928301774
     Call-ID: a84b4c76e66710
     CSeq: 314159 INVITE
     Max-Forwards: 70
     Contact: <sip:alice@pc33.atlanta.com>
     Content-Type: application/pkcs7-mime; smime-type=enveloped-data;
          name=smime.p7m
     Content-Transfer-Encoding: base64
     Content-Disposition: attachment; filename=smime.p7m
        handling=required

   *******************************************************
   * Content-Type: application/sdp                       *
   *                                                     *
   * v=0                                                 *
   * o=alice 53655765 2353687637 IN IP4 pc33.atlanta.com *
   * s=-                                                 *
   * t=0 0                                               *
   * c=IN IP4 pc33.atlanta.com                           *
   * m=audio 3456 RTP/AVP 0 1 3 99                       *
   * a=rtpmap:0 PCMU/8000                                *
   *******************************************************
```

22 Security Considerations

SIP is not an easy protocol to secure. Its use of intermediaries, its multi-faceted trust relationships, its expected usage between elements with no trust at all, and its user-to-user operation make security far from trivial. Security solutions are needed that are deployable today, without extensive coordination, in a wide variety of environments and usages. In order to meet these diverse needs, several distinct mechanisms applicable to different aspects and usages of SIP will be required.

Note that the security of SIP signaling itself has no bearing on the security of protocols used in concert with SIP such as RTP, or with the security implications of any specific bodies SIP might carry (although MIME security plays a substantial role in securing SIP). Any media associated with a session can be encrypted end-to-end independently of any associated SIP signaling. Media encryption is outside the scope of this document.

The considerations that follow first examine a set of classic threat models which broadly identify the security needs of SIP. The set of security services required to address these threats is then detailed, followed by an explanation of several security mechanisms that can be used to provide these services. Next, the requirements for implementers of SIP are enumerated, along with exemplary deployments in which these security mechanisms could be used to improve the security of SIP. Some notes on privacy conclude this section.

22.1 Attacks and Threat Models

This section details some threats that should be common to most deployments of SIP. These threats have been chosen specifically to illustrate each of the security services that SIP requires.

The following examples by no means provide an exhaustive list of the threats against SIP; rather, these are "classic" threats that demonstrate the need for particular security services which can potentially prevent whole categories of threats.

These attacks assume an environment in which attackers can potentially read any packet on the network - it is anticipated that SIP will frequently be used on the public Internet. Attackers on the network may be able to modify packets (perhaps at some compromised intermediary). Attackers may wish to steal services, eavesdrop on communications, or disrupt sessions.

22.1.1 Registration Hijacking

The SIP registration mechanism allows a user agent to identify itself to a registrar as a device at which a user (designated by an address of record) is located. A registrar assesses the identity asserted in the From header field of a REGISTER message to determine whether this request can modify the contact addresses associated with the address of record in the To header field. While these two fields are frequently the same, there are many valid deployments in which a third-party may register contacts on a user's behalf.

The From header field of a SIP request, however, can be modified arbitrarily by the owner of a UA, and this opens the door to malicious registrations. An attacker that successfully impersonates a party authorized to change contacts associated with an address of record could, for example, de-register all existing contacts for a URI and then register their own device as the appropriate contact address, thereby directing all requests for the affected user to the attacker's device.

This threat belongs to a family of threats that rely on the absence of cryptographic assurance of a request's originator. Any SIP UAS that represents a valuable service (a gateway that interworks SIP requests with traditional telephone calls, for example) might want to control access to its resources by authenticating requests that it receives. Even end-user UAs, for example SIP phones, have an interest in ascertaining the identities of originators of requests.

This threat demonstrates the need for security services that enable SIP entities to authenticate the originators of requests.

22.1.2 Impersonating a Server

The domain to which a request is destined is generally specified in the Request-URI. UAs commonly contact a server in this domain directly in order to deliver a request. However, there is always a possibility that an attacker could impersonate the remote server, and that the UA's request could be intercepted by some other party.

For example, consider a case in which a redirect server at one domain, chicago.com, impersonates a redirect server at another domain, biloxi.com. A user agent sends a request to biloxi.com, but the redirect server at chicago.com answers with a forged response that has appropriate SIP headers for a response from biloxi.com. The forged contact addresses in the redirection response could direct the originating UA to inappropriate or insecure resources, or simply prevent requests for biloxi.com from succeeding.

This family of threats has a vast membership, many of which are critical. As a converse to the registration hijacking threat, consider the case in which a registration sent to biloxi.com is intercepted by chicago.com, which replies to the intercepted registration with a forged 301 (Moved Permanently) response. This response might seem to come from biloxi.com yet designate chicago.com as the appropriate registrar. All future REGISTER requests from the originating UA would then go to chicago.com.

Prevention of this threat requires a means by which UAs can authenticate the servers to whom they send requests.

22.1.3 Tampering with Message Bodies

As a matter of course, SIP UAs route requests through trusted proxy servers. Regardless of how that trust is established (authentication of proxies is discussed elsewhere in this section), a UA may trust a proxy server to route a request, but not to inspect or possibly modify the bodies contained in that request.

Consider a UA that is using SIP message bodies to communicate session encryption keys for a media session. Although it trusts the proxy server of the domain it is contacting to deliver signaling properly, it may not want the administrators of that domain to be capable of decrypting any subsequent media session. Worse yet, if the proxy server were actively malicious, it could modify the session key, either acting as a man-in-the-middle, or perhaps changing the security characteristics requested by the originating UA.

This family of threats applies not only to session keys, but to most conceivable forms of content carried end-to-end in SIP. These might include MIME bodies that should be rendered to the user, SDP, or encapsulated telephony signals, among others. Attackers might attempt to modify SDP bodies, for example, in order to point RTP media streams to a wiretapping device in order to eavesdrop on subsequent voice communications.

Also note that some header fields in SIP are meaningful end-to-end, for example, Subject. UAs might be protective of these headers as well as bodies (a malicious intermediary changing the Subject header field might make an important request appear to be spam, for example). However, since many header fields are legitimately inspected or altered by proxy servers as a request is routed, not all headers should be secured end-to-end.

For these reasons, the UA might want to secure SIP message bodies, and in some limited cases headers, end-to-end. The security services required for bodies include confidentiality, integrity, and authentication.

These end-to-end services should be independent of the means used to secure interactions with intermediaries such as proxy servers.

22.1.4 Tearing Down Sessions

Once a dialog has been established by initial messaging, subsequent requests can be sent that modify the state of the dialog and/or session. It is critical that principals in a session can be certain that such requests are not forged by attackers.

Consider a case in which a third-party attacker captures some initial messages in a dialog shared by two parties in order to learn the parameters of the session (To, From, and so forth) and then inserts a BYE request into the session. The attacker could opt to forge the request such that it seemed to come from either participant. Once the BYE is received by its target, the session will be torn down prematurely.

Similar mid-session threats include the transmission of forged re-INVITEs that alter the session (possibly to reduce session security or redirect media streams as part of a wiretapping attack).

The most effective countermeasure to this threat is the authentication of the sender of the BYE. In this instance, the recipient needs only know that the BYE came from the same party with whom the corresponding dialog was established (as opposed to ascertaining the absolute identity of the sender). Also, if the attacker is unable to learn the parameters of the session due to confidentiality, it would not be possible to forge the BYE. However, some intermediaries (like proxy servers) will need to inspect those parameters as the session is established.

22.1.5 Denial of Service and Amplification

Denial-of-service attacks focus on rendering a particular network element unavailable, usually by directing an excessive amount of network traffic at its interfaces. A distributed denial-of-service attack allows one network user to cause multiple network hosts to flood a target host with a large amount of network traffic.

In many architectures, SIP proxy servers face the public Internet in order to accept requests from worldwide IP endpoints. SIP creates a number of potential opportunities for distributed denial-of-service attacks that must be recognized and addressed by the implementers and operators of SIP systems.

Attackers can create bogus requests that contain a falsified source IP address and a corresponding Via header field that identify a targeted host as the originator of the request and then send this request to a large number of SIP network elements, thereby using hapless SIP UAs or proxies to generate denial-of-service traffic aimed at the target.

Similarly, attackers might use falsified Route headers in a request that identify the target host and then send such messages to forking proxies that will amplify messaging sent to the target. Record-Route could be used to similar effect when the attacker is certain that the SIP dialog initiated by the request will result in numerous transactions originating in the backwards direction.

A number of denial-of-service attacks open up if REGISTER requests are not properly authenticated and authorized by registrars. Attackers could de-register some or all users in an administrative domain, thereby preventing these users from being invited to new sessions. An attacker could also register a large number of contacts designating the same host for a given address of record in order to use the registrar and any associated proxy servers as amplifiers in a denial-of-service attack. Attackers might also attempt to deplete available memory and disk resources of a registrar by registering huge numbers of bindings.

The use of multicast to transmit SIP requests can greatly increase the potential for denial-of-service attacks.

These problems demonstrate a general need to define architectures that minimize the risks of denial-of-service, and the need to be mindful in recommendations for security mechanisms of this class of attacks.

22.2 Security Mechanisms

From the threats described above, we gather that the fundamental security services required for the SIP protocol are: preserving the confidentiality and integrity of messaging, preventing replay attacks or message spoofing, providing for the authentication and privacy of the participants in a session, and preventing denial-of-service attacks. Bodies within SIP messages separately require the security services of confidentiality, integrity, and authentication.

Rather than defining new security mechanisms specific to SIP, SIP reuses wherever possible existing security models derived from the HTTP and SMTP space.

Full encryption of messages provides the best means to preserve the confidentiality of signaling - it can also guarantee that messages are not modified by any malicious intermediaries. However, SIP requests and responses cannot be naively encrypted end-to-end in their entirety because message fields such as the Request-URI, Route, and Via need to be visible to proxies in most network architectures so that SIP requests are routed correctly. Note that proxy servers need to modify some features of messages as well (such as adding Via headers) in order for SIP to function. Proxy servers must therefore be trusted, to some degree, by SIP UAs. To this purpose, low-layer security mechanisms for SIP are recommended, which encrypt the entire SIP requests or responses on the wire on a hop-by-hop basis, and which allow endpoints to verify the identity of proxy servers to whom they send requests.

SIP entities also have a need to identify one another in a secure fashion. When a SIP endpoint asserts the identity of its user to a peer UA or to a proxy server, that identity should in some way be verifiable. A cryptographic authentication mechanism is provided in SIP to address this requirement.

An independent security mechanism for SIP message bodies supplies an alternative means of end-to-end mutual authentication, as well as providing a limit on the degree to which user agents must trust intermediaries.

22.2.1 Transport and Network Layer Security

Transport or network layer security encrypts signaling traffic, guaranteeing message confidentiality and integrity. Oftentimes, certificates are used in the establishment of lower-layer security, and these certificates can also be used to provide a means of authentication in many architectures.

Two popular alternatives for providing security at the transport and network layer are, respectively, TLS [9] and IPSec [14].

IPSec is a set of network-layer protocol tools that collectively can be used as a secure replacement for traditional IP (Internet Protocol). IPSec is most commonly used in architectures in which a set of hosts or administrative domains have an existing trust relationship with one another. IPSec is usually implemented at the operating system level in a host, or on a security gateway that provides confidentiality and integrity for all traffic it receives from a particular interface (as in a VPN architecture). IPSec can also be used on a hop-by-hop basis.

In many architectures IPSec does not require integration with SIP applications; IPSec is perhaps best suited to deployments in which adding security directly to SIP hosts would be arduous. UAs which have a pre-shared keying relationship with their first-hop proxy server are also good candidates to use IPSec. Any deployment of IPSec for SIP would require an IPSec profile describing the protocol tools that would be required to secure SIP. No such profile is given in this document.

TLS provides transport-layer security over connection-oriented protocols (for the purposes of this document, TCP); "tls" (signifying TLS over TCP) can be specified as the desired transport protocol within a Via header field or a SIP-URI. TLS is most suited to architectures in which hop-by-hop security is required between hosts with no pre-existing trust association. For example, Alice trusts her local proxy server, which after a certificate exchange decides to trust Bob's local proxy server, which Bob trusts, hence Bob and Alice can communicate securely.

TLS must be tightly coupled with a SIP application. Note that transport mechanisms are specified on a hop-by-hop basis in SIP, and that thus a UA that sends requests over TLS to a proxy server has no assurance that TLS will be used end-to-end.

The TLS_RSA_WITH_AES_128_CBC_SHA ciphersuite MUST be supported at a minimum by implementors when TLS is used in a SIP application. For purposes of backwards compatibility, proxy servers, redirect servers, and registrars SHOULD support TLS_RSA_WITH_3DES_EDE_CBC_SHA. Implementers MAY also support any other ciphersuite.

22.2.2 HTTP Authentication

SIP provides a challenge capability, based on HTTP authentication, that relies on the 401 and 407 response codes as well as headers for carrying challenges and credentials. Without significant modification, the reuse of the HTTP Digest authentication scheme in SIP allows for replay protection and one-way authentication.

The usage of Digest authentication in SIP is detailed in Section 20.

22.2.3 S/MIME

As is discussed above, encrypting entire SIP messages end-to-end for the purpose of confidentiality is not appropriate because network intermediaries (like proxy servers) need to view certain headers in order to route messages correctly, and if these intermediaries are excluded from security associations, then SIP messages will essentially be non-routable.

However, S/MIME allows SIP UAs to encrypt MIME bodies within SIP, securing these bodies end-to-end without affecting message headers. S/MIME can provide end-to-end confidentiality and integrity for message bodies, as well as mutual authentication. It is also possible to use S/MIME to provide a form of integrity and confidentiality for SIP headers through SIP message tunneling.

The usage of S/MIME in SIP is detailed in Section 21.

22.3 Implementing Security Mechanisms

22.3.1 Requirements for Implementers of SIP

Proxy servers, redirect servers, and registrars MUST implement TLS, and MUST support both mutual and one-way authentication. It is strongly RECOMMENDED that UAs be capable initiating TLS; UAs MAY also be capable of acting as a TLS server. Proxy servers, redirect servers, and registrars SHOULD possess a site certificate whose subject corresponds to their hostname. UAs MAY have certificates of their own for mutual authentication with TLS, but no provisions are set forth in this document for their use. UAs MUST support a mechanism for verifying certificates they receive during TLS negotiation.

Proxy servers, redirect servers, registrars, and UAs MAY also implement IPSec or other lower-layer security protocols.

When a UA attempts to contact a proxy server, redirect server, or registrar, the UAC SHOULD initiate a TLS connection over which it will send SIP messages. In some architectures, UACs MAY receive requests over such TLS connections as well.

Proxy servers, redirect servers, registrars, and UAs MUST implement Digest Authorization. Proxy servers, redirect servers, and registrars SHOULD be configured with at least one Digest realm, and at least one "realm" string supported by a given server SHOULD correspond to the server's hostname or domainname.

Proxy servers, redirect servers, registrars, and UAs MAY also implement enhancements to Digest or alternate header-level security mechanisms.

UAs SHOULD support S/MIME encryption and signing of SIP message MIME bodies. If a UA holds one or more root certificates of certificate authorities in order to verify certificates for TLS or IPSec, it SHOULD be capable of reusing these to verify an S/MIME certificates, as appropriate. A UA MAY hold root certificates specifically for verifying S/MIME certifices.

22.3.2 Security Solutions

The operation of these security mechanisms in concert can follow the existing web and email security models to some degree. At a high level, UAs authenticate themselves to servers (proxy servers, redirect servers, and registrars) with a Digest username and password; servers authenticate themselves to UAs, and to one another, with a site certificate delivered by TLS.

On a peer-to-peer level, UAs transitively trust the network to authenticate one another ordinarily; however, S/MIME can also be used to provide direct authentication when the network does not, or if the network itself is not trusted.

The following is an illustrative example in which these security mechanisms are used by various UAs and servers to prevent the sorts of threats described in Section 22. While implementers and network administrators MAY follow the normative guidelines given in the remainder of this section, these are provided only as example implementations.

22.3.2.1 Registration When a UA comes online and registers with its local administrative domain, it SHOULD establish a TLS connection with its registrar (Section 10 describes how the UA reaches its registrar). The registrar SHOULD offer a certificate to the UA, and the site identified by the certificate MUST correspond with the domain in which the UA intends to register; for example, if the UA intends to register the address of record 'alice@atlanta.com', the site certificate must identify a host within the atlanta.com domain (such as 'sip.atlanta.com'). When it receives the TLS Certificate message, the UA SHOULD verify the certificate and inspect the site identified by the certificate. If the certificate is invalid, revoked, or if it does not identify the appropriate party, the UA MUST NOT send the REGISTER message and otherwise proceed with the registration.

> When a valid certificate has been provided by the registrar, the UA knows that the registrar is not an attacker who might redirect the UA, steal passwords, or attempt any similar attacks.

The UA then creates a REGISTER request that SHOULD be addressed to a Request-URI corresponding to the site certificate received from the registrar. When the UA sends the REGISTER request over the existing TLS connection, the registrar SHOULD challenge the request with a 407 (Proxy Authentication Required) response. The "realm" parameter within the Proxy-Authenticate header field of the response SHOULD correspond to the domain previously given by the site certificate. When the UAC receives the challenge, it SHOULD either prompt the user for credentials or take an appropriate credential from a keyring corresponding to the “realm” parameter in the challenge. The username of this credential SHOULD correspond with the “userinfo” portion of the URI in the To header field of the REGISTER request. Once the Digest credentials have been inserted into an appropriate Proxy-Authorization header field, the REGISTER should be resubmitted to the registrar.

> Since the registrar requires the user agent to authenticate itself, it would be difficult for an attacker to forge REGISTER requests for the user’s address of record. Also note that since the REGISTER is sent over a confidential TLS connection, attackers will not be able to intercept the REGISTER to record credentials for any possible replay attack.

Once the registration has been accepted by the registrar, the UA SHOULD leave this TLS connection open provided that the registrar also acts as the proxy server to which requests are sent for users in this administrative domain. The existing TLS connection will be reused to deliver incoming requests to the UA that has just completed registration.

> Because the UA has already authenticated the server on the other side of the TLS connection, all requests that come over this connection are known to have passed through the proxy server - attackers cannot create spoofed requests that appear to have been sent through that proxy server.

22.3.2.2 Requests and Transitive Trust Now let’s say that Alice’s UA would like to initiate a session with a user in a remote administrative domain, namely ’bob@biloxi.com’. We will also say that the local administrative domain (’atlanta.com’) has a local outbound proxy.

The proxy server that handles inbound requests for an administrative domain MAY also act as a local outbound proxy; for simplicity’s sake we’ll assume this to be the case for ’atlanta.com’ (otherwise the user agent would initiate a new TLS connection to a separate server at this point). Assuming that the client has completed the registration process described in the preceding section, it SHOULD reuse the TLS connection to the local proxy server when it sends an INVITE request to another user. The UA SHOULD reuse cached credentials in the INVITE to avoid prompting the user unnecessarily.

When the local outbound proxy server has validated the credentials presented by the UA in the INVITE, it SHOULD inspect the Request-URI to determine how the message should be routed (see [2]). If the “domainname” portion of the Request-URI had corresponded to the local domain (’atlanta.com’) rather than “biloxi.com”, then the proxy server would have consulted its location service to determine how best to reach the requested user.

> Had ’alice@atlanta.com’ been attempting to contact, say, ’alex@atlanta.com’, the local proxy would have proxied to the request to the TLS connection Alex had established with the registrar when he registered. Since Alex would receive this request over his authenticated channel, he would be assured that Alice’s request had been authorized by the proxy server of the local administrative domain.

However, in this instance the Request-URI designates a remote domain. The local outbound proxy server at ’atlanta.com’ SHOULD therefore establish a TLS connection with the remote proxy server at ’biloxi.com’. Since both of the participants in this TLS connection are servers that possess site certificates, mutual TLS authentication SHOULD occur. Each side of the connection SHOULD verify and inspect the certificate of the other, noting the domain name that appears in the certificate for comparison with the headers of SIP messages. The ’atlanta.com’ proxy server, for example, SHOULD verify at this stage that the certificate received from the remote side corresponds with the ’biloxi.com’ domain. Once it has done so, and TLS negotiation has completed, resulting in a secure channel between the two proxies, the ’atlanta.com’ proxy can forward the INVITE request to ’biloxi.com’.

The proxy server at ’biloxi.com’ SHOULD inspect the certificate of the proxy server at ’atlanta.com’ in turn and compare the domain asserted by the certificate with the “domainname” portion of the From header field in the INVITE request. The biloxi proxy can thereby ascertain whether it should consider Alice to be authenticated transitively. The biloxi proxy MAY have a strict security policy that requires it to reject requests that do not match the administrative domain from which they have been proxied, or perhaps even more strictly, requests that originate from administrative domains that do not have some policy agreement with biloxi.

> Such security policies could be instituted to prevent the SIP equivalent of SMTP 'open relays' which are frequently exploited to generate spam.

Once the INVITE has been approved by the biloxi proxy, the proxy server SHOULD identify the existing TLS channel, if any, associated with the user targeted by this request (in this case 'bob@biloxi.com'). The INVITE should be proxied through this channel to Bob. Since the request is received over a TLS connection that had previously been authenticated as the biloxi proxy, Bob transitively trusts the identity asserted in the From header.

Before they forward the request, both proxy servers SHOULD add Record-Route header fields to the request so that all future requests in this dialog will pass through the proxy servers. The proxy servers can thereby continue to provide transitive authentication, confidentiality, replay protection, and so forth for lifetime of this dialog. If the proxy servers do not add themselves to the Record-Route, future messages will pass directly end-to-end between Alice and Bob without any security services (unless the two parties agree on some independent end-to-end security).

> An attacker preying on this architecture would, for example, be unable to forge a BYE request and insert it into the signaling stream between Bob and Alice because the attacker has no way of ascertaining the parameters of the session and also because the integrity mechanism transitively protects the traffic between Alice and Bob.

22.3.2.3 Peer to Peer Requests Alternatively, consider a UA asserting the identity 'carol@chicago.com' that has no local outbound proxy. When Carol wishes to send an INVITE to 'bob@biloxi.com', her UA SHOULD initiate a TLS connection with the biloxi proxy directly (using the mechanism described in [2] to determine how to best to reach the given Request-URI). When her UA receives a certificate from the biloxi proxy, it SHOULD be verified normally before she passes her INVITE across the TLS connection. However, 'carol@chicago.com' has no means of proving her identity to the biloxi proxy, but she does have a CMS-detached signature over a "message/sip" body in the INVITE. It is unlikely in this instance that Carol would have any credentials in the 'biloxi.com' realm, since she has no formal association with biloxi.com. The biloxi proxy MAY also have a strict policy that precludes it from even bothering to challenge requests that do not have 'biloxi.com' in the "domainname" portion of the From header - it treats these users as unauthenticated.

The biloxi proxy has a policy for Bob that all non-authenticated requests should be redirected to the appropriate contact address registered against 'bob@biloxi.com', namely <sip:bob@192.0.2.4>. Carol receives the redirection response over the TLS connection she established with the biloxi proxy, so she trusts the veracity of the contact address.

Carol SHOULD then establish a TCP connection with the designated address and send a new INVITE with a Request-URI containing the received contact address (recomputing the signature in the body as the request is readied). Bob receives this INVITE on an insecure interface, but his UA inspects and, in this instance, recognizes the From header field of the request and subsequently matches a locally cached certificate with the one presented in the signature of the body of the INVITE. He replies in similar fashion, authenticating himself to Carol, and a secure dialog begins.

> Sometimes firewalls or NATs in an administrative domain could preclude the establishment of a direct TCP connection to a UA. In these cases, proxy servers could also potentially relay requests to UAs in a way that has no

trust implications (for example, forgoing an existing TLS connection and forwarding the request over cleartext TCP) as local policy dictates.

22.3.2.4 DoS Protection

In order to minimize the risk of a denial-of-service attack against architectures using these security solutions, implementers should take note of the following guidelines.

When the host on which a SIP proxy server is operating is routable from the public Internet, it SHOULD be deployed in an administrative domain with secure routing policies (blocking source-routed traffic, preferably filtering ping traffic). Both TLS and IPSec can also make use of bastion hosts at the edges of administrative domains that participate in the security associations to aggregate secure tunnels and sockets. These bastion hosts can also take the brunt of denial-of-service attacks, ensuring that SIP hosts within the administrative domain are not encumbered with superfluous messaging.

No matter what security solutions are deployed, floods of messages directed at proxy servers can lock up proxy server resources and prevent desirable traffic from reaching its destination. There is a computational expense associated with processing a SIP transaction at a proxy server, and that expense is greater for stateful proxy servers than it is for stateless proxy servers. Therefore, stateful proxies are more susceptible to flooding than stateless proxy servers.

UAs and proxy servers SHOULD challenge questionable requests with only a *single* 401 (Unauthorized) or 407 (Proxy Authentication Required), forgoing the normal response retransmission algorithm, and behaving statelessly towards unauthenticated requests.

Retransmitting the 401 (Unauthorized) or 407 (Proxy Authentication Required) status response amplifies the problem of an attacker using a falsified header (such as Via) to direct traffic to a third party.

With either TCP or UDP, a denial-of-service attack exists by a rogue proxy sending 6xx responses. Although a client SHOULD choose to ignore such responses if it requested authentication, a proxy cannot do so. It is obliged to forward the 6xx response back to the client. The client can then ignore the response, but if it repeats the request, it will probably reach the same rogue proxy again, and the process will repeat.

22.4 Limitations

Although these security mechanisms, when applied in a judicious manner, can thwart many threats, there are limitations in the scope of the mechanisms that must be understood by implementers and network operators.

22.4.1 HTTP Digest

One of the primary limitations of using HTTP Digest in SIP is that the integrity mechanisms in Digest do not work very well for SIP. Specifically, they offer protection of the Request-URI and the method of a message, but not for any of the headers that UAs would most likely wish to secure.

The existing replay protection mechanisms described in RFC 2617 also have some limitations for SIP. The next-nonce mechanism, for example, does not support pipelined requests. The nonce-count mechanism should be used for replay protection.

Another limitation of HTTP Digest is the scope of realms. Digest is valuable when a user wants to authenticate themselves to a resource with which they have a pre-existing association, like a service provider of which the user is a customer. Consider that, by contrast, the scope of TLS is global, since certificates are globally verifiable regardless of any pre-existing association between the UA and the server.

Future enhancements to HTTP Digest could conceivably resolve some or all of these limitations.

22.4.2 S/MIME

The largest outstanding defect with the S/MIME mechanism is the lack of prevalent public key infrastructure for end users. If self-signed certificates (or certificates that cannot be verified by one of the participants in a dialog) are used, the SIP-based key exchange mechanism described in Section 21.2 is susceptible to a man-in-the-middle attack with which an attacker can potentially inspect and modify S/MIME bodies. The attacker needs to intercept the first exchange of keys between the two parties in a dialog, remove the existing CMS-detached signatures from the request and response, and insert a different CMS-detached signature containing a certificate supplied by the attacker (but which seems to be a certificate for the proper address of record). Each party will think they have exchanged keys with the other, when in fact each has the public key of the attacker.

It is important to note that the attacker can only leverage this vulnerability on the first exchange of keys between two parties - on subsequent occasions, the alteration of the key would be noticeable to the UAs. It would also be difficult for the attacker to remain in the path of all future dialogs between the two parties over time (as potentially days, weeks, or years pass).

SSH is susceptible to the same man-in-the-middle attack on the first exchange of keys; however, it is widely acknowledged that while SSH is not perfect, it does improve the security of connections. The use of key fingerprints could provide some assistance to SIP, just as it does for SSH. For example, if two parties use SIP to establish a voice communications session, each could read off the fingerprint of the key they received from the other, which could be compared against the original. It would certainly be more difficult for the man-in-the-middle to emulate the voices of the participants than their signaling.

The S/MIME mechanism allows UAs to send encrypted requests without preamble if they possess a certificate for the destination address of record on their keyring. However, it is also possible that a device that does not hold certificates, or at least not that particular certificate, will be currently registered as the sole contact address for that address of record, and it will therefore be unable to process the encrypted request properly, which could lead to some avoidable error signaling. This is especially likely when an encrypted request is forked.

The keys associated with S/MIME are most useful when associated with a particular user (an address of record) rather than a device (a UA). When users move between devices, it may be difficult to transport private keys securely between UAs; how such keys might be acquired by a device is outside the scope of this document.

Another, more prosaic difficulty with the S/MIME mechanism is that it can result in very large messages, especially when the SIP tunneling mechanism described in Section 21.4 is used. For that reason, it is RECOMMENDED that TCP should be used as a transport protocol when S/MIME tunneling is employed.

22.4.3 TLS

The most commonly voiced concern about TLS is that it cannot run over UDP; TLS requires a connection-oriented underlying transport protocol, which for the purposes of this document means TCP. Even running TCP, regardless of any additional overhead incurred by TLS, is argued to be too intensive for some embedded devices.

It may also be arduous for a local outbound proxy server and/or registrar to maintain many simultaneous long-lived TLS connections with numerous UAs. This introduces some valid scalability concerns, especially for intensive ciphersuites. Maintaining redundancy of long-lived TLS connections, especially when a UA is solely responsible for their establishment, could also be cumbersome.

TLS only allows SIP entities to authenticate servers to which they are adjacent; TLS offers strictly hop-by-hop security. Neither TLS, nor any other mechanism specified in this document, allows clients to authenticate proxy servers to whom they cannot form a direct TCP connection.

Note, however, when any lower-layer network security is employed the originator and recipient of a session may be deducible by observers performing a network traffic analysis.

22.5 Privacy

SIP messages frequently contain sensitive information about their senders - not just what they have to say, but with whom they communicate, when they communicate and for how long, and from where they participate in sessions. Many applications and their users require that this sort of private information be hidden from any parties that do not need to know it.

Note that there are also less direct ways in which private information can be divulged. If a user or service chooses to be reachable at an address that is guessable from the person's name and organizational affiliation (which describes most addresses of record), the traditional method of ensuring privacy by having an unlisted "phone number" is compromised. A user location service can infringe on the privacy of the recipient of a session invitation by divulging their specific whereabouts to the caller; an implementation consequently SHOULD be able to restrict, on a per-user basis, what kind of location and availability information is given out to certain classes of callers.

23 Common Message Components

There are certain components of SIP messages that appear in various places within SIP messages (and sometimes, outside of them) that merit separate discussion.

23.1 SIP Uniform Resource Indicators

A SIP URI identifies a communications resource. Like all URIs, SIP URIs may be placed in web pages, email messages, or printed literature. They contain sufficient information to initiate and maintain a communication session with the resource.

Examples of communications resources include the following:

- a user of an online service
- an appearance on a multi-line phone
- a mailbox on a messaging system
- a PSTN number at a gateway service
- a group (such as "sales" or "helpdesk") in an organization

23.1.1 SIP URI Components

The "sip:" scheme follows the guidelines in RFC 2396 [13]. It uses a form similar to the mailto URL, allowing the specification of SIP request-header fields and the SIP message-body. This makes it possible to specify the subject, media type, or urgency of sessions initiated by using a URI on a web page or in an email message. The formal syntax for a SIP URI is presented in Section 27. Its general form is sip:user:password@host:port;url-parameters?headers

These tokens, and some of the tokens in their expansions, have the following meanings:

user: The identifier of a particular resource at the host being addressed. The term "host" in this context frequently refers to a domain. The "userpart" of a URI consists of this user field, the password field, and the @ sign following them. The userpart of a URI is optional and MAY be absent when the destination host does not have a notion of users or when the host itself is the resource being identified. If the @ sign is present in a SIP URI, the user field MUST NOT be empty.

If the host being addressed can process telephone numbers, for instance, an Internet telephony gateway, a telephone-subscriber field defined in RFC 2806 [19] MAY be used to populate the user field. There are special escaping rules for encoding telephone-subscriber fields in SIP URIs described in Section 23.1.2.

password: A password associated with the user. While the SIP URI syntax allows this field to be present, its use is NOT RECOMMENDED, because the passing of authentication information in clear text (such as URIs) has proven to be a security risk in almost every case where it has been used. For instance, transporting a PIN number in this field exposes the PIN.

Note that the password field is just an extension of user portion. Implementations not wishing to give special significance to the password portion of the field MAY simply treat "user:password" as a single string.

host: The entity hosting the SIP resource. The host part contains either a fully-qualified domain name or numeric IPv4 or IPv6 address. Using the fully-qualified domain name form is RECOMMENDED whenever possible.

port: The port number where the request is to be sent.

URI parameters: Parameters affecting a request constructed from the URI.

URI parameters are added after the hostport component and are separated by semi-colons.

URI parameters take the form:

parameter-name "=" parameter-value

Even though an arbitrary number of URI parameters may be included in a URI, any given parameter-name MUST NOT appear more than once.

This extensible mechanism includes the transport, maddr, ttl, user, method and lr parameters.

The transport parameter determines the transport mechanism to be used for sending SIP messages, as specified in [2]. SIP can use any network transport protocol. Parameter names are defined for UDP [23], TCP [22], TLS [9] (note that this is specifically TLS over TCP), and SCTP [21].

The maddr parameter indicates the server address to be contacted for this user, overriding any address derived from the host field. When an maddr parameter is present, the port and transport components of the URI apply to the address indicated in the maddr parameter value. [2] describes the proper interpretation of the transport, maddr, and hostport in order to obtain the destination address, port, and transport for sending a request.

> The maddr field has been used as a simple form of loose source routing. It allows a URI to specify a proxy that must be traversed en-route to the destination. Continuing to use the maddr parameter this way is strongly discouraged (the mechanisms that enable it are deprecated). Implementations should instead use the Route mechanism described in this document, establishing a pre-existing route set if necessary (see item 8.1.1.1 in section 8.1.1). This provides a full URI to describe the node to be traversed.

The ttl parameter determines the time-to-live value of the UDP multicast packet and MUST only be used if maddr is a multicast address and the transport protocol is UDP. For example, to specify to call `alice@atlanta.com` using multicast to 239.255.255.1 with a ttl of 15, the following URI would be used:

```
sip:alice@atlanta.com;maddr=239.255.255.1;ttl=15
```

The set of valid telephone-subscriber strings is a subset of valid user strings. The user URI parameter exists to distinguish telephone numbers from user names that happen to look like telephone numbers. If the user string contains a telephone number formatted as a telephone-subscriber, the user parameter value "phone" SHOULD be present. Even without this parameter, recipients of SIP URIs MAY interpret the pre-@ part as a telephone number if local restrictions on the name space for user name allow it.

The method of the SIP request constructed from the URI can be specified with the method parameter.

The lr parameter, when present, indicates that the element responsible for this resource implements the routing mechanisms specified in this document. This parameter will be used in the URIs proxies place into Record-Route header field values, and may appear in the URIs in a pre-existing route set.

> This parameter is used to achieve backwards compatibility with systems implementing the strict-routing mechanisms of RFC2543 and the rfc2543bis drafts up to bis-05. An element preparing to send a request based on a URI not containing this parameter can assume the receiving element implements strict-routing and reformat the message to preserve the information in the Request-URI.

Since the url-parameter mechanism is extensible, SIP elements MUST silently ignore any url-parameters that they do not understand.

Headers: Headers to be included in a request constructed from the URI. Headers fields in the SIP request can be specified with the "?" mechanism within a SIP URI. The header names and values are encoded in ampersand separated hname = hvalue pairs. The special hname "body" indicates that the associated hvalue is the message-body of the SIP request.

Table 1 summarizes the use of SIP URI components based on the context in which the URI appears. The external column describes URIs appearing anywhere outside of a SIP message, for instance on a web page or business card. Entries marked "m" are mandatory, those marked "o" are optional, and those marked "-" are not allowed. Elements processing URIs SHOULD ignore any disallowed components if they are present. The second column indicates the default value of an optional element if it is not present. "–" indicates that the element is either not optional, or has no default value.

SIP URIs in Contact header fields have different restrictions depending on the context in which the header field appears. One set applies to messages that establish and maintain dialogs (INVITE and its 200 (OK) response). The other applies to registration and redirection messages (REGISTER, its 200 (OK) response, and 3xx class responses to any method).

	default	Req.-URI	To	From	reg./redir. Contact	dialog Contact/ R-R/Route	external
user	–	o	o	o	o	o	o
password	–	o	o	o	o	o	o
host	–	m	m	m	m	m	m
port	5060	o	-	-	o	o	o
user-param	ip	o	o	o	o	o	o
method	INVITE	-	-	-	-	-	o
maddr-param	–	o	-	-	o	o	o
ttl-param	1	o	-	-	o	-	o
transp.-param	udp	o	-	-	o	o	o
lr-param	–	o	-	-	-	o	o
other-param	–	o	o	o	o	o	o
headers	–	-	-	-	o	-	o

Table 1: Use and default values of URI components for SIP headers, Request-URI and references

23.1.2 Character Escaping Requirements

SIP follows the requirements and guidelines of RFC 2396 [13] when defining the set of characters that must be escaped in a SIP URI, and uses its “”%” HEX HEX” mechanism for escaping. From RFC 2396:

> The set of characters actually reserved within any given URI component is defined by that component. In general, a character is reserved if the semantics of the URI changes if the character is replaced with its escaped US-ASCII encoding. [13].

Excluded US-ASCII characters [13, Sec. 2.4.3], such as space and control characters and characters used as URI delimiters, also MUST be escaped. URIs MUST NOT contain unescaped space and control characters.

For each component, the set of valid BNF expansions defines exactly which characters may appear unescaped. All other characters MUST be escaped.

For example, “@” is not in the set of characters in the user component, so the user “j@s0n” must have at least the @ sign encoded, as in “j%40s0n”.

Expanding the hname and hvalue tokens in Section 27 show that all URI reserved characters in header names and values MUST be escaped.

The telephone-subscriber subset of the user component has special escaping considerations. The set of characters not reserved in the RFC 2806 [19] description of telephone-subscriber contains a number of characters in various syntax elements that need to be escaped when used in SIP URIs. Any characters occurring in a telephone-subscriber that do not appear in an expansion of the BNF for the user rule MUST be escaped.

Note that character escaping is not allowed in the host component of a SIP URI (the % character is not valid in its expansion). This is likely to change in the future as requirements for Internationalized Domain Names are finalized. Current implementations MUST NOT attempt to improve robustness by treating received escaped characters in the host component as literally equivalent to their unescaped counterpart. The behavior required to meet the requirements of IDN may be significantly different.

23.1.3 Example SIP URIs

```
sip:alice@atlanta.com
sip:alice:secretword@atlanta.com;transport=tcp
sip:alice@atlanta.com?subject=project%20x&priority=urgent
sip:+1-212-555-1212:1234@gateway.com;user=phone
sip:1212@gateway.com
sip:alice@192.0.2.4
sip:atlanta.com;method=REGISTER?to=alice%40atlanta.com
sip:alice;day=tuesday@atlanta.com
```

The last example URI above has a user field value of “alice;day=tuesday”. The escaping rules defined above allow a semicolon to appear unescaped in this field. Note, however, that for the purposes of this protocol, the field is opaque. The apparent structure in that value is only useful to the entity responsible for the resource.

23.1.4 SIP URI Comparison

SIP URIs are compared for equality according to the following rules:

- Comparison of the userpart of sip URIs is case-sensitive. This includes userparts containing passwords or formatted as telephone-subscribers. Comparison of all other components of the URI is case-insensitive unless explicitly defined otherwise.
- The ordering of parameters and headers is not significant in comparing SIP URIs.
- Characters other than those in the “reserved” and “unsafe” sets (see RFC 2396 [13]) are equivalent to their “”%” HEX HEX” encoding.
- An IP address that is the result of a DNS lookup of a host name does **not** match that host name.
- For two URIs to be equal, the user, password, host, and port components must match. A URI omitting the optional port component will match a URI explicitly declaring port 5060. A URI omitting the user component will **not** match a URI that includes one. A URI omitting the password component will **not** match a URI that includes one.
- URI uri-parameter components are compared as follows
  - Any uri-parameter appearing in both URIs must match.
  - A user, transport, ttl, or method url-parameter appearing in only one URI must contain its default value or the URIs do not match.

    A URI that includes an maddr parameter will *not* match a URI that contains no maddr parameter.
  - All other url-parameters appearing in only one URI are ignored when comparing the URIs.
- URI header components are never ignored. Any present header component MUST be present in both URIs and match for the URIs to match. The matching rules are defined for each header in Section sec:header-fields.

The URIs within each of the following sets are equivalent:

```
sip:%61lice@atlanta.com:5060
sip:alice@AtLanTa.CoM;Transport=udp

sip:carol@chicago.com
sip:carol@chicago.com;newparam=5
sip:carol@chicago.com;security=on

sip:biloxi.com;transport=tcp;method=REGISTER?to=sip:bob%40biloxi.com
sip:biloxi.com;method=REGISTER;transport=tcp?to=sip:bob%40biloxi.com

sip:alice@atlanta.com?subject=project%20x&priority=urgent
sip:alice@atlanta.com?priority=urgent&subject=project%20x
```

The URIs within each of the following sets are **not** equivalent:

```
SIP:ALICE@AtLanTa.CoM;Transport=udp               (different usernames)
sip:alice@AtLanTa.CoM;Transport=UDP

sip:bob@biloxi.com                        (different port and transport)
sip:bob@biloxi.com:6000;transport=tcp

sip:carol@chicago.com                       (different header component)
sip:carol@chicago.com?Subject=next%20meeting

sip:bob@phone21.boxesbybob.com     (even though that's what
sip:bob@192.0.2.4                    phone21.boxesbybob.com resolves to)
```

Note that equality is not transitive:

sip:carol@chicago.com and sip:carol@chicago.com;security=on are equivalent

and sip:carol@chicago.com and sip:carol@chicago.com;security=off are equivalent

But sip:carol@chicago.com;security=on and sip:carol@chicago.com;security=off are **not** equivalent

Comparing URIs is a major part of comparing several SIP headers (see Section 24).

23.1.5 Forming Requests from a SIP URI

An implementation must take care when forming requests directly from a URI. URIs from business cards, web pages, and even from sources inside the protocol such as registered contacts may contain inappropriate header fields or body parts.

An implementation MUST include any provided transport, maddr, ttl, or user parameter in the Request-URI of the formed request. If the URI contains a method parameter, its value MUST be used as the method of the request. The method parameter MUST NOT be placed in the Request-URI. Unknown URI parameters MUST be placed in the message's Request-URI.

An implementation SHOULD treat the presence of any headers or body parts in the URI as a request to include them in the message, and choose to honor the request on an per-component basis.

An implementation SHOULD NOT honor these obviously dangerous header fields: From, Call-ID, CSeq, Via, and Record-Route.

An implementation SHOULD honor any requested Route header field values in order to not be used as an unwitting agent in malicious attacks.

An implementation SHOULD NOT honor requests to include headers that may cause it to falsely advertise its location or capabilities. These include: Accept, Accept-Encoding, Accept-Language, Allow, Contact (in its dialog usage), Organization, Supported, and User-Agent.

An implementation SHOULD verify the accuracy of any requested descriptive headers, including: Content-Disposition, Content-Encoding, Content-Language, Content-Length, Content-Type, Date, Mime-Version, and Timestamp.

If the request formed from constructing a message from a given URI is not a valid SIP request, the URI is invalid. An implementation MUST NOT proceed with transmitting the request. It should instead pursue the course of action due an invalid URI in the context it occurs.

> The constructed request can be invalid in many ways. These include, but are not limited to, syntax error in header fields, invalid combinations of URI parameters, or an incorrect description of the message body.

Sending a request formed from a given URI may require capabilities unavailable to the implementation. The URI might indicate use of an unimplemented transport or extension, for example. An implementation SHOULD refuse to send these requests rather than modifying them to match their capabilities. An implementation MUST NOT send a request requiring an extension that it does not support.

> For example, such a request can be formed through the presence of a headerRequire header parameter or a method URI parameter with an unknown or explicitly unsupported value.

23.1.6 Relating SIP URIs and tel URLs

When a tel URL [19] is converted to a SIP URI, the entire telephone-subscriber portion of the tel URL, including any parameters, is placed into the userpart of the SIP URI.

Thus, tel:+358-555-1234567;postd=pp22 becomes

```
sip:+358-555-1234567;postd=pp22@foo.com
```

not

```
sip:+358-555-1234567@foo.com;postd=pp22
```

In general, equivalent "tel" URLs converted to SIP URIs in this fashion may not produce equivalent SIP URIs. The userpart of SIP URIs is compared as a case-sensitive string. Variance in case-insensitive portions of tel URLs and reordering of tel URL parameters does not affect tel URL equivalence, but does affect the equivalence of SIP URIs formed from them.

For example,

```
tel:+358-555-1234567;postd=pp22
```

```
tel:+358-555-1234567;POSTD=PP22
```

are equivalent, while

```
sip:+358-555-1234567;postd=pp22@foo.com
sip:+358-555-1234567;POSTD=PP22@foo.com
```

are not.

Likewise,

```
tel:+358-555-1234567;postd=pp22;isub=1411
tel:+358-555-1234567;isub=1411;postd=pp22
```

are equivalent, while

```
sip:+358-555-1234567;postd=pp22;isub=1411@foo.com
sip:+358-555-1234567;isub=1411;postd=pp22@foo.com
```

are not.

To mitigate this problem, elements constructing telephone-subscriber fields to place in the userpart of a SIP URI SHOULD fold any case-insensitive portion of telephone-subscriber to lower case, and order the telephone-subscriber parameters lexically by parameter name. (All components of a tel URL except for future-extension parameters are defined to be compared case-insensitive.)

Following this suggestion, both

```
tel:+358-555-1234567;postd=pp22
tel:+358-555-1234567;POSTD=PP22
```

become

```
sip:+358-555-1234567;postd=pp22@foo.com
```

and both

```
tel:+358-555-1234567;postd=pp22;isub=1411
tel:+358-555-1234567;isub=1411;postd=pp22
```

become

```
sip:+358-555-1234567;isub=1411;postd=pp22
```

23.2 Option Tags

Option tags are unique identifiers used to designate new options (extensions) in SIP. These tags are used in Require (Section 24.33), Proxy-Require (Section 24.29, Supported (Section 24.39) and Unsupported (Section 24.42) header fields. Note that these options appear as parameters in those headers in an option-tag = token form (see Section 27 for the definition of token).

The creator of a new SIP option MUST either prefix the option with their reverse domain name or register the new option with the Internet Assigned Numbers Authority (IANA) (See Section 28).

An example of a reverse-domain-name option is "com.foo.mynewfeature", whose inventor can be reached at "foo.com". For these features, individual organizations are responsible for ensuring that option names do not collide within the same domain. The host name part of the option MUST use lower-case; the option name is case-insensitive.

Options registered with IANA do not contain periods and are globally unique. IANA option tags are case-insensitive.

23.3 Tags

The "tag" parameter is used in the To and From fields of SIP messages. It serves as a general mechanism to identify a particular instance of a user agent for a particular SIP URI.

As proxies can fork requests, the same request can reach multiple instances of a user (mobile and home phones, for example). Since each can respond, there needs to be a means for the originator of a session to distinguish the responses. Tag fields in the To and From disambiguate these multiple instances of the same user.

This situation also arises with multicast requests.

When a tag is generated by a UA for insertion into a request or response, it MUST be globally unique and cryptographically random with at least 32 bits of randomness. A property of this selection requirement is that a UA will place a different tag into the From header of an INVITE as it would place into the To header of the response to the same INVITE. This is needed in order for a UA to invite itself to a session, a common case for "hairpinning" of calls in PSTN gateways. Similarly, two INVITEs for different calls will have different From tags.

Besides the requirement for global uniqueness, the algorithm for generating a tag is implementation specific. Tags are helpful in fault tolerant systems, where a dialog is to be recovered on an alternate server after a failure. A UAS can select the tag in such a way that a backup can recognize a request as part of a dialog on the failed server, and therefore determine that it should attempt to recover the dialog and any other state associated with it.

24 Header Fields

The general syntax for header fields is covered in Section 7.3. This section lists the full set of header fields along with notes on syntax, meaning, and usage. Throughout this section, we use [HX.Y] to refer to Section X.Y of the current HTTP/1.1 specification RFC 2616 [15]. Examples of each header field are given.

Information about header fields in relation to methods and proxy processing is summarized in Tables 2 and 3.

The "where" column describes the request and response types in which the header field can be used. Values in this column are:

R: header fields may only appear in requests;

r: header field may only appear in responses;

2xx, 4xx, etc.: A numerical value or range indicates response codes with which the header field can be used;

c: header field is copied from the request to the response.

An empty entry in the “where” column indicates that the header may be present in all requests and responses.

The “proxy” column describes the operations a proxy may perform on a header:

c: A proxy can add (concatenate) comma-separated elements to the header.

m: A proxy can modify the header.

a: A proxy can add the header if not present.

r: A proxy must be be able to read the header and thus this header cannot be encrypted.

The next six columns relate to the presence of a header field in a method:

o: The header field is optional.

m: The header field is mandatory.

m*: The header field SHOULD be sent, but servers need to be prepared to receive messages without that header field.

t: The header field SHOULD be sent, but servers need to be prepared to receive messages without that header field. If TCP is used as transport, then the header field MUST be sent.

***:** The header field is required if the message body is not empty. See sections 24.14, 24.15 and 7.4 for details.

-: The header field is ignored.

c: Conditional; the header field is either mandatory or optional, depending on the presence of a route set or the response code.

“Optional” means that a UA MAY include the header field in a request or response, and a UA MAY ignore the header field if present in the request or response (The exception to this rule is the Require header field discussed in 24.33). A “mandatory” header field MUST be present in a request, and MUST be understood by the UAS receiving the request. A mandatory response header field MUST be present in the response, and the header field MUST be understood by the UAC processing the response. “Not applicable” means that the header field MUST NOT be present in a request. If one is placed in a request by mistake, it MUST be ignored by the UAS receiving the request. Similarly, a header field labeled “not applicable” for a response means that the UAS MUST NOT place the header in the response, and the UAC MUST ignore the header in the response.

A UA SHOULD ignore extension header parameters that are not understood.

A compact form of some common header fields is also defined for use when overall message size is an issue.

The Contact, From, and To header fields contain a URI. If the URI contains a comma, question mark or semicolon, the URI MUST be enclosed in angle brackets (< and >). Any URI parameters are contained within these brackets. If the URI is not enclosed in angle brackets, any semicolon-delimited parameters are header-parameters, not URI parameters.

Header field	where	proxy	ACK	BYE	CAN	INV	OPT	REG	PRA
Accept	R		-	o	-	m*	m*	o	o
Accept	2xx		-	-	-	m*	m*	o	-
Accept	415		-	o	-	o	o	o	o
Accept-Encoding	R		-	o	-	m*	o	o	o
Accept-Encoding	2xx		-	-	-	m*	m*	o	-
Accept-Encoding	415		-	o	-	o	o	o	o
Accept-Language	R		-	o	-	m*	o	o	o
Accept-Language	2xx		-	-	-	m*	m*	o	-
Accept-Language	415		-	o	-	o	o	o	o
Alert-Info	R	am	-	-	-	o	-	-	-
Alert-Info	180	am	-	-	-	o	-	-	-
Allow	R		o	o	o	o	o	o	o
Allow	2xx		-	o	o	m*	m*	o	o
Allow	r		-	o	o	o	o	o	o
Allow	405		-	m	m	m	m	m	m
Authentication-Info	2xx		-	o	-	o	o	o	o
Authorization	R		o	o	o	o	o	o	o
Call-ID	c	r	m	m	m	m	m	m	m
Call-Info		am	-	-	-	o	o	o	-
Contact	R		o	-	-	m	o	o	-
Contact	1xx		-	-	-	o	o	-	-
Contact	2xx		-	-	-	m	o	o	-
Contact	3xx		-	o	-	o	o	o	o
Contact	485		-	o	-	o	o	o	o
Content-Disposition			o	o	-	o	o	o	o
Content-Encoding			o	o	-	o	o	o	o
Content-Language			o	o	-	o	o	o	o
Content-Length		r	t	t	t	t	t	t	t
Content-Type			*	*	-	*	*	*	*
CSeq	c	r	m	m	m	m	m	m	m
Date		a	o	o	o	o	o	o	o
Error-Info	300-699		-	o	o	o	o	o	o
Expires			-	-	-	o	-	o	-
From	c	r	m	m	m	m	m	m	m
In-Reply-To	R		-	-	-	o	-	-	-
Max-Forwards	R	amr	m	m	m	m	m	m	m
Min-Expires	423		-	-	-	-	-	m	-
MIME-Version			o	o	o	o	o	o	o
Organization		am	-	-	-	o	o	o	-

Table 2: Summary of header fields, A–O

Header field	where	proxy	ACK	BYE	CAN	INV	OPT	REG	PRA
Priority	R	a	-	-	-	o	-	-	-
Proxy-Authenticate	407		-	m	m	m	m	m	m
Proxy-Authorization	R	r	o	o	o	o	o	o	o
Proxy-Require	R	r	-	o	-	o	o	o	o
RAck	R		-	-	-	-	-	-	m
Record-Route	R	amr	o	o	o	o	o	-	o
Record-Route	2xx,401,484		-	o	o	o	o	-	o
Reply-To			-	-	-	o	-	-	-
Require		acr	-	o	-	o	o	o	o
Retry-After	404,413,480,486		-	o	o	o	o	o	o
	500,503		-	o	o	o	o	o	o
	600,603		-	o	o	o	o	o	o
Route	R	r	c	c	c	c	c	-	c
RSeq	1xx		-	o	-	o	o	o	-
Server	r		-	o	o	o	o	o	o
Subject	R		-	-	-	o	-	-	-
Supported	R		-	o	o	o	o	o	o
Supported	2xx		-	o	o	o	m*	o	o
Timestamp			o	o	o	o	o	o	o
To	c(1)	r	m	m	m	m	m	m	m
Unsupported	420		-	o	o	o	o	o	o
User-Agent			o	o	o	o	o	o	o
Via	c	acmr	m	m	m	m	m	m	m
Warning	r		-	o	o	o	o	o	o
WWW-Authenticate	401		-	m	m	m	m	m	m

Table 3: Summary of header fields, P–Z; (1): copied with possible addition of tag

24.1 Accept

The Accept header follows the syntax defined in [H14.1]. The semantics are also identical, with the exception that if no Accept header is present, the server SHOULD assume a default value of `application/sdp`.

An empty Accept header field means that no formats are acceptable.

Example:

```
Accept: application/sdp;level=1, application/x-private, text/html
```

24.2 Accept-Encoding

The Accept-Encoding header field is similar to Accept, but restricts the content-codings [H3.5] that are acceptable in the response. See [H14.3]. The syntax of this header is defined in [H14.3]. The semantics in SIP are identical to those defined in [H14.3].

An empty Accept-Encoding header field is permissible, even though the syntax in [H14.3] does not provide for it. It is equivalent to Accept-Encoding: identity, that is, only the identity encoding, meaning no encoding, is permissible.

If no Accept-Encoding header is present, the server SHOULD assume a default value of identity.

This differs slightly from the HTTP definition, which indicates that when not present, any encoding can be used, but the identity encoding is preferred.

Example:

```
Accept-Encoding: gzip
```

24.3 Accept-Language

The Accept-Language header is used in requests to indicate the preferred languages for reason phrases, session descriptions, or status responses carried as message bodies in the response. If no Accept-Language header is present, the server SHOULD assume all languages are acceptable to the client.

The Accept-Language header follows the syntax defined in [H14.4]. The rules for ordering the languages based on the "q" parameter apply to SIP as well.

Example:

```
Accept-Language: da, en-gb;q=0.8, en;q=0.7
```

24.4 Alert-Info

When present in an INVITE request, the Alert-Info header field specifies an alternative ring tone to the UAS. When present in a 180 (Ringing) response, the Alert-Info header field specifies an alternative ringback tone to the UAC. A typical usage is for a proxy to insert this header to provide a distinctive ring feature.

The Alert-Info header can introduce security risks. These risks and the ways to handle them are discussed in Section 24.9, which discusses the Call-Info header since the risks are identical.

In addition, a user SHOULD be able to disable this feature selectively.

> This helps prevent disruptions that could result from the use of this header by untrusted elements.

Example:

```
Alert-Info: <http://wwww.example.com/sounds/moo.wav>
```

24.5 Allow

The Allow header field lists the set of methods supported by the UA generating the message.

All methods, including ACK and CANCEL, understood by the UA MUST be included in the list of methods in the Allow header, when present. The absence of an Allow header MUST NOT be interpreted to mean that the UA sending the message supports no methods. Rather, it implies that the UA is not providing any information on what methods it supports.

Supplying an Allow header in responses to methods other than OPTIONS reduces the number of messages needed.

Example:

```
Allow: INVITE, ACK, OPTIONS, CANCEL, BYE
```

24.6 Authentication-Info

The Authentication-Info header provides for mutual authentication with HTTP Digest. A UAS MAY include this header in a 2xx response to a request that was successfully authenticated using digest based on the Authorization header.

Syntax and semantics follow those specified in RFC 2617 [16].

Example:

```
Authentication-Info: nextnonce="47364c23432d2e131a5fb210812c"
```

24.7 Authorization

The Authorization header field contains authentication credentials of a UA. Section 20.2 overviews the use of the Authorization header field, and Section 20.4 describes the syntax and semantics when used with HTTP authentication.

This header field, along with Proxy-Authorization, breaks the general rules about multiple header fields. Although not a comma-separated list, this header field may be present multiple times, and MUST NOT be combined into a single header using the usual rules described in Section 7.3.

In the example below, there are no quotes around the Digest parameter:

```
Authorization: Digest username="Alice", realm="Bob's Friends",
 nonce="84a4cc6f3082121f32b42a2187831a9e",
 response="7587245234b3434cc3412213e5f113a5432"
```

24.8 Call-ID

The Call-ID header field uniquely identifies a particular invitation or all registrations of a particular client. A single multimedia conference can give rise to several calls with different Call-IDs, for example, if a user invites a single individual several times to the same (long-running) conference. Call-IDs are case- sensitive and are simply compared byte-by-byte.

The compact form of the Call-ID header field is i.

Examples:

```
Call-ID: f81d4fae-7dec-11d0-a765-00a0c91e6bf6@biloxi.com
i:f81d4fae-7dec-11d0-a765-00a0c91e6bf6@192.0.2.4
```

24.9 Call-Info

The Call-Info header field provides additional information about the caller or callee, depending on whether it is found in a request or response. The purpose of the URI is described by the "purpose" parameter. The "icon" parameter designates an image suitable as an iconic representation of the caller or callee. The "info" parameter describes the caller or callee in general, for example, through a web page. The "card" parameter provides a business card, for example, in vCard [37] or LDIF [38] formats. Additonal tokens can be registered using IANA and the procedures in Section 28.

Use of the Call-Info header field can pose a security risk. If a callee fetches the URIs provided by a malicious caller, the callee may be at risk for displaying inappropriate or offensive content, dangerous or illegal content, and so on. Therefore, it is RECOMMENDED that a UA only render the information in the Call-Info header if it can verify the authenticity of the element that originated the header and trusts that element. This need not be the peer UA; a proxy can insert this header into requests.

Example:

```
Call-Info: <http://wwww.example.com/alice/photo.jpg> ;purpose=icon,
  <http://www.example.com/alice/> ;purpose=info
```

24.10 Contact

The Contact header field provides a URI whose meaning depends on the the type of request or response it is in.

A Contact header field can contain a display name, a URI with URI parameters, and header parameters.

This document defines the Contact parameters “q” and “expires”. These parameters are only used when the Contact is present in a REGISTER request or response, or in a 3xx response. Additional parameters may be defined in other specifications.

When the header field contains a display name, the URI including all URI parameters is enclosed in “<” and “>”. If no “<” and “>” are present, all parameters after the URI are header parameters, not URI parameters. The display name can be tokens, or a quoted string, if a larger character set is desired.

Even if the “display-name” is empty, the “name-addr” form MUST be used if the “addr-spec” contains a comma, semicolon, or question mark. There may or may not be LWS between the display-name and the “<”.

These rules for parsing a display name, URI and URI parameters, and header parameters also apply for the header fields To and From.

> The Contact header has a role similar to the Location header field in HTTP. However, the HTTP header field only allows one address, unquoted. Since URIs can contain commas and semicolons as reserved characters, they can be mistaken for header or parameter delimiters, respectively.

The compact form of the Contact header field is m (for “moved”).

The second example below shows a Contact header field containing both a URI parameter (transport) and a header parameter (expires).

```
Contact: "Mr. Watson" <sip:watson@worcester.bell-telephone.com>
   ;q=0.7; expires=3600,
   "Mr. Watson" <mailto:watson@bell-telephone.com> ;q=0.1
m: <sip:bob@192.0.2.4;transport=tcp>;expires=60
```

24.11 Content-Disposition

The Content-Disposition header field describes how the message body or, for multipart messages, a message body part is to be interpreted by the UAC or UAS. This SIP header field extends the MIME Content-Type (RFC 1806 [6]).

The value “session” indicates that the body part describes a session, for either calls or early (pre-call) media. The value “render” indicates that the body part should be displayed or otherwise rendered to the user. For backward-compatibility, if the Content-Disposition header is missing,

the server SHOULD assume bodies of Content-Type `application/sdp` are the disposition “session”, while other content types are “render”.

The disposition type “icon” indicates that the body part contains an image suitable as an iconic representation of the caller or callee. The value “alert” indicates that the body part contains information, such as an audio clip, that should be rendered instead of ring tone.

The handling parameter, handling-parm, describes how the UAS should react if it receives a message body whose content type or disposition type it does not understand. The parameter has defined values of “optional” and “required”. If the handling parameter is missing, the value “required” SHOULD be assumed.

If this header field is missing, the MIME type determines the default content disposition. If there is none, “render” is assumed.

Example:

```
Content-Disposition: session
```

24.12 Content-Encoding

The Content-Encoding header field is used as a modifier to the “media-type”. When present, its value indicates what additional content codings have been applied to the entity-body, and thus what decoding mechanisms MUST be applied in order to obtain the media-type referenced by the Content-Type header field. Content-Encoding is primarily used to allow a body to be compressed without losing the identity of its underlying media type.

If multiple encodings have been applied to an entity, the content codings MUST be listed in the order in which they were applied.

All content-coding values are case-insensitive. IANA acts as a registry for content-coding value tokens. See [H3.5] for a definition of the syntax for content-coding.

Clients MAY apply content encodings to the body in requests. A server MAY apply content encodings to the bodies in responses. The server MUST only use encodings listed in the Accept-Encoding header in the request.

The compact form of the Content-Encoding header field is e. Examples:

```
Content-Encoding: gzip
e: tar
```

24.13 Content-Language

See [H14.12]. Example:

```
Content-Language: fr
```

24.14 Content-Length

The Content-Length header field indicates the size of the message-body, in decimal number of octets, sent to the recipient. Applications SHOULD use this field to indicate the size of the message-body to be transferred, regardless of the media type of the entity. If TCP is used as transport, the header field MUST be used.

The size of the message-body does *not* include the CRLF separating headers and body. Any Content-Length greater than or equal to zero is a valid value. If no body is present in a message, then the Content-Length header field MUST be set to zero.

> The ability to omit Content-Length simplifies the creation of cgi-like scripts that dynamically generate responses.

The compact form of the header is l.

Examples:

```
Content-Length: 349
l: 173
```

24.15 Content-Type

The Content-Type header field indicates the media type of the message-body sent to the recipient. The "media-type" element is defined in [H3.7]. The Content-Type header MUST be present if the body is not empty. If the body is empty, and a Content-Type header is present, it indicates that the body of the specific type has zero length (for example, an empty audio file).

The compact form of the header is c.

Examples:

```
Content-Type: application/sdp
c: text/html; charset=ISO-8859-4
```

24.16 CSeq

A CSeq header field in a request contains a single decimal sequence number and the request method. The sequence number MUST be expressible as a 32-bit unsigned integer. The CSeq header serves to order transactions within a dialog, to provide a means to uniquely identify transactions, and to differentiate between new requests and request retransmissions.

Example:

```
CSeq: 4711 INVITE
```

24.17 Date

The Date header field contains an RFC 1123 date (see [H14.18]). Unlike HTTP/1.1, SIP only supports the most recent RFC 1123 [3] format for dates. As in [H3.3], SIP restricts the timezone in SIP-date to "GMT", while RFC 1123 allows any timezone. rfc1123-date is case-sensitive.

The Date header field reflects the time when the request or response is first sent.

> The Date header field can be used by simple end systems without a battery-backed clock to acquire a notion of current time. However, in its GMT form, it requires clients to know their offset from GMT.

Example:

```
Date: Sat, 13 Nov 2010 23:29:00 GMT
```

24.18 Error-Info

The Error-Info header field provides a pointer to additional information about the error status response.

> SIP UACs have user interface capabilities ranging from pop-up windows and audio on PC softclients to audio-only on "black" phones or endpoints connected via gateways. Rather than forcing a server generating an error to choose between sending an error status code with a detailed reason phrase and playing an audio recording, the Error-Info header field allows both to be sent. The UAC then has the choice of which error indicator to render to the caller.

A UAC MAY treat a SIP URI in an Error-Info header field as if it were a Contact in a redirect and generate a new INVITE, resulting in a recorded announcement session being established. A non-SIP URI MAY be rendered to the user.

Examples:

```
SIP/2.0 404 The number you have dialed is not in service
Error-Info: <sip:not-in-service-recording@atlanta.com>
```

24.19 Expires

The Expires header field gives the relative time after which the message (or content) expires.

The precise meaning of this is method dependent.

The expiration time in an INVITE does *not* affect the duration of the actual session that may result from the invitation. Session description protocols may offer the ability to express time limits on the session duration, however.

The value of this field is an integer number of seconds (in decimal), measured from the receipt of the request.

Example:

```
Expires: 5
```

24.20 From

The From header field indicates the initiator of the request. This may be different from the initiator of the dialog. Requests sent by the callee to the caller use the callee's address in the From header field.

The optional "display-name" is meant to be rendered by a human user interface. A system SHOULD use the display name "Anonymous" if the identity of the client is to remain hidden. Even if the "display-name" is empty, the "name-addr" form MUST be used if the "addr-spec" contains a comma, question mark, or semicolon. Syntax issues are discussed in Section 7.3.1.

Section 12 describes how From header fields are compared for the purpose of matching requests to dialogs. See Section 24.10 for the rules for parsing a display name, URI and URI parameters, and header parameters.

The compact form of the header is f.

Examples:

```
From: "A. G. Bell" <sip:agb@bell-telephone.com> ;tag=a48s
From: sip:+12125551212@server.phone2net.com;tag=887s
f: Anonymous <sip:c8oqz84zk7z@privacy.org>;tag=hyh8
```

24.21 In-Reply-To

The In-Reply-To header field enumerates the Call-IDs that this call references or returns. These Call-IDs may have been cached by the client then included in this header in a return call.

> This allows automatic call distribution systems to route return calls to the originator of the first call. This also allows callees to filter calls, so that only return calls for calls they originated will be accepted. This field is not a substitute for request authentication.

Example:

```
In-Reply-To: 70710@saturn.bell-tel.com, 17320@saturn.bell-tel.com
```

24.22 Max-Forwards

The Max-Forwards header field must be used with any SIP method to limit the number of proxies or gateways that can forward the request to the next downstream server. This can also be useful when the client is attempting to trace a request chain that appears to be failing or looping in mid-chain.

The Max-Forwards value is an integer in the range 0-255 indicating the remaining number of times this request message is allowed to be forwarded. This count is decremented by each server that forwards the request.

This header field should be inserted by elements that can not otherwise guarantee loop detection. For example, a B2BUA should insert a Max-Forwards header field.

Example:

```
Max-Forwards: 6
```

24.23 Min-Expires

The Min-Expires header field conveys the minimum registration expiration interval to a registrar. The header field contains a decimal integer number of seconds. The use of the header field in a 423 (Registration Too Brief) response is described in Sections 10.2.8, 10.3, and 25.4.17.

Example:

```
Min-Expires: 60
```

24.24 MIME-Version

See [H19.4.1].

Example:

```
MIME-Version: 1.0
```

24.25 Organization

The Organization header field conveys the name of the organization to which the entity issuing the request or response belongs.

> The field MAY be used by client software to filter calls.

Example:

```
Organization: Boxes by Bob
```

24.26 Priority

The Priority header field indicates the urgency of the request as perceived by the client. The Priority header field describes the priority that the SIP request should have to the receiving human or its agent. For example, it may be factored into decisions about call routing and acceptance. It does not influence the use of communications resources such as packet forwarding priority in routers or access to circuits in PSTN gateways. The header field can have the values "non-urgent", "normal", "urgent", and "emergency", but additional values can be defined elsewhere. It is RECOMMENDED that the value of "emergency" only be used when life, limb, or property are in imminent danger. Otherwise, there are no semantics defined for this header field.

These are the values of RFC 2076 [34], with the addition of "emergency".

Examples:

```
Subject: A tornado is heading our way!
Priority: emergency
```

or

```
Subject: Weekend plans
Priority: non-urgent
```

24.27 Proxy-Authenticate

The Proxy-Authenticate header field contains an authentication challenge.

The syntax for this header and its use is defined in [H14.33]. See 20.3 for further details on its usage.

Example:

```
 Proxy-Authenticate: Digest realm="Carrier SIP",
  domain="sip:ss1.carrier.com",
  nonce="f84f1cec41e6cbe5aea9c8e88d359",
  opaque="", stale=FALSE, algorithm=MD5
```

24.28 Proxy-Authorization

The Proxy-Authorization header field allows the client to identify itself (or its user) to a proxy that requires authentication. The Proxy-Authorization field value consists of credentials containing the authentication information of the user agent for the proxy and/or realm of the resource being requested.

See [H14.34] for a definition of the syntax, and section 20.3 for a discussion of its usage.

This header field, along with Authorization, breaks the general rules about multiple header fields. Although not a comma-separated list, this header field may be present multiple times, and MUST NOT be combined into a single header using the usual rules described in Section 7.3.1.

Example:

```
Proxy-Authorization: Digest username="Alice", realm="Atlanta ISP",
   nonce="c60f3082ee1212b402a21831ae",
   response="245f23415f11432b3434341c022"
```

24.29 Proxy-Require

The Proxy-Require header field is used to indicate proxy-sensitive features that must be supported by the proxy. See Section 24.33 for more details on the mechanics of this message and a usage example.

Example:

```
Proxy-Require: foo
```

24.30 RAck

The RAck header is sent in a PRACK request to support reliability of provisional responses. It contains two numbers and a method tag. The first number is the value from the RSeq header in the provisional response that is being acknowledged. The next number, and the method, are copied from the CSeq in the response that is being acknowledged. The method name in the RAck header is case sensitive.

Example:

```
RAck: 776656 1 INVITE
```

24.31 Record-Route

The Record-Route is inserted by proxies in a request to force future requests in the session to be routed through the proxy.

Details of its use with the Route header field are described in Section 16.4.

Example:

```
Record-Route: <sip:bob@biloxi.com;maddr=192.0.2.4>,
 <sip:bob@biloxi.com;maddr=192.0.6.1>
```

24.32 Reply-To

The Reply-To header field contains a logical return URI which may be different from the From header field. For example, the URI MAY be used to return missed calls or unestablished sessions. If the user wished to remain anonymous, the header field SHOULD either be omitted from the request or populated in such as way that does not reveal any private information.

Even if the “display-name” is empty, the “name-addr” form MUST be used if the “addr-spec” contains a comma, question mark, or semicolon. Syntax issues are discussed in Section 7.3.1.

Example:

```
Reply-To: Bob <sip:bob@biloxi.com>
```

24.33 Require

The Require header field is used by UACs to tell UASs about options that the UAC expects the UAS to support in order to process the request. Although an optional header, the Require MUST NOT be ignored if it is present.

The Require header contains a list of option tags, described in Section 23.2. Each option tag defines a SIP extension that MUST be understood to process the request. Frequently, this is used to indicate that a specific set of extension headers need to be understood. A UAC compliant to this specification MUST only include option tags corresponding to standards-track RFCs.

Example:

```
Require: 100rel
```

24.34 Retry-After

The Retry-After header field can be used with a 503 (Service Unavailable) response to indicate how long the service is expected to be unavailable to the requesting client and with a 404 (Not Found), 600 (Busy), or 603 (Decline) response to indicate when the called party anticipates being available again. The value of this field is a positive integer number of seconds (in decimal) after the time of the response.

An optional comment can be used to indicate additional information about the time of callback. An optional “duration” parameter indicates how long the called party will be reachable starting at the initial time of availability. If no duration parameter is given, the service is assumed to be available indefinitely.

Examples:

```
Retry-After: 18000;duration=3600
Retry-After: 120 (I’m in a meeting)
```

24.35 Route

The Route is used to force routing for a request through the listed set of proxies. Details of its use with the Record-Route header field are described in Section 13.

Example:

```
Route: <sip:bob@biloxi.com;maddr=192.0.2.4>, <sip:bob@pc33.atlanta.com>
```

24.36 RSeq

The RSeq header is used in provisional responses in order to transmit them reliably. It contains a single numeric value from 1 to 2**32 - 1. For details on its usage, see Section 18.1.

Example:

```
RSeq: 988789
```

24.37 Server

The Server header field contains information about the software used by the UAS to handle the request. The syntax for this field is defined in [H14.38].

Revealing the specific software version of the server might allow the server to become more vulnerable to attacks against software that is known to contain security holes. Implementors SHOULD make the Server header field a configurable option.

Example:

```
Server: HomeProxy v2
```

24.38 Subject

The Subject header field provides a summary or indicates the nature of the call, allowing call filtering without having to parse the session description. The session description does not have to use the same subject indication as the invitation.

The compact form of the header is s.

Example:

```
Subject: Need more boxes
s: Tech Support
```

24.39 Supported

The Supported header field enumerates all the extensions supported by the UAC or UAS.

The Supported header contains a list of option tags, described in Section 23.2, that are understood by the UAC or UAS. A UA compliant to this specification MUST only include option tags corresponding to standards-track RFCs. If empty, it means that no extensions are supported.

Example:

```
Supported: 100rel
```

24.40 Timestamp

The Timestamp header field describes when the UAC sent the request to the UAS.

See Section 8.2.6 for details on how to generate a response to a request that contains the header field, and Section 17.3 for usage in RTT estimation.

Example:

```
Timestamp: 54
```

24.41 To

The To header field specifies the logical recipient of the request.

The optional "display-name" is meant to be rendered by a human-user interface. The "tag" parameter serves as a general mechanism to distinguish multiple instances of a user identified by a single SIP URI.

See Section 13 for details of the "tag" parameter.

Section 12 describes how To and From header fields are compared for the purpose of matching requests to dialogs. See Section 24.10 for the rules for parsing a display name, URI and URI parameters, and header parameters.

The compact form of the header is t.

The following are examples of valid To headers:

```
To: The Operator <sip:operator@cs.columbia.edu>;tag=287447
t: sip:+12125551212@server.phone2net.com
```

24.42 Unsupported

The Unsupported header field lists the features not supported by the UAS. See Section 24.33 for motivation.

Example:

```
Unsupported: foo
```

24.43 User-Agent

The User-Agent header field contains information about the UAC originating the request. The syntax and semantics are defined in [H14.43].

Revealing the specific software version of the user agent might allow the user agent to become more vulnerable to attacks against software that is known to contain security holes. Implementors SHOULD make the User-Agent header field a configurable option.

Example:

```
User-Agent: Softphone Beta1.5
```

24.44 Via

The Via field indicates the path taken by the request so far and indicates the path that should be followed in routing responses. The branch ID parameter in the Via header serves as a transaction identifier, and is used by proxies to detect loops.

The Via header field contains the transport protocol used to send the message, the client's host name or network address and, if not the default port number, the port number at which it wishes to receive responses. The Via header field can also contain parameters such as "maddr", "ttl", "received", and "branch", whose meaning and use are described in other sections.

Transport protocols defined here are "UDP", "TCP", "TLS", and "SCTP". "TLS" means TLS over TCP.

The host or network address and port number are not required to follow the SIP URI syntax. Specifically, LWS on either side of the ":" or "/" is allowed, as shown in the second example below.

```
Via: SIP/2.0/UDP erlang.bell-telephone.com:5060;branch=z9hG4bK87asdks7
Via: SIP/2.0/UDP 128.59.16.1:5060 ;received=128.59.19.3;branch=z9hG4bK77asjd
```

The compact form of the header is v.

In this example, the message originated from a multi-homed host with two addresses, 128.59.16.1 and 128.59.19.3. The sender guessed wrong as to which network interface would be used. Erlang.bell-telephone.com noticed the mismatch and added a parameter to the previous hop's Via header field, containing the address that the packet actually came from.

Another example:

```
Via: SIP / 2.0 / UDP first.example.com: 4000;ttl=16
  ;maddr=224.2.0.1 ;branch=z9hG4bKa7c6a8dlze.1
```

Even though this specification mandates that the branch parameter be present in all requests, the BNF for the header indicates that it is optional. This allows interoperation with RFC 2543 elements, which did not have to insert the branch parameter.

24.45 Warning

The Warning header field is used to carry additional information about the status of a response. Warning headers are sent with responses and contain a three-digit warning code, host name, and warning text.

The “warn-text” should be in a natural language that is most likely to be intelligible to the human user receiving the response. This decision can be based on any available knowledge, such as the location of the user, the Accept-Language field in a request, or the Content-Language field in a response. The default language is i-default [10].

The currently-defined “warn-code”s are listed below, with a recommended warn-text in English and a description of their meaning. These warnings describe failures induced by the session description. The first digit of warning codes beginning with “3” indicates warnings specific to SIP. Warnings 300 through 329 are reserved for indicating problems with keywords in the session description, 330 through 339 are warnings related to basic network services requested in the session description, 370 through 379 are warnings related to quantitative QoS parameters requested in the session description, and 390 through 399 are miscellaneous warnings that do not fall into one of the above categories.

300 Incompatible network protocol: One or more network protocols contained in the session description are not available.

301 Incompatible network address formats: One or more network address formats contained in the session description are not available.

302 Incompatible transport protocol: One or more transport protocols described in the session description are not available.

303 Incompatible bandwidth units: One or more bandwidth measurement units contained in the session description were not understood.

304 Media type not available: One or more media types contained in the session description are not available.

305 Incompatible media format: One or more media formats contained in the session description are not available.

306 Attribute not understood: One or more of the media attributes in the session description are not supported.

307 Session description parameter not understood: A parameter other than those listed above was not understood.

330 Multicast not available: The site where the user is located does not support multicast.

331 Unicast not available: The site where the user is located does not support unicast communication (usually due to the presence of a firewall).

370 Insufficient bandwidth: The bandwidth specified in the session description or defined by the media exceeds that known to be available.

399 Miscellaneous warning: The warning text can include arbitrary information to be presented to a human user or logged. A system receiving this warning MUST NOT take any automated action.

1xx and 2xx have been taken by HTTP/1.1.

Additional "warn-code"s, as in the example below, can be defined through IANA.

Examples:

```
Warning: 307 isi.edu "Session parameter 'foo' not understood"
Warning: 301 isi.edu "Incompatible network address type 'E.164'"
```

24.46 WWW-Authenticate

The WWW-Authenticate header field contains an authentication challenge. The syntax for this header field and use is defined in [H14.47]. See 20.2 for further details on its usage.

Example:

```
WWW-Authenticate: Digest realm="Bob's Friends",
  domain="sip:boxesbybob.com",
  nonce="f84f1cec41e6cbe5aea9c8e88d359",
  opaque="", stale=FALSE, algorithm=MD5
```

25 Response Codes

The response codes are consistent with, and extend, HTTP/1.1 response codes. Not all HTTP/1.1 response codes are appropriate, and only those that are appropriate are given here. Other HTTP/1.1 response codes SHOULD NOT be used. Response codes not defined by HTTP/1.1 have codes x80 upwards to avoid clashes with future HTTP response codes. Also, SIP defines a new class, 6xx.

25.1 Provisional 1xx

Provisional responses, also known as informational responses, indicate that the server or proxy contacted is performing some further action and does not yet have a definitive response. A server typically sends a 1xx response if it expects to take more than 200 ms to obtain a final response. Note that 1xx responses are not transmitted reliably. That is, they do not cause the client to send an ACK. Provisional (1xx) responses MAY contain message bodies, including session descriptions.

25.1.1 100 Trying

This response indicates that the request has been received by the next-hop server and that some unspecified action is being taken on behalf of this call (for example, a database is being consulted). This response, like all other provisional responses, stops retransmissions of an INVITE by a UAC. The 100 (Trying) response is different from other provisional responses, in that it is never forwarded upstream by a stateful proxy.

25.1.2 180 Ringing

The UA receiving the INVITE is trying to alert the user. This response MAY be used to initiate local ringback.

25.1.3 181 Call Is Being Forwarded

A proxy server MAY use this status code to indicate that the call is being forwarded to a different set of destinations.

25.1.4 182 Queued

The called party is temporarily unavailable, but the callee has decided to queue the call rather than reject it. When the callee becomes available, it will return the appropriate final status response. The reason phrase MAY give further details about the status of the call, for example, “5 calls queued; expected waiting time is 15 minutes”. The server MAY issue several 182 (Queued) responses to update the caller about the status of the queued call.

25.1.5 183 Session Progress

The 183 (Session Progress) response is used to convey information about the progress of the call which is not otherwise classified. The Reason-Phrase, header fields, or message body MAY be used to convey more details about the call progress.

25.2 Successful 2xx

The request was successful.

25.2.1 200 OK

The request has succeeded. The information returned with the response depends on the method used in the request.

25.3 Redirection 3xx

3xx responses give information about the user’s new location, or about alternative services that might be able to satisfy the call.

25.3.1 300 Multiple Choices

The address in the request resolved to several choices, each with its own specific location, and the user (or UA) can select a preferred communication end point and redirect its request to that location.

The response MAY include a message body containing a list of resource characteristics and location(s) from which the user or UA can choose the one most appropriate, if allowed by the Accept request header. However, no MIME types have been defined for this message body.

The choices SHOULD also be listed as Contact fields (Section 24.10). Unlike HTTP, the SIP response MAY contain several Contact fields or a list of addresses in a Contact field. UAs MAY use the Contact header field value for automatic redirection or MAY ask the user to confirm a choice. However, this specification does not define any standard for such automatic selection.

> This status response is appropriate if the callee can be reached at several different locations and the server cannot or prefers not to proxy the request.

25.3.2 301 Moved Permanently

The user can no longer be found at the address in the Request-URI, and the requesting client SHOULD retry at the new address given by the Contact header field (Section 24.10). The requestor SHOULD update any local directories, address books, and user location caches with this new value and redirect future requests to the address(es) listed.

25.3.3 302 Moved Temporarily

The requesting client SHOULD retry the request at the new address(es) given by the Contact header field (Section 24.10). The Request-URI of the new request uses the value of the Contact header in the response.

The duration of the validity of the Contact URI can be indicated through an Expires (Section 24.19) header field or an expires parameter in the Contact header field. Both proxies and UAs MAY cache this URI for the duration of the expiration time. If there is no explicit expiration time, the address is only valid once for recursing, and MUST NOT be cached for future transactions.

If the URI cached from the Contact header field fails, the Request-URI from the redirected request MAY be tried again a single time.

> The temporary URI may have become out-of-date sooner than the expiration time, and a new temporary URI may be available.

25.3.4 305 Use Proxy

The requested resource MUST be accessed through the proxy given by the Contact field. The Contact field gives the URI of the proxy. The recipient is expected to repeat this single request via the proxy. 305 (Use Proxy) responses MUST only be generated by UASs.

25.3.5 380 Alternative Service

The call was not successful, but alternative services are possible. The alternative services are described in the message body of the response. Formats for such bodies are not defined here, and may be the subject of future standardization.

25.4 Request Failure 4xx

4xx responses are definite failure responses from a particular server. The client SHOULD NOT retry the same request without modification (for example, adding appropriate authorization). However, the same request to a different server might be successful.

25.4.1 400 Bad Request

The request could not be understood due to malformed syntax. The Reason-Phrase SHOULD identify the syntax problem in more detail, for example, "Missing Call-ID header".

25.4.2 401 Unauthorized

The request requires user authentication. This response is issued by UASs and registrars, while 407 (Proxy Authentication Required) is used by proxy servers.

25.4.3 402 Payment Required

Reserved for future use.

25.4.4 403 Forbidden

The server understood the request, but is refusing to fulfill it. Authorization will not help, and the request SHOULD NOT be repeated.

25.4.5 404 Not Found

The server has definitive information that the user does not exist at the domain specified in the Request-URI. This status is also returned if the domain in the Request-URI does not match any of the domains handled by the recipient of the request.

25.4.6 405 Method Not Allowed

The method specified in the Request-Line is understood, but not allowed for the address identified by the Request-URI.

The response MUST include an Allow header field containing a list of valid methods for the indicated address.

25.4.7 406 Not Acceptable

The resource identified by the request is only capable of generating response entities that have content characteristics not acceptable according to the Accept header fields sent in the request.

25.4.8 407 Proxy Authentication Required

This code is similar to 401 (Unauthorized), but indicates that the client MUST first authenticate itself with the proxy. SIP access authentication is explained in section 22 and 20.3.

This status code can be used for applications where access to the communication channel (for example, a telephony gateway) rather than the callee requires authentication.

25.4.9 408 Request Timeout

The server could not produce a response within a suitable amount of time, for example, if it could not determine the location of the user in time. The client MAY repeat the request without modifications at any later time.

25.4.10 410 Gone

The requested resource is no longer available at the server and no forwarding address is known. This condition is expected to be considered permanent. If the server does not know, or has no facility to determine, whether or not the condition is permanent, the status code 404 (Not Found) SHOULD be used instead.

25.4.11 413 Request Entity Too Large

The server is refusing to process a request because the request entity is larger than the server is willing or able to process. The server MAY close the connection to prevent the client from continuing the request.

If the condition is temporary, the server SHOULD include a Retry-After header field to indicate that it is temporary and after what time the client MAY try again.

25.4.12 414 Request-URI Too Long

The server is refusing to service the request because the Request-URI is longer than the server is willing to interpret.

25.4.13 415 Unsupported Media Type

The server is refusing to service the request because the message body of the request is in a format not supported by the server for the requested method. The server SHOULD return a list of acceptable formats using the Accept, Accept-Encoding and Accept-Language header fields. UAC processing of this response is described in Section 8.1.3.6.

25.4.14 416 Unsupported URI Scheme

The server cannot process the request because the scheme of the URI in the Request-URI is unknown to the server. Client processing of this response is described in Section 8.1.3.6.

25.4.15 420 Bad Extension

The server did not understand the protocol extension specified in a Proxy-Require (Section 24.29) or Require (Section 24.33) header field. The server SHOULD include a list of the unsupported extensions in an Unsupported header in the response. UAC processing of this response is described in Section 8.1.3.6.

25.4.16 421 Extension Required

The UAS needs a particular extension to process the request, but this extension is not listed in a Supported header in the request. Responses with this status code MUST contain a Require header field listing the required extensions.

A UAS SHOULD NOT use this response unless it truly cannot provide any useful service to the client. Instead, if a desirable extension is not listed in the Supported header field, servers SHOULD process the request using baseline SIP capabilities and any extensions supported by the client.

25.4.17 423 Registration Too Brief

The registrar is rejecting a registration request because a Contact header field expiration time was too small. The use of this response and the related Min-Expires header field are described in Sections 10.2.8, 10.3, and 24.23.

25.4.18 480 Temporarily Unavailable

The callee's end system was contacted successfully but the callee is currently unavailable (for example, is not logged in, logged in such a manner as to preclude communication with the callee, or has activated the "do not disturb" feature). The response MAY indicate a better time to call in the Retry-After header. The user could also be available elsewhere (unbeknownst to this host). The reason phrase SHOULD indicate a more precise cause as to why the callee is unavailable. This value SHOULD be settable by the UA. Status 486 (Busy Here) MAY be used to more precisely indicate a particular reason for the call failure.

This status is also returned by a redirect or proxy server that recognizes the user identified by the Request-URI, but does not currently have a valid forwarding location for that user.

25.4.19 481 Call/Transaction Does Not Exist

This status indicates that the UAS received a request that does not match any existing dialog or transaction.

25.4.20 482 Loop Detected

The server has detected a loop (Section 3).

25.4.21 483 Too Many Hops

The server received a request that contains a Max-Forwards (Section 24.22) header with the value zero.

25.4.22 484 Address Incomplete

The server received a request with a Request-URI that was incomplete. Additional information SHOULD be provided in the reason phrase.

> This status code allows overlapped dialing. With overlapped dialing, the client does not know the length of the dialing string. It sends strings of increasing lengths, prompting the user for more input, until it no longer receives a 484 (Address Incomplete) status response.

25.4.23 485 Ambiguous

The Request-URI was ambiguous. The response MAY contain a listing of possible unambiguous addresses in Contact header fields. Revealing alternatives can infringe on privacy of the user or the organization. It MUST be possible to configure a server to respond with status 404 (Not Found) or to suppress the listing of possible choices for ambiguous Request-URIs.

Example response to a request with the Request-URI `sip:lee@example.com`:

```
485 Ambiguous SIP/2.0
Contact: Carol Lee <sip:carol.lee@example.com>
Contact: Ping Lee <sip:p.lee@example.com>
Contact: Lee M. Foote <sip:lee.foote@example.com>
```

Some email and voice mail systems provide this functionality. A status code separate from 3xx is used since the semantics are different: for 300, it is assumed that the same person or service will be reached by the choices provided. While an automated choice or sequential search makes sense for a 3xx response, user intervention is required for a 485 (Ambiguous) response.

25.4.24 486 Busy Here

The callee's end system was contacted successfully, but the callee is currently not willing or able to take additional calls at this end system. The response MAY indicate a better time to call in the Retry-After header. The user could also be available elsewhere, such as through a voice mail service. Status 600 (Busy Everywhere) SHOULD be used if the client knows that no other end system will be able to accept this call.

25.4.25 487 Request Terminated

The request was terminated by a BYE or CANCEL request. This response is never returned for a CANCEL request itself.

25.4.26 488 Not Acceptable Here

The response has the same meaning as 606 (Not Acceptable), but only applies to the specific entity addressed by the Request-URI and the request may succeed elsewhere.

A message body containing a description of media capabilities MAY be present in the response, which is formatted according to the Accept header field in the INVITE (or application/sdp if not present), the same as a message body in a 200 (OK) response to an OPTIONS request.

25.4.27 491 Request Pending

The request was received by a UAS which had a pending request within the same dialog. Section 14.2 describes how such "glare" situations are resolved.

25.4.28 493 Undecipherable

The request was received by a UAS that contained an encrypted MIME body for which the recipient does not possess or will not provide an appropriate decryption key. This response MAY have a single body containing an appropriate public key that should be used to encrypt MIME bodies sent to this UA. Details of the usage of this response code can be found in Section 21.2.

25.5 Server Failure 5xx

5xx responses are failure responses given when a server itself has erred.

25.5.1 500 Server Internal Error

The server encountered an unexpected condition that prevented it from fulfilling the request. The client MAY display the specific error condition and MAY retry the request after several seconds.

If the condition is temporary, the server MAY indicate when the client may retry the request using the Retry-After header.

25.5.2 501 Not Implemented

The server does not support the functionality required to fulfill the request. This is the appropriate response when a UAS does not recognize the request method and is not capable of supporting it for any user. (Proxies forward all requests regardless of method.)

Note that a 405 (Method Not Allowed) is sent when the server recognizes the request method, but that method is not allowed or supported.

25.5.3 502 Bad Gateway

The server, while acting as a gateway or proxy, received an invalid response from the downstream server it accessed in attempting to fulfill the request.

25.5.4 503 Service Unavailable

The server is temporarily unable to process the request due to a temporary overloading or maintenance of the server. The server MAY indicate when the client should retry the request in a Retry-After header field. If no Retry-After is given, the client MUST act as if it had received a 500 (Server Internal Error) response.

A client (proxy or UAC) receiving a 503 (Service Unavailable) SHOULD attempt to forward the request to an alternate server. It SHOULD NOT forward any other requests to that server for the duration specified in the Retry-After header field, if present.

Servers MAY refuse the connection or drop the request instead of responding with 503 (Service Unavailable).

25.5.5 504 Server Time-out

The server did not receive a timely response from an external server it accessed in attempting to process the request. 408 (Request Timeout) should be used instead if there was no response within the period specified in the Expires header field from the upstream server.

25.5.6 505 Version Not Supported

The server does not support, or refuses to support, the SIP protocol version that was used in the request. The server is indicating that it is unable or unwilling to complete the request using the same major version as the client, other than with this error message.

25.5.7 513 Message Too Large

The server was unable to process the request since the message length exceeded its capabilities.

25.6 Global Failures 6xx

6xx responses indicate that a server has definitive information about a particular user, not just the particular instance indicated in the Request-URI.

25.6.1 600 Busy Everywhere

The callee's end system was contacted successfully but the callee is busy and does not wish to take the call at this time. The response MAY indicate a better time to call in the Retry-After header. If the callee does not wish to reveal the reason for declining the call, the callee uses status code 603 (Decline) instead. This status response is returned only if the client knows that no other end point (such as a voice mail system) will answer the request. Otherwise, 486 (Busy Here) should be returned.

25.6.2 603 Decline

The callee's machine was successfully contacted but the user explicitly does not wish to or cannot participate. The response MAY indicate a better time to call in the Retry-After header. This status response is returned only if the client knows that no other end point will answer the request.

25.6.3 604 Does Not Exist Anywhere

The server has authoritative information that the user indicated in the Request-URI does not exist anywhere.

25.6.4 606 Not Acceptable

The user's agent was contacted successfully but some aspects of the session description such as the requested media, bandwidth, or addressing style were not acceptable.

A 606 (Not Acceptable) response means that the user wishes to communicate, but cannot adequately support the session described. The 606 (Not Acceptable) response MAY contain a list of reasons in a Warning header field describing why the session described cannot be supported.

A message body containing a description of media capabilities MAY be present in the response, which is formatted according to the Accept header field in the INVITE (or application/sdp if not present), the same as a message body in a 200 (OK) response to an OPTIONS request.

Reasons are listed in Section 24.45. It is hoped that negotiation will not frequently be needed, and when a new user is being invited to join an already existing conference, negotiation may not be possible. It is up to the invitation initiator to decide whether or not to act on a 606 (Not Acceptable) response.

This status response is returned only if the client knows that no other end point will answer the request.

26 Examples

In the following examples, we often omit the message body and the corresponding Content-Length and Content-Type headers for brevity.

26.1 Registration

Bob registers on start-up. The message flow is shown in Figure 9.

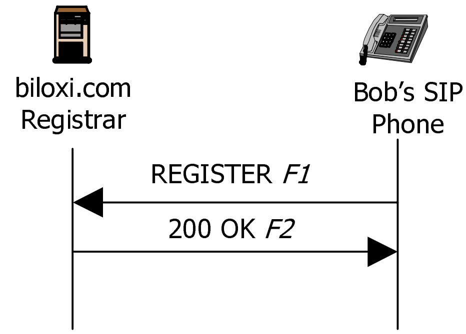


Figure 9: SIP Registration Example

F1 REGISTER Bob -> Registrar

```
  REGISTER sip:registrar.biloxi.com SIP/2.0
  Via: SIP/2.0/UDP 192.0.2.4:5060;branch=z9hG4bKnashds7
  To: Bob <sip:bob@biloxi.com>
  From: Bob <sip:bob@biloxi.com>;tag=456248
  Call-ID: 843817637684230@998sdasdh09
  CSeq: 1826 REGISTER
  Contact: <sip:bob@192.0.2.4>
  Max-Forwards: 70
  Expires: 7200
  Content-Length: 0
```

The registration expires after two hours. The registrar responds with a 200 OK:

F2 200 OK Registrar -> Bob

```
  SIP/2.0 200 OK
  Via: SIP/2.0/UDP 192.0.2.4:5060;branch=z9hG4bKnashds7
  To: Bob <sip:bob@biloxi.com>
  From: Bob <sip:bob@biloxi.com>;tag=456248
  Call-ID: 843817637684230@998sdasdh09
  CSeq: 1826 REGISTER
  Contact: <sip:bob@192.0.2.4>
  Expires: 7200
  Content-Length: 0
```

26.2 Session Setup

This example contains the full details of the example session setup in Section 4. The message flow is shown in Figure 1.

```
F1 INVITE Alice -> atlanta.com proxy

  INVITE sip:bob@biloxi.com SIP/2.0
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Contact: <sip:alice@pc33.atlanta.com>
  Max-Forwards: 70
  Content-Type: application/sdp
  Content-Length: 142

  (Alice's SDP not shown)
```

```
F2 100 Trying atlanta.com proxy -> Alice

  SIP/2.0 100 Trying
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Content-Length: 0
```

```
F3 INVITE atlanta.com proxy -> biloxi.com proxy

  INVITE sip:bob@biloxi.com SIP/2.0
  Via: SIP/2.0/UDP bigbox3.site3.atlanta.com;branch=z9hG4bK77ef4c2312983.1
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Contact: <sip:alice@pc33.atlanta.com>
  Max-Forwards: 69
  Content-Type: application/sdp
```

```
  Content-Length: 142

  (Alice’s SDP not shown)
```

F4 100 Trying biloxi.com proxy -> atlanta.com proxy

```
  SIP/2.0 100 Trying
  Via: SIP/2.0/UDP bigbox3.site3.atlanta.com;branch=z9hG4bK77ef4c2312983.1
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Content-Length: 0
```

F5 INVITE biloxi.com proxy -> Bob

```
  INVITE sip:bob@192.0.2.4 SIP/2.0
  Via: SIP/2.0/UDP server10.biloxi.com;branch=z9hG4bK4b43c2ff8.1
  Via: SIP/2.0/UDP bigbox3.site3.atlanta.com;branch=z9hG4bK77ef4c2312983.1
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Contact: <sip:alice@pc33.atlanta.com>
  Max-Forwards: 68
  Content-Type: application/sdp
  Content-Length: 142

  (Alice’s SDP not shown)
```

F6 180 Ringing Bob -> biloxi.com proxy

```
  SIP/2.0 180 Ringing
  Via: SIP/2.0/UDP server10.biloxi.com;branch=z9hG4bK4b43c2ff8.1
  Via: SIP/2.0/UDP bigbox3.site3.atlanta.com;branch=z9hG4bK77ef4c2312983.1
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
```

```
  Content-Length: 0
```

F7 180 Ringing biloxi.com proxy -> atlanta.com proxy

```
  SIP/2.0 180 Ringing
  Via: SIP/2.0/UDP bigbox3.site3.atlanta.com;branch=z9hG4bK77ef4c2312983.1
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Content-Length: 0
```

F8 180 Ringing atlanta.com proxy -> Alice

```
  SIP/2.0 180 Ringing
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Content-Length: 0
```

F9 200 OK Bob -> biloxi.com proxy

```
  SIP/2.0 200 OK
  Via: SIP/2.0/UDP server10.biloxi.com;branch=z9hG4bK4b43c2ff8.1
  Via: SIP/2.0/UDP bigbox3.site3.atlanta.com;branch=z9hG4bK77ef4c2312983.1
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Contact: <sip:bob@192.0.2.4>
  Content-Type: application/sdp
  Content-Length: 131

  (Bob’s SDP not shown)
```

F10 200 OK biloxi.com proxy -> atlanta.com proxy

```
  SIP/2.0 200 OK
  Via: SIP/2.0/UDP bigbox3.site3.atlanta.com;branch=z9hG4bK77ef4c2312983.1
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Contact: <sip:bob@192.0.2.4>
  Content-Type: application/sdp
  Content-Length: 131

  (Bob's SDP not shown)
```

```
F11 200 OK atlanta.com proxy -> Alice

  SIP/2.0 200 OK
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds8
  To: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 INVITE
  Contact: <sip:bob@192.0.2.4>
  Content-Type: application/sdp
  Content-Length: 131

  (Bob's SDP not shown)
```

```
F12 ACK Alice -> Bob

  ACK sip:bob@192.0.2.4 SIP/2.0
  Via: SIP/2.0/UDP pc33.atlanta.com;branch=z9hG4bKnashds9
  To: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  From: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 314159 ACK
  Max-Forwards: 70
  Content-Length: 0
```

The media session between Alice and Bob is now established.

Bob hangs up first. Note that Bob's SIP phone maintains its own CSeq numbering space, which, in this example, begins with 231. Since Bob is making the request, the To and From URIs and tags have been swapped.

```
F13 BYE Bob -> Alice

  BYE sip:alice@pc33.atlanta.com SIP/2.0
  Via: SIP/2.0/UDP 192.0.2.4;branch=z9hG4bKnashds10
  From: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  To: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 231 BYE
  Max-Forwards: 70
  Content-Length: 0
```

```
F14 200 OK Alice -> Bob

  SIP/2.0 200 OK
  Via: SIP/2.0/UDP 192.0.2.4;branch=z9hG4bKnashds10
  From: Bob <sip:bob@biloxi.com>;tag=a6c85cf
  To: Alice <sip:alice@atlanta.com>;tag=1928301774
  Call-ID: a84b4c76e66710
  CSeq: 231 BYE
  Content-Length: 0
```

The SIP Call Flows document [30] contains further examples of SIP messages.

27 Augmented BNF for the SIP Protocol

All of the mechanisms specified in this document are described in both prose and an augmented Backus-Naur Form (BNF) defined in RFC 2234 [28]. Section 6.1 of RFC 2234 defines a set of core rules which are used by this specification, and not repeated here. Implementors need to be familiar with the notation and content of RFC 2234 in order to understand this specification. Certain basic rules are in uppercase, such as SP, LWS, HTAB, CRLF, DIGIT, ALPHA, etc. Angle brackets are used within definitions to clarify the use of rule names.

27.1 Basic Rules

The following rules are used throughout this specification to describe basic parsing constructs. The US-ASCII coded character set is defined by ANSI X3.4-1986.

```
alphanum  =  ALPHA / DIGIT
```

Several rules are incorporated from RFC 2396 [13] but are updated to make them compliant with RFC 2234 [28]. These include:

```
reserved     =  ";" / "/" / "?" / ":" / "@" / "&" / "=" / "+"
                / "$" / ","
unreserved   =  alphanum / mark
mark         =  "-" / "_" / "." / "!" / "~" / "*" / "'"
                / "(" / ")"
escaped      =  "%" HEXDIG HEXDIG
```

SIP header field values can be folded onto multiple lines if the continuation line begins with a space or horizontal tab. All linear white space, including folding, has the same semantics as SP. A recipient MAY replace any linear white space with a single SP before interpreting the field value or forwarding the message downstream. This is intended to behave exactly as HTTP 1.1 as described in RFC 2616 [15]. The SWS construct is used when linear white space is optional, generally between tokens and separators.

```
LWS  =  [*WSP CRLF] 1*WSP ; linear whitespace
SWS  =  [LWS] ; sep whitespace
```

To separate the header name from the rest of value, a colon is used, which, by the above rule, allows whitespace before, but no line break, and whitespace after, including a linebreak. The HCOLON defines this construct.

```
HCOLON  =  *( SP / HTAB ) ":" SWS
```

The TEXT-UTF8 rule is only used for descriptive field contents and values that are not intended to be interpreted by the message parser. Words of *TEXT-UTF8 contain characters from the UTF-8 character set (RFC 2279 [25]). The TEXT-UTF8-TRIM rule is used for descriptive field contents that are *not* quoted strings, where leading and trailing LWS is not meaningful. In this regard, SIP differs from HTTP, which uses the ISO 8859-1 character set.

```
TEXT-UTF8       =  *(TEXT-UTF8char / LWS)
TEXT-UTF8-TRIM  =  *TEXT-UTF8char *(*LWS TEXT-UTF8char)
TEXT-UTF8char   =  %x21-7E / UTF8-NONASCII
UTF8-NONASCII   =  %xC0-DF 1UTF8-CONT
                /  %xE0-EF 2UTF8-CONT
                /  %xF0-F7 3UTF8-CONT
                /  %xF8-Fb 4UTF8-CONT
                /  %xFC-FD 5UTF8-CONT
UTF8-CONT       =  %x80-BF
```

A CRLF is allowed in the definition of TEXT-UTF8 only as part of a header field continuation. It is expected that the folding LWS will be replaced with a single SP before interpretation of the TEXT-UTF8 value.

Hexadecimal numeric characters are used in several protocol elements. Some elements (authentication) force hex alphas to be lower case.

```
LHEX  =  DIGIT / %x61-66 ;lowercase a-f
```

Many SIP header field values consist of words separated by LWS or special characters. Unless otherwise stated, tokens are case-insensitive. These special characters MUST be in a quoted string to be used within a parameter value. The word construct is used in Call-ID to allow most separators to be used.

```
token       =  1*(alphanum / ”-” / ”.” / ”!” / ”%” / ”*”
                  / ”_” / ”+” / ”‘” / ”’” / ”˜” )
separators  =  ”(” / ”)” / ”<” / ”>” / ”@” /
               ”,” / ”;” / ”:” / ”\” / <”> /
               ”/” / ”[” / ”]” / ”?” / ”=” /
               ”{” / ”}” / SP / HTAB
word        =  1*(alphanum / ”-” / ”.” / ”!” / ”%” / ”*”
               / ”_” / ”+” / ”‘” / ”’” / ”˜”
               ”(” / ”)” / ”<” / ”>”
               ”:” / ”\” / <”> /
               ”/” / ”[” / ”]” / ”?” /
               ”{” / ”}” )
```

When tokens are used or separators are used between elements, whitespace is often allowed before or after these characters:

```
MINUS     =  SWS ”-” SWS ; minus
DOT       =  SWS ”.” SWS ; period
PERCENT   =  SWS ”%” SWS ; percent
BANG      =  SWS ”!” SWS ; exclamation
PLUS      =  SWS ”+” SWS ; plus
STAR      =  SWS ”*” SWS ; asterisk
SLASH     =  SWS ”/” SWS ; slash
TILDE     =  SWS ”˜” SWS ; tilde
EQUAL     =  SWS ”=” SWS ; equal
LPAREN    =  SWS ”(” SWS ; left parenthesis
RPAREN    =  SWS ”)” SWS ; right parenthesis
LANGLE    =  SWS ”<” SWS ; left angle bracket
RAQUOT    =  ”>” SWS ; right angle quote
LAQUOT    =  SWS ”<”; left angle quote
RANGLE    =  SWS ”>” SWS ; right angle bracket
BAR       =  SWS ”|” SWS ; vertical bar
ATSIGN    =  SWS ”@” SWS ; atsign
COMMA     =  SWS ”,” SWS ; comma
SEMI      =  SWS ”;” SWS ; semicolon
COLON     =  SWS ”:” SWS ; colon
DQUOT     =  SWS <”> SWS ; double quotation mark
LDQUOT    =  SWS <”>; open double quotation mark
RDQUOT    =  <”> SWS ; close double quotation mark
LBRACK    =  SWS ”{” SWS ; left square bracket
RBRACK    =  SWS ”}” SWS ; right square bracket
```

Comments can be included in some SIP header fields by surrounding the comment text with parentheses. Comments are only allowed in fields containing “comment” as part of their field value definition. In all other fields, parentheses are considered part of the field value.

```
comment   =  LPAREN *(ctext / quoted-pair / comment) RPAREN
ctext     =  %x21-27 / %x2A-5B / %x5D-7E / UTF8-NONASCII
             / LWS
```

ctext includes all chars except left and right parens and backslash. A string of text is parsed as a single word if it is quoted using double-quote marks. In quoted strings, quotation marks (”) and backslashes (\) need to be escaped.

```
quoted-string  =  ( SWS <”> *(qdtext / quoted-pair ) <”> )
qdtext         =  LWS / %x21 / %x23-5B / %x5D-7E
                  / UTF8-NONASCII
```

The backslash character (”\”) MAY be used as a single-character quoting mechanism only within quoted-string and comment constructs. Unlike HTTP/1.1, the characters CR and LF cannot be escaped by this mechanism to avoid conflict with line folding and header separation.

```
quoted-pair  =  ”\” (%x00-09 / %x0A / %x0C
                / %x0E-7F)

SIP-URI           =  ”sip:” [ userinfo ”@” ] hostport
                     url-parameters [ headers ]
userinfo          =  [ user / telephone-subscriber [ ”:” password ]]
user              =  *( unreserved / escaped / user-unreserved )
user-unreserved   =  ”&” / ”=” / ”+” / ”$” / ”,” / ”;” / ”?” / ”/”
password          =  *( unreserved / escaped /
                     ”&” / ”=” / ”+” / ”$” / ”,” )
hostport          =  host [ ”:” port ]
host              =  hostname / IPv4address / IPv6reference
hostname          =  *( domainlabel ”.” ) toplabel [ ”.” ]
domainlabel       =  alphanum
                     / alphanum *( alphanum / ”-” ) alphanum
toplabel          =  ALPHA / ALPHA *( alphanum / ”-” ) alphanum

IPv4address    =  1*3DIGIT ”.” 1*3DIGIT ”.” 1*3DIGIT ”.” 1*3DIGIT
IPv6reference  =  ”[” IPv6address ”]”
IPv6address    =  hexpart [ ”:” IPv4address ]
hexpart        =  hexseq / hexseq ”::” [ hexseq ] / ”::” [ hexseq ]
hexseq         =  hex4 *( ”:” hex4)
hex4           =  1*4HEXDIG
port           =  1*DIGIT
```

The BNF for telephone-subscriber can be found in RFC 2806 [19]. Note, however, that any characters allowed there which are not allowed in the user part of the SIP URI MUST be escaped.

```
     url-parameters     =  *( ”;” url-parameter)
     url-parameter      =  transport-param / user-param / method-param
                           / ttl-param / maddr-param / lr-param / other-param
     transport-param    =  ”transport=”
                           ( ”udp” / ”tcp” / ”sctp” / ”tls”
                           / other-transport)
     other-transport    =  token
     user-param         =  ”user=” ( ”phone” / ”ip” / other-user)
     other-user         =  token
     method-param       =  ”method=” Method
     ttl-param          =  ”ttl=” ttl
     maddr-param        =  ”maddr=” host
     lr-param           =  ”lr”
     other-param        =  pname [ ”=” pvalue ]
     pname              =  1*paramchar
     pvalue             =  1*paramchar
     paramchar          =  param-unreserved / unreserved / escaped
5981 param-unreserved   =  ”[” / ”]” / ”/” / ”:” / ”&” / ”+” / ”$”

     headers          =  ”?” header *( ”&” header )
     header           =  hname ”=” hvalue
     hname            =  1*( hnv-unreserved / unreserved / escaped )
     hvalue           =  *( hnv-unreserved / unreserved / escaped )
5982 hnv-unreserved   =  ”[” / ”]” / ”/” / ”?” / ”:” / ”+” / ”$”
```

```
     SIP-message     =  Request / Response
     Request         =  Request-Line
                        *( message-header )
                        CRLF
                        [ message-body ]
     Request-Line    =  Method SP Request-URI SP SIP-Version CRLF
     Request-URI     =  SIP-URI / absoluteURI
     absoluteURI     =  scheme ”:” ( hier-part / opaque-part )
     hier-part       =  ( net-path / abs-path ) [ ”?” query ]
     net-path        =  ”//” authority [ abs-path ]
     abs-path        =  ”/” path-segments
     opaque-part     =  uric-no-slash *uric
     uric            =  reserved / unreserved / escaped
     uric-no-slash   =  unreserved / escaped / ”;” / ”?” / ”:” / ”@”
                        / ”&” / ”=” / ”+” / ”$” / ”,”
     path-segments   =  segment *( ”/” segment )
     segment         =  *pchar *( ”;” param )
     param           =  *pchar
     pchar           =  unreserved / escaped /
                        ”:” / ”@” / ”&” / ”=” / ”+” / ”$” / ”,”
     scheme          =  ALPHA *( ALPHA / DIGIT / ”+” / ”-” / ”.” )
     authority       =  srvr / reg-name
     srvr            =  [ [ userinfo ”@” ] hostport ]
     reg-name        =  1*( unreserved / escaped / ”$” / ”,”
                        / ”;” / ”:” / ”@” / ”&” / ”=” / ”+” )
     query           =  *uric
5983 SIP-Version     =  ”SIP/2.0”
```

```
message-header  =  (Accept
                /  Accept-Encoding
                /  Accept-Language
                /  Alert-Info
                /  Allow
                /  Authentication-Info
                /  Authorization
                /  Call-ID
                /  Call-Info
                /  Contact
                /  Content-Disposition
                /  Content-Encoding
                /  Content-Language
                /  Content-Length
                /  Content-Type
                /  CSeq
                /  Date
                /  Error-Info
                /  Expires
                /  From
                /  In-Reply-To
                /  Max-Forwards
                /  MIME-Version
                /  Min-Expires
                /  Organization
                /  Priority
                /  Proxy-Authenticate
                /  Proxy-Authorization
                /  Proxy-Require
                /  RAck
                /  Record-Route
                /  Reply-To
                /  Require
                /  Retry-After
                /  Route
                /  RSeq
                /  Server
                /  Subject
                /  Supported
                /  Timestamp
                /  To
                /  Unsupported
                /  User-Agent
                /  Via
                /  Warning
                /  WWW-Authenticate
                /  extension-header) CRLF
```

```
INVITEm          =  %x49.4E.56.49.54.45 ; INVITE in caps
ACKm             =  %x41.43.4B ; ACK in caps
OPTIONSm         =  %x4F.50.54.49.4F.4E.53 ; OPTIONS in caps
BYEm             =  %x42.59.45 ; BYE in caps
CANCELm          =  %x43.41.4E.43.45.4C ; CANCEL in caps
REGISTERm        =  %x52.45.47.49.53.54.45.52 ; REGISTER in caps
PRACKm           =  %x50.52.41.43.4B ; PRACK in caps
Method           =  INVITEm / ACKm / OPTIONSm / BYEm
                    / CANCELm / REGISTERm / PRACKm
                    / extension-method
extension-method =  token
Response         =  Status-Line
                    *( message-header )
                    CRLF
5985                [ message-body ]
```

```
Status-Line     =  SIP-Version SP Status-Code SP Reason-Phrase CRLF
Status-Code     =  Informational
                /  Redirection
                /  Success
                /  Client-Error
                /  Server-Error
                /  Global-Failure
                /  extension-code
extension-code  =  3DIGIT
Reason-Phrase   =  *(reserved / unreserved / escaped
5986               / UTF8-NONASCII / UTF8-CONT / SP / HTAB)
```

```
Informational  =  ”100”  ; Trying
               /  ”180”  ; Ringing
               /  ”181”  ; Call Is Being Forwarded
               /  ”182”  ; Queued
5987           /  ”183”  ; Session Progress
```

```
5988 Success  =  ”200”  ; OK
```

```
Redirection  =  ”300”  ; Multiple Choices
             /  ”301”  ; Moved Permanently
             /  ”302”  ; Moved Temporarily
             /  ”305”  ; Use Proxy
5989         /  ”380”  ; Alternative Service
```

```
     Client-Error  =  ”400”  ; Bad Request
                   /  ”401”  ; Unauthorized
                   /  ”402”  ; Payment Required
                   /  ”403”  ; Forbidden
                   /  ”404”  ; Not Found
                   /  ”405”  ; Method Not Allowed
                   /  ”406”  ; Not Acceptable
                   /  ”407”  ; Proxy Authentication Required
                   /  ”408”  ; Request Timeout
                   /  ”409”  ; Conflict
                   /  ”410”  ; Gone
                   /  ”413”  ; Request Entity Too Large
                   /  ”414”  ; Request-URI Too Large
                   /  ”415”  ; Unsupported Media Type
                   /  ”416”  ; Unsupported URI Scheme
                   /  ”420”  ; Bad Extension
                   /  ”423”  ; Registration Too Brief
                   /  ”480”  ; Temporarily not available
                   /  ”481”  ; Call Leg/Transaction Does Not Exist
                   /  ”482”  ; Loop Detected
                   /  ”483”  ; Too Many Hops
                   /  ”484”  ; Address Incomplete
                   /  ”485”  ; Ambiguous
                   /  ”486”  ; Busy Here
                   /  ”487”  ; Request Terminated
                   /  ”488”  ; Not Acceptable Here
                   /  ”491”  ; Request Pending
5990               /  ”493”  ; Undecipherable

     Server-Error  =  ”500”  ; Internal Server Error
                   /  ”501”  ; Not Implemented
                   /  ”502”  ; Bad Gateway
                   /  ”503”  ; Service Unavailable
                   /  ”504”  ; Server Time-out
5991               /  ”505”  ; SIP Version not supported

     Global-Failure  =  ”600”  ; Busy Everywhere
                     /  ”603”  ; Decline
                     /  ”604”  ; Does not exist anywhere
5992                 /  ”606”  ; Not Acceptable
```

```
Accept            =  ”Accept” HCOLON
                     ( accept-range *(COMMA accept-range) )
accept-range      =  media-range [ accept-params ]
media-range       =  ( ”*/*”
                     / ( m-type SWS ”/” ”*” SWS )
                     / ( m-type SLASH m-subtype )
                     ) *( SEMI m-parameter )
accept-params     =  SEMI ”q” EQUAL qvalue *( accept-extension )
accept-extension  =  SEMI ae-name [ EQUAL ae-value ]
ae-name           =  token
5993 ae-value     =  token / quoted-string

Accept-Encoding   =  ”Accept-Encoding” HCOLON
                     ( encoding *(COMMA encoding) )
encoding          =  codings [ SEMI ”q” EQUAL qvalue ]
codings           =  content-coding / ”*”
content-coding    =  token
qvalue            =  ( ”0” [ ”.” 0*3DIGIT ] )
5994                 / ( ”1” [ ”.” 0*3(”0”) ] )

Accept-Language   =  ”Accept-Language” HCOLON
                     ( language *(COMMA language) )
language          =  language-range [ SEMI ”q” EQUAL qvalue ]
5995 language-range  =  ( ( 1*8ALPHA *( ”-” 1*8ALPHA ) ) / ”*” )

Alert-Info      =  ”Alert-Info” HCOLON alert-param *(COMMA alert-param)
alert-param     =  LAQUOT URI RAQUOT *( SEMI generic-param )
generic-param   =  token [ EQUAL gen-value ]
5996 gen-value  =  token / host / quoted-string

5997 Allow  =  ”Allow” HCOLON Method *(COMMA Method)
```

```
Authorization      =  "Authorization" HCOLON credentials
credentials        =  ("Digest" LWS digest-response)
                      / other-response
digest-response    =  dig-resp *(COMMA dig-resp)
dig-resp           =  username / realm / nonce / digest-uri
                      / dresponse / [ algorithm ] / [cnonce]
                      / [opaque] / [message-qop]
                      / [nonce-count] / [auth-param]
username           =  "username" EQUAL username-value
username-value     =  quoted-string
digest-uri         =  "uri" EQUAL digest-uri-value
digest-uri-value   =  rquest-uri ; Equal to request-uri as specified by HTTP/1.1
message-qop        =  "qop" EQUAL qop-value
cnonce             =  "cnonce" EQUAL cnonce-value
cnonce-value       =  nonce-value
nonce-count        =  "nc" EQUAL nc-value
nc-value           =  8LHEX
dresponse          =  "response" EQUAL request-digest
request-digest     =  LDQUOT 32LHEX RDQUOT
auth-param         =  auth-param-name EQUAL
                      ( token / quoted-string )
auth-param-name    =  token
other-response     =  auth-scheme LWS auth-param
                      *(COMMA auth-param)
5998 auth-scheme   =  token
```

```
Authentication-Info  =  "Authentication-Info" HCOLON ainfo
                        *(COMMA ainfo)
ainfo                =  [nextnonce] / [ message-qop ]
                        / [ response-auth ] / [ cnonce ]
                        / [nonce-count]
nextnonce               "nextnonce" EQUAL nonce-value
response-auth        =  "rspauth" EQUAL response-digest
5999 response-digest =  LDQUOT *LHEX RDQUOT
```

```
Call-ID      =  ( "Call-ID" / "i" ) HCOLON callid
6000 callid  =  word [ "@" word ]
```

```
Call-Info    =  "Call-Info" HCOLON info *(COMMA info)
info         =  LAQUOT URI RAQUOT *( SEMI info-param)
info-param   =  ( "purpose" EQUAL ( "icon" / "info"
6001            / "card" / token ) ) / generic-param
```

```
     Contact             =  (”Contact” / ”m” ) HCOLON
                            STAR / (contact-param *(COMMA contact-param))
     contact-param       =  (name-addr / addr-spec) *(SEMI contact-params)
     name-addr           =  [ display-name ] LAQUOT addr-spec RAQUOT
     addr-spec           =  SIP-URI / URI
6002 display-name        =  *(token LWS)/ quoted-string

     contact-params      =  c-p-q / c-p-expires
                            / contact-extension
     c-p-q               =  ”q” EQUAL qvalue
     c-p-expires         =  ”expires” EQUAL delta-seconds
     contact-extension   =  generic-param
6003 delta-seconds       =  1*DIGIT

     Content-Disposition  =  ”Content-Disposition” HCOLON
                             disp-type *( SEMI disp-param )
     disp-type            =  ”render” / ”session” / ”icon” / ”alert”
                             / disp-extension-token
     disp-param           =  handling-param / generic-param
     handling-param       =  ”handling” EQUAL
                             ( ”optional” / ”required”
                             / other-handling )
     other-handling       =  token
6004 disp-extension-token =  token

     Content-Encoding  =  ( ”Content-Encoding” / ”e” ) HCOLON
6005                      content-coding *(COMMA content-coding)

     Content-Language  =  ”Content-Language” HCOLON
                          language-tag *(COMMA language-tag)
     language-tag      =  primary-tag *( ”-” subtag )
     primary-tag       =  1*8ALPHA
6006 subtag            =  1*8ALPHA

6007 Content-Length  =  ( ”Content-Length” / ”l” ) HCOLON 1*DIGIT
```

```
Content-Type      =  ( ”Content-Type” / ”c” ) HCOLON media-type
media-type        =  m-type SLASH m-subtype *(SEMI m-parameter)
m-type            =  discrete-type / composite-type
discrete-type     =  ”text” / ”image” / ”audio” / ”video”
                     / ”application” / extension-token
composite-type       ”message” / ”multipart” / extension-token
extension-token   =  ietf-token / x-token
ietf-token        =  token
x-token           =  ”x-” token
m-subtype         =  extension-token / iana-token
iana-token        =  token
m-parameter       =  m-attribute EQUAL m-value
m-attribute       =  token
6008 m-value      =  token / quoted-string

6009 CSeq  =  ”CSeq” HCOLON 1*DIGIT LWS Method

Date          =  ”Date” HCOLON SIP-date
SIP-date      =  rfc1123-date
rfc1123-date  =  wkday ”,” date1 SP time SP ”GMT”
date1         =  2DIGIT SP month SP 4DIGIT
                 ; day month year (e.g., 02 Jun 1982)
time          =  2DIGIT ”:” 2DIGIT ”:” 2DIGIT
                 ; 00:00:00 - 23:59:59
wkday         =  ”Mon” / ”Tue” / ”Wed”
                 / ”Thu” / ”Fri” / ”Sat” / ”Sun”
month         =  ”Jan” / ”Feb” / ”Mar” / ”Apr”
                 / ”May” / ”Jun” / ”Jul” / ”Aug”
6010             / ”Sep” / ”Oct” / ”Nov” / ”Dec”

Error-Info  =  ”Error-Info” HCOLON error-uri *(COMMA error-uri)
6011 error-uri   =  LAQUOT URI RAQUOT *( SEMI generic-param )

Expires     =  ”Expires” HCOLON delta-seconds
From        =  ( ”From” / ”f” ) HCOLON from-spec
from-spec   =  ( name-addr / addr-spec )
               *( SEMI from-param )
from-param  =  tag-param / generic-param
6012 tag-param   =  ”tag” EQUAL token

6013 In-Reply-To  =  ”In-Reply-To” HCOLON callid *(COMMA callid)

6014 Max-Forwards  =  ”Max-Forwards” HCOLON 1*DIGIT

6015 MIME-Version  =  ”MIME-Version” HCOLON 1*DIGIT ”.” 1*DIGIT
```

```
6016 Min-Expires  =  "Min-Expires" HCOLON delta-seconds

6017 Organization  =  "Organization" HCOLON TEXT-UTF8-TRIM

Priority        =  "Priority" HCOLON priority-value
priority-value  =  "emergency" / "urgent" / "normal"
                   / "non-urgent" / other-priority
6018 other-priority  =  token

Proxy-Authenticate  =  "Proxy-Authenticate" HCOLON challenge
challenge           =  ("Digest" LWS digest-cln *(COMMA digest-cln))
                       / other-challenge
other-challenge     =  auth-scheme LWS auth-param
                       *(COMMA auth-param)
digest-cln          =  realm / [ domain ] / nonce
                       / [ opaque ] / [ stale ] / [ algorithm ]
                       / [ qop-options ] / [auth-param]
realm               =  "realm" EQUAL realm-value
realm-value         =  quoted-string
domain              =  "domain" EQUAL LDQUOT URI
                       *( 1*SP URI ) RDQUOT
URI                 =  absoluteURI / abs-path
nonce               =  "nonce" EQUAL nonce-value
nonce-value         =  quoted-string
opaque              =  "opaque" EQUAL quoted-string
stale               =  "stale" EQUAL ( "true" / "false" )
algorithm           =  "algorithm" EQUAL ( "MD5" / "MD5-sess"
                       / token )
qop-options         =  "qop" EQUAL LDQUOT qop-value
                       *("," qop-value) RDQUOT
6019 qop-value           =  "auth" / "auth-int" / token

6020 Proxy-Authorization  =  "Proxy-Authorization" HCOLON credentials

Proxy-Require  =  "Proxy-Require" HCOLON option-tag
                  *(COMMA option-tag)
6021 option-tag     =  token

RAck          =  "RAck" HCOLON response-num LWS CSeq-num LWS Method
response-num  =  1*DIGIT
6022 CSeq-num      =  1*DIGIT

Record-Route  =  "Record-Route" HCOLON rec-route *(COMMA rec-route)
rec-route     =  name-addr *( SEMI rr-param )
6023 rr-param      =  generic-param
```

```
     Reply-To       =  "Reply-To" HCOLON rplyto-spec
     rplyto-spec    =  ( name-addr / addr-spec )
                       *( SEMI rplyto-param )
     rplyto-param   =  generic-param
6024 Require        =  "Require" HCOLON option-tag *(COMMA option-tag)

     Retry-After    =  "Retry-After" HCOLON delta-seconds
                       [ comment ] *( SEMI retry-param )
     retry-param    =  ("duration" EQUAL delta-seconds)
6025                   / generic-param

     Route          =  "Route" HCOLON route-param *(COMMA route-param)
6026 route-param    =  name-addr *( SEMI rr-param )

6027 RSeq  =  "RSeq" HCOLON response-num

     Server           =  "Server" HCOLON 1*( product / comment )
     product          =  token [SLASH product-version]
6028 product-version  =  token

6029 Subject  =  ( "Subject" / "s" ) HCOLON TEXT-UTF8-TRIM

     Supported  =  ( "Supported" / "k" ) HCOLON
6030               option-tag *(COMMA option-tag)

     Timestamp  =  "Timestamp" HCOLON 1*(DIGIT)
                   [ "." *(DIGIT) ] [ delay ]
6031 delay      =  *(DIGIT) [ "." *(DIGIT) ]

     To        =  ( "To" / "t" ) HCOLON ( name-addr
                  / addr-spec ) *( SEMI to-param )
6032 to-param  =  tag-param / generic-param

6033 Unsupported  =  "Unsupported" HCOLON option-tag *(COMMA option-tag)

6034 User-Agent  =  "User-Agent" HCOLON 1*( product / comment )
```

```
Via               =  ( "Via" / "v" ) HCOLON via-parm *(COMMA via-parm)
via-parm          =  sent-protocol LWS sent-by *( SEMI via-params )
via-params        =  via-ttl / via-maddr
                     / via-received / via-branch
                     / via-extension
via-ttl           =  "ttl" EQUAL ttl
via-maddr         =  "maddr" EQUAL host
via-received      =  "received" EQUAL (IPv4address / IPv6address)
via-branch        =  "branch" EQUAL token
via-extension     =  generic-param
sent-protocol     =  protocol-name SLASH protocol-version
                     SLASH transport
protocol-name     =  "SIP" / token
protocol-version  =  token
transport         =  "UDP" / "TCP" / "TLS" / "SCTP"
                     / other-transport
sent-by           =  host [ COLON port ]
6035 ttl          =  1*3DIGIT ; 0 to 255
```

```
Warning        =  "Warning" HCOLON warning-value *(COMMA warning-value)
warning-value  =  warn-code SP warn-agent SP warn-text
warn-code      =  3DIGIT
warn-agent     =  hostport / pseudonym
                  ; the name or pseudonym of the server adding
                  ; the Warning header, for use in debugging
warn-text      =  quoted-string
6036 pseudonym =  token
```

```
6037 WWW-Authenticate  =  "WWW-Authenticate" HCOLON challenge
```

```
extension-header  =  header-name HCOLON header-value
header-name       =  token
6038 header-value  =  *(TEXT-UTF8CHAR / UTF8-CONT / LWS)
```

```
6039 message-body  =  *OCTET
```

6040 28 IANA Considerations

6041 All new or experimental method names, header field names, and status codes used in SIP applications
6042 SHOULD be registered with IANA in order to prevent potential naming conflicts. It is RECOMMENDED that
6043 new "option- tag"s and "warn-code"s also be registered. Before IANA registration, new protcol elements
6044 SHOULD be described in an Internet-Draft or, preferably, an RFC.

6045 For Internet-Drafts, IANA is requested to make the draft available as part of the registration database.

6046 By the time an RFC is published, colliding names may have already been implemented.

When a registration for either a new header field, new method, or new status code is created based on an Internet-Draft, and that Internet-Draft becomes an RFC, the person that performed the registration MUST notify IANA to change the registration to point to the RFC instead of the Internet-Draft.

Registrations should be sent to `iana@iana.org`.

28.1 Option Tags

Option tags are used in header fields such as Require, Supported, Proxy-Require, and Unsupported in support of SIP compatibility mechanisms for extensions (Section 23.2). The option tag itself is a string that is associated with a particular SIP option (that is, an extension). It identifies the option to SIP endpoints.

When registering a new SIP option with IANA, the following information MUST be provided:

- Name and description of option. The name MAY be of any length, but SHOULD be no more than twenty characters long. The name MUST consist of alphanum (Section 27) characters only.
- A listing of any new SIP header fields, header parameter fields, or parameter values defined by this option. A SIP option MUST NOT redefine header fields or parameters defined in either RFC 2543, any standards-track extensions to RFC 2543, or other extensions registered through IANA.
- Indication of who has change control over the option (for example, IETF, ISO, ITU-T, other international standardization bodies, a consortium, or a particular company or group of companies).
- A reference to a further description if available, for example (in order of preference) an RFC, a published paper, a patent filing, a technical report, documented source code, or a computer manual.
- Contact information (postal and email address).

This procedure has been borrowed from RTSP [35] and the RTP AVP [33].

28.1.1 Registration of 100rel

This specification registers a single option tag, “100rel”. The required information is:

Name: “100rel”

Description: This option tag is for reliability of provisional responses. When present in a Supported header, it indicates that the UA can send or receive reliable provisional responses. When present in a Require header in a request, it indicates that the UAS MUST send all provisional responses reliably. When present in a Require header in a reliable provisional response, it indicates that the response is to be sent reliably.

New Headers: The RSeq and RAck header fieds are defined by this optio.

Change Control: IETF.

Reference: RFCXXXX [Note to IANA: Fill in with the RFC number of this specification.

Contact Information: Jonathan Rosenberg, jdrosen@jdrosen.net. 72 Eagle Rock Avenue, First Floor, East Hanover, NJ, 07936, USA.

28.2 Warn-Codes

Warning codes provide information supplemental to the status code in SIP response messages when the failure of the transaction results from a Session Description Protocol (SDP, [11]). New "warn-code" values can be registered with IANA as they arise.

The "warn-code" consists of three digits. A first digit of "3" indicates warnings specific to SIP.

Warnings 300 through 329 are reserved for indicating problems with keywords in the session description, 330 through 339 are warnings related to basic network services requested in the session description, 370 through 379 are warnings related to quantitative QoS parameters requested in the session description, and 390 through 399 are miscellaneous warnings that do not fall into one of the above categories.

1xx and 2xx have been taken by HTTP/1.1.

28.3 Header Field Names

Header field names do not require working group or working group chair review prior to IANA registration, but SHOULD be documented in an RFC or Internet-Draft before IANA is consulted.

The following information needs to be provided to IANA in order to register a new header field name:

- The name and email address of the individual performing the registration;
- the name of the header field being registered;
- a compact form version for that header field, if one is defined;
- the name of the draft or RFC where the header field is defined;
- a copy of the draft or RFC where the header field is defined.

Header fields SHOULD NOT use the X- prefix notation and MUST NOT duplicate the names of header fields used by SMTP or HTTP unless the syntax is a compatible superset and the semantics are similar. Some common and widely used header fields MAY be assigned one-letter compact forms (Section 7.3.3). Compact forms can only be assigned after SIP working group review. In the absence of this working group, a designated expert reviews the request.

28.4 Method and Response Codes

Because the status code space is limited, they do require working group or working group chair review, and MUST be documented in an RFC or Internet draft. The same procedures apply to new method names.

The following information needs to be provided to IANA in order to register a new response code or method:

- The name and email address of the individual performing the registration;
- the number of the response code or name of the method being registered;
- the default reason phrase for that status code, if applicable;
- the name of the draft or RFC where the method or status code is defined;
- a copy of the draft or RFC where the method or status code is defined.

29 Changes From RFC 2543

This RFC revises RFC 2543. It is mostly backwards compatible with RFC 2543. The changes described here fix many errors discovered in RFC 2543 and provide information on scenarios not detailed in RFC 2543. The protocol has been presented in a more cleanly layered model here.

We break the differences into functional behavior that is a substantial change from RFC 2543, which has impact on interoperability or correct operation in some cases, and functional behavior that is different from RFC 2543 but not a potential source of interoperability problems. There have been countless clarifications as well, which are not documented here.

29.1 Major Functional Changes

- When a UAC wishes to terminate a call before it has been answered, it sends CANCEL. If the original INVITE still returns a 2xx, the UAC then sends BYE. BYE can only be sent on an existing call leg (now called a dialog in this RFC), whereas it could be sent at any time in RFC 2543.
- The SIP BNF was converted to be RFC 2234 compliant.
- SIP URL BNF was made more general, allowing a greater set of characters in the user part. Furthermore, comparison rules were simplified to be primarily case insensitive, and detailed handling of comparison in the presence of parameters was described.
- Removed Via hiding. It had serious trust issues, since it relied on the next hop to perform the obfuscation process. Instead, Via hiding can be done as a local implementation choice in stateful proxies, and thus is no longer documented.
- In RFC 2543, CANCEL and INVITE transactions were intermingled. THey are separated now. When a user sends an INVITE, and then a CANCEL, the INVITE transaction still terminates normally. A UAS needs to respond to the original INVITE request with a 487 response.
- Similarly, CANCEL and BYE transactions were intermingled; RFC 2543 allowed the UAS not to send a response to INVITE when a BYE was received. That is disallowed here. The original INVITE needs to be responded to.
- In RFC 2543, UAs needed to only support UDP. In this RFC, UAs need to support both UDP and TCP.
- In RFC 2543, a forking proxy only passed up one challenge from downstream elements in the event of multiple challenges. In this RFC, proxies are supposed to collect all challenges and place them into the forwarded response.
- In Digest credentials the URI needs to be quoted; this is unclear from RFC 2617 and RFC 2069 which are both inconsistent on it.
- SDP processing has been split off into a separate specification [1], and more fully specified as a formal offer/answer exchange process that is effectively tunnelled through SIP. SDP is allowed in INVITE/200 or 200/ACK for baseline SIP implementations; RFC 2543 alluded to the ability to use it in INVITE, 200 and ACK in a single transaction, but this was not well specified. More complex SDP usages are allowed in extensions.

- Added full support for IPv6 in URIs and in the Via header.
- DNS SRV procedure is now documented in a separate specification [2]. This procedure uses both SRV and NAPTR resource records, and no longer combines data from across SRV records as described in RFC 2543.
- Loop detection has been made optional, supplanted by a mandatory usage of Max-Forwards. The loop detection procedure in RFC 2543 had a serious bug which would report "spirals" as an error condition when it was not. The optional loop detection procedure is more fully and correctly specified here.
- Usage of tags is now mandatory (they were optional in RFC 2543), as they are now the fundamental building blocks of dialog identification.
- Added the Supported header, allowing for clients to indicate what extensions are supported to a server, which can apply those extensions to the response, and indicate their usage with a Require in the response.
- Extension parameters were missing from the BNF for several headers, and they have been added.
- Handling of Route and Record-Route construction was very underspecified in RFC 2543, and also not the right approach. It has been substantially reworked in this specification (and vastly simpler), and this is arguably the largest change. Backwards compatibility is still provided for deployments that do not use "pre-loaded routes", where the initial request has a set of Route headers obtained in some way outside of Record-Route. In those situations, the new mechanism is not interoperable.
- In RFC 2543, lines in a message could be terminated with CR, LF, or CRLF. This specification only allows CRLF.
- Comments (expressed with rounded brackets) have been removed from the grammar of SIP.
- Usage of Route in CANCEL and ACK was not well defined in RFC 2543. It is now well specified; if a request had Route headers, its CANCEL or ACK for a non-2xx response to the request need to carry the same Route headers. ACK for 2xx responses use the Route headers learned from the Record-Route of the 2xx responses.
- RFC 2543 allowed multiple requests in a single UDP packet. This usage has been removed.
- Usage of absolute time in the Expires header and parameter has been removed. It caused interoperability problems in elements that were not time synchronized, a common occurence. Relative times are used instead.
- The branch parameter of the Via header is now mandatory for all elements to use. It now plays the role of a unique transaction identifier. This avoids the complex and bug-laden transaction identification rules from RFC 2543. A magic cookie is used in the Via header to determine if the previous hop has made the parameter globally unique, and comparison falls back to the old rules when it is not present. Thus, interoperability is assured.

- In RFC 2543, closure of a TCP connection was made equivalent to a CANCEL. This was nearly impossible to implement (and wrong) for TCP connections between proxies. This has been eliminated, so that there is no coupling between TCP connection state and SIP processing.
- RFC 2543 was silent on whether a UA could initiate a new transaction to a peer while another was in progress. That is now specified here. It is allowed for non-INVITE requests, disallowed for INVITE.
- PGP was removed. It was not sufficiently specified, and not compatible with the more complete PGP MIME. It was replaced with S/MIME.
- Additional security features were added with TLS, and these are described in a much larger and complete security considerations section.
- In RFC 2543, a proxy was not required to forward provisional responses from 101 to 199 upstream. This was changed to MUST. This is important, since many subsequent features depend on delivery of all provisional responses from 101 to 199.
- Little was said about the 503 response code in RFC 2543. It has since found substantial use in indicating failure or overload conditions in proxies. This requires somewhat special treatment. Specifically, receipt of a 503 should trigger an attempt to contact the next element in the result of a DNS SRV lookup. Also, 503 response is only forwarded upstream by a proxy under certain conditions.
- RFC 2543 defined, but did no sufficiently specify, a mechanism for UA authentication of a server. That has been removed. Instead, the mutual authentication procedures of RFC 2617 are allowed.
- A UA cannot send a BYE for a call until its gotten an ACK for the initital INVITE. This was allowed in RFC 2543 but leads to a potential race condition.
- A UA or proxy cannot send CANCEL for a transaction until it gets a provisional response for the request. This was allowed in RFC 2543 but leads to potential race conditions.
- The action parameter in registrations has been deprecated. It was insufficent for any useful services, and caused conflicts when application processing was applied in proxies.
- RFC 2543 had a number of special cases for multicast. For example, certain responses were supressed, timers were adjusted, and so on. Multicast now plays a more limited role, and the protocol operation is unaffected by usage of multicast as opposed to unicast. The limitations as a result of that are documented.
- Basic authentication has been removed entirely and its usage forbidden.
- Proxies no longer forward a 6xx immediately on receiving it. Instead, they CANCEL pending branches immediately. This avoids a potential race condition that would result in a UAC getting a 6xx followed by a 2xx. In all cases except this race condition, the result will be the same - the 6xx is forwarded upstream.
- Reliability of provisional responses was developed as an extension so SIP, and has been folded into this specification.

- RFC 2543 did not address the problem of request merging. This occurs when a request forks at a proxy, and later rejoins at an element. Handling of merging is done only at a UA, and procedures are defined for rejecting all but the first request.

29.2 Minor Functional Changes

- Added the Alert-Info, Error-Info and Call-Info headers for optional content presentation to users.
- Added the Content-Language, Content-Disposition and MIME-Version headers.
- Added a “glare handling” mechanism to deal with the case where both parties send each other a re-INVITE simultaneously. It uses the new 491 (Request Pending) error code.
- Added the In-Reply-To and Reply-To headers for supporting the return of missed calls or messages at a later time.
- Added TLS and SCTP as valid SIP transports.
- There were a variety of mechanisms described for handling failures at any time during a call; those are now generally unified. BYE is sent to terminate.
- RFC 2543 mandating retransmission of INVITE responses over TCP, but noted it was really only needed for 2xx. That was an artifact of insufficient protocol layering. With a more coherent transaction layer defined here, that is no longer needed. Only the 2xx response to INVITE is transmitted over TCP.
- Formally specified an RTT estimation procedure using Timestamp. Its usage was mentioned in RFC 2543, but no details provided.
- Client and server transaction machines are now driven based on timeouts rather than retransmit counts. This allows the state machines to be properly specified for TCP and UDP.
- The Date header is used in REGISTER responses to provide a simple means for auto-configuration of dates in user agents.
- Allowed a registrar to reject registrations with expirations that are too short in duration. Defined the 423 response code and the Min-Expires for this purpose.

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Brian Rosen provided the compiled BNF.

This work is based, inter alia, on [41, 42].

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32 Normative References

[1] J. Rosenberg and H. Schulzrinne, "An offer/answer model with SDP," Internet Draft, Internet Engineering Task Force, Jan. 2002. Work in progress.

[2] H. Schulzrinne and J. Rosenberg, "SIP: Session initiation protocol – locating SIP servers," Internet Draft, Internet Engineering Task Force, Mar. 2001. Work in progress.

[3] R. Braden, "Requirements for internet hosts - application and support," Request for Comments 1123, Internet Engineering Task Force, Oct. 1989.

[4] T. Berners-Lee, L. Masinter, and M. McCahill, "Uniform resource locators (URL)," Request for Comments 1738, Internet Engineering Task Force, Dec. 1994.

[5] D. Eastlake, S. Crocker, and J. Schiller, "Randomness recommendations for security," Request for Comments 1750, Internet Engineering Task Force, Dec. 1994.

[6] R. Troost and S. Dorner, "Communicating presentation information in internet messages: The content-disposition header," Request for Comments 1806, Internet Engineering Task Force, June 1995.

[7] J. Galvin, S. Murphy, S. Crocker, and N. Freed, "Security multiparts for MIME: multipart/signed and multipart/encrypted," Request for Comments 1847, Internet Engineering Task Force, Oct. 1995.

[8] N. Freed and N. Borenstein, "Multipurpose internet mail extensions (MIME) part two: Media types," Request for Comments 2046, Internet Engineering Task Force, Nov. 1996.

[9] T. Dierks and C. Allen, "The TLS protocol version 1.0," Request for Comments 2246, Internet Engineering Task Force, Jan. 1999.

[10] H. Alvestrand, "IETF policy on character sets and languages," Request for Comments 2277, Internet Engineering Task Force, Jan. 1998.

[11] M. Handley and V. Jacobson, "SDP: session description protocol," Request for Comments 2327, Internet Engineering Task Force, Apr. 1998.

[12] D. Meyer, "Administratively scoped IP multicast," Request for Comments 2365, Internet Engineering Task Force, July 1998.

[13] T. Berners-Lee, R. Fielding, and L. Masinter, “Uniform resource identifiers (URI): generic syntax,” Request for Comments 2396, Internet Engineering Task Force, Aug. 1998.

[14] S. Kent and R. Atkinson, “Security architecture for the internet protocol,” Request for Comments 2401, Internet Engineering Task Force, Nov. 1998.

[15] R. Fielding, J. Gettys, J. Mogul, H. Frystyk, L. Masinter, P. Leach, and T. Berners-Lee, “Hypertext transfer protocol – HTTP/1.1,” Request for Comments 2616, Internet Engineering Task Force, June 1999.

[16] J. Franks, P. Hallam-Baker, J. Hostetler, S. Lawrence, P. Leach, A. Luotonen, and L. Stewart, “HTTP authentication: Basic and digest access authentication,” Request for Comments 2617, Internet Engineering Task Force, June 1999.

[17] R. Housley, “Cryptographic message syntax,” Request for Comments 2630, Internet Engineering Task Force, June 1999.

[18] B. Ramsdell and Ed, “S/MIME version 3 message specification,” Request for Comments 2633, Internet Engineering Task Force, June 1999.

[19] A. Vaha-Sipila, “URLs for telephone calls,” Request for Comments 2806, Internet Engineering Task Force, Apr. 2000.

[20] P. Resnick and Editor, “Internet message format,” Request for Comments 2822, Internet Engineering Task Force, Apr. 2001.

[21] R. Stewart, Q. Xie, K. Morneault, C. Sharp, H. Schwarzbauer, T. Taylor, I. Rytina, M. Kalla, L. Zhang, and V. Paxson, “Stream control transmission protocol,” Request for Comments 2960, Internet Engineering Task Force, Oct. 2000.

[22] J. Postel, “DoD standard transmission control protocol,” Request for Comments 761, Internet Engineering Task Force, Jan. 1980.

[23] J. Postel, “User datagram protocol,” Request for Comments 768, Internet Engineering Task Force, Aug. 1980.

[24] S. Bradner, “Key words for use in RFCs to indicate requirement levels,” Request for Comments 2119, Internet Engineering Task Force, Mar. 1997.

[25] F. Yergeau, “UTF-8, a transformation format of ISO 10646,” Request for Comments 2279, Internet Engineering Task Force, Jan. 1998.

[26] V. Paxson and M. Allman, “Computing TCP’s retransmission timer,” Request for Comments 2988, Internet Engineering Task Force, Nov. 2000.

[27] J. Franks, P. Hallam-Baker, J. Hostetler, P. Leach, A. Luotonen, E. Sink, and L. Stewart, “An extension to HTTP : Digest access authentication,” Request for Comments 2069, Internet Engineering Task Force, Jan. 1997.

[28] D. Crocker, Ed., and P. Overell, “Augmented BNF for syntax specifications: ABNF,” Request for Comments 2234, Internet Engineering Task Force, Nov. 1997.

33 Non-Normative References

[29] R. Pandya, “Emerging mobile and personal communication systems,” Vol. 33, pp. 44–52, June 1995.

[30] A. Johnston, S. Donovan, R. Sparks, C. Cunningham, D. Willis, J. Rosenberg, K. Summers, and H. Schulzrinne, “SIP telephony call flow examples,” Internet Draft, Internet Engineering Task Force, Apr. 2001. Work in progress.

[31] R. Rivest, “The MD5 message-digest algorithm,” Request for Comments 1321, Internet Engineering Task Force, Apr. 1992.

[32] H. Schulzrinne, S. Casner, R. Frederick, and V. Jacobson, “RTP: a transport protocol for real-time applications,” Request for Comments 1889, Internet Engineering Task Force, Jan. 1996.

[33] H. Schulzrinne, “RTP profile for audio and video conferences with minimal control,” Request for Comments 1890, Internet Engineering Task Force, Jan. 1996.

[34] J. Palme, “Common internet message headers,” Request for Comments 2076, Internet Engineering Task Force, Feb. 1997.

[35] H. Schulzrinne, A. Rao, and R. Lanphier, “Real time streaming protocol (RTSP),” Request for Comments 2326, Internet Engineering Task Force, Apr. 1998.

[36] P. Hoffman, L. Masinter, and J. Zawinski, “The mailto URL scheme,” Request for Comments 2368, Internet Engineering Task Force, July 1998.

[37] F. Dawson and T. Howes, “vcard MIME directory profile,” Request for Comments 2426, Internet Engineering Task Force, Sept. 1998.

[38] G. Good, “The LDAP data interchange format (LDIF) - technical specification,” Request for Comments 2849, Internet Engineering Task Force, June 2000.

[39] S. Donovan, “The SIP INFO method,” Request for Comments 2976, Internet Engineering Task Force, Oct. 2000.

[40] E. M. Schooler, “A multicast user directory service for synchronous rendezvous,” Master’s Thesis CS-TR-96-18, Department of Computer Science, California Institute of Technology, Pasadena, California, Aug. 1996.

[41] E. M. Schooler, “Case study: multimedia conference control in a packet-switched teleconferencing system,” *Journal of Internetworking: Research and Experience*, Vol. 4, pp. 99–120, June 1993. ISI reprint series ISI/RS-93-359.

[42] H. Schulzrinne, “Personal mobility for multimedia services in the Internet,” in *European Workshop on Interactive Distributed Multimedia Systems and Services (IDMS)*, (Berlin, Germany), Mar. 1996.

[43] F. Cuervo, N. Greene, A. Rayhan, C. Huitema, B. Rosen, and J. Segers, “Megaco protocol version 1.0,” Request for Comments 3015, Internet Engineering Task Force, Nov. 2000.

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