Internet Telephony: Status and Directions

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Overview

- new Internet services: “telephone”, “radio”, “television”
- why Internet telephony?
- why not already?
- Internet telephony modalities
- components needed:
  - data transport
  - resource reservation
  - signaling
  - service location
New Internet services

- tougher: replacing dedicated electronic media
- typewriter model of development
- yet another convergence?

Historical perspective

1876 invention of telephone
1915 first transcontinental telephone (NY–SF)
1920’s first automatic switches
1956 TAT-1 transatlantic cable (35 lines)
1962 digital transmission (T1)
1965 1ESS analog switch
1977 4ESS digital switch
1980s Signaling System #7 (out-of-band)
Overview of telephone system

- analog narrowband circuits to “central office”
- 64 kb/s continuous transmission, with compression across oceans
- AT&T: 136 “toll” switches in U.S.
- interconnected by T1 and T3 digital circuits → SONET rings (50)
- call establishment “out-of-band” using packet-switched signaling system (SS7)

The phone works — why bother with VoIP?

<table>
<thead>
<tr>
<th>user perspective</th>
<th>carrier perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td>variable compression: tin can to broadcast quality</td>
<td>silence suppression ⇒ traffic ↓</td>
</tr>
<tr>
<td>security through encryption</td>
<td>shared facilities ⇒ management, redundancy</td>
</tr>
<tr>
<td>caller, talker identification</td>
<td>advanced services (simpler than AIN and CTI)</td>
</tr>
<tr>
<td>better user interface</td>
<td>operational advantages</td>
</tr>
<tr>
<td>internat. calls: TAT transatlantic cable = $0.03/hr</td>
<td>cheaper switching</td>
</tr>
<tr>
<td>no local access fees (3.4c)</td>
<td>fax as data</td>
</tr>
<tr>
<td>easy: video, whiteboard, . . .</td>
<td></td>
</tr>
</tbody>
</table>
The new phone companies

- separation bit carriage ↔ services
- anybody with Internet connection can provide services (ACD, 800, 900, directory, …)
- distinction “in” vs. “out” of network not useful
- incremental start-up investment not large
- new players:
  - cable companies ➔ no new infrastructure, but mostly one-way
  - electric utilities ➔ need line management anyway
  - Qwest, IXC (resell to ISPs), …

Internet telephony as PBX replacement

global Internet not quite ready ➔ try as PBX

- have mission-critical LAN, PCs anyway
- usually ample (if switched) bandwidth, low latency
- packet switching is cheaper
- network PCs = ISDN phones
- no need for billing
**Internet telephony services**

- voice mail → email
- calendar integration
- user-programmable call processing logic
- call first available sales person (ACD)
- call whole department
- web IVR
- return web page with favorite “on hold” music

**Internet telephony services**

- camp-on without holding a line
- short message service (“instant messaging”)
- schedule call into the future
- call with expiration date
- add/remove parties to/from call ➔ mesh
- “buddy lists”
### Switching costs

<table>
<thead>
<tr>
<th>switching method</th>
<th>ports</th>
<th>Gb/s</th>
<th>cents/kb/s</th>
<th>$/interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>10BaseT hub</td>
<td>16</td>
<td>0.16</td>
<td>0.1</td>
<td>9.4</td>
</tr>
<tr>
<td>100BaseT hub</td>
<td>16</td>
<td>1.6</td>
<td>0.05</td>
<td>46</td>
</tr>
<tr>
<td>10BaseT switch</td>
<td>24</td>
<td>0.24</td>
<td>1.2</td>
<td>121</td>
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<tr>
<td>100BaseTX switch</td>
<td>8</td>
<td>0.80</td>
<td>0.15</td>
<td>156</td>
</tr>
<tr>
<td>router</td>
<td></td>
<td>2.1</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>local ATM switch</td>
<td>16</td>
<td>2.48</td>
<td>1.0</td>
<td>1581</td>
</tr>
<tr>
<td>PBX</td>
<td>256</td>
<td>0.02</td>
<td>218.</td>
<td>140</td>
</tr>
<tr>
<td>5ESS local (no AIN)</td>
<td>5,000</td>
<td>0.32</td>
<td>469.</td>
<td>300</td>
</tr>
<tr>
<td>5ESS local (AIN)</td>
<td>20,000</td>
<td>1.28</td>
<td>273.</td>
<td>175</td>
</tr>
<tr>
<td>4ESS toll</td>
<td>100,000</td>
<td>6.40</td>
<td>7.8</td>
<td></td>
</tr>
</tbody>
</table>

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### Why aren’t we using it now?

Internet capacity ≪ phone traffic:

- 600 Gb/s world phone traffic
- 13 Gb/s international traffic
- 1.8 Gb/s MCI Internet
- 368 Gb/s U.S. total
- 55 Gb/s U.S. interstate
- 61 Gb/s AT&T long distance

- unpredictable sound quality, reliability
- doesn’t work well for dial-up users
- no cheap Internet devices
- 640 M phone lines, 122 M in U.S. gateways
- no billing infrastructure
Projections

- MCI: “80% data, 20% voice”
- “AT&T could lose $350 million in international calls by 2001”
- “By 2002, the Internet could account for 11% of U.S. and international long-distance voice traffic”
- “Up to 10% of the world’s fax market, which generates $45 billion in telecom revenue a year, will move to Internet in 2 or 3 years”
- but: cable modems only 250,000 to 275,000 users in US, 10% of Internet users by 2000
Components for Internet Multimedia

Internet multimedia protocol stack
Components for Internet Multimedia

**multicast:** routing, address allocation

**data transport:** RTP

**resource reservation:** RSVP, YESSIR, diff-serv

“TV” – announcing multicast sessions: SAP

“phone” – session setup for conferences/telephony: SIP

“VCR” – control of streaming media: RTSP

**local applications:** conference bus

**policy issues:** billing, firewall access, clearing houses

Applications for Multicast

- audio-video distribution (1-to-many) and symmetric (all-to-all)
- distributed simulation (war gaming, multi-player Doom, ...)
- resource discovery (where’s the next time server?)
- file distribution (stock market quotes, new software, ...)
- network news (Usenet)
**Host group model**

Deering, 1991:

- senders need not be members;
- groups may have any number of members;
- there are no topological restrictions on group membership;
- membership is dynamic and autonomous;
- host groups may be transient or permanent.

**IP Multicast: Problems**

- multicast routing $\implies$ state $\propto S, G$
- proposals:
  - DVMRP, PIM-DM for dense groups
  - PIM-SM or CBT for sparse groups (“core”)
- overlay networks (Mbone) hard to maintain
- billing and charging (satellite TV problem)
- multimedia applications mostly on-demand
Multicast address allocation

- about 268 mio. “class D” addresses
- can’t have FCC assign channels
- hierarchical borrowing, using DHCP locally
- IETF malloc WG

Data transport – RTP

Real-Time Transport Protocol (RTP) = data + control

data: timing, loss detection, content labeling, talkspurts, encryption

control: (RTCP) periodic with $T \sim$ population
  - QOS feedback
  - membership estimation
  - loop detection
RTP functions

- segmentation/reassembly done by UDP (or similar)
- resequencing (if needed)
- loss detection for quality estimation, recovery
- intra-media synchronization: remove delay jitter through playout buffer
- intra-media synchronization: drifting sampling clocks
- inter-media synchronization (lip sync between audio and video)
- quality-of-service feedback and rate adaptation
- source identification

Resource Reservation

- *can’t* compensate for lack of bandwidth or reliability
- *can* provide incumbency protection
- receiver makes requests ⇒ RSVP
- sender makes requests ⇒ YESSIR
- issues: scaling (state), security, complexity
Internet telephony modes

- tail-end hop off ➔ callee has phone
- front-end hop on ➔ caller uses phone
- Internet in the middle: per-call, multiplexed

Internet “signaling”

all non-data (“out-of-band”) functions:

**routing**: unicast; DVMRP, PIM, CBT for multicast ✓

**quality of service**: RSVP, RTCP, diff-serv ✓

**user Contact**: map name to location (IP address)

**call set-up/teardown**: SIP, H.323

**policy, billing**: “vertical” protocols
Differences: Internet Telephony ↔ POTS

- separate control, transport (UDP) → no triangle routing
- separate connectivity from resource availability
- separate services from bit transport
- datagram service → less bootstrapping
- in-band signaling → higher speed
- features “network” → end system: distinctive ringing, caller id, speed dialing, number translation, ... → scaling
- features: intra-PBX = inter-LATA and general
- protocols: user-network = network-network signaling
Internet Telephony

- multimedia basically free (unlike ISDN)
- minimal extensions: signaling, not “stove pipe”
- leverage existing work: email, HTTP security, URIs, HTML, cgi, ...

Light-weight signaling: Session Initiation Protocol (SIP)

IETF MMUSIC working group (RFC 2543)

- light-weight generic signaling protocol
- typical post-dial delay: 1.5 round-trip time (with UDP)
- network-protocol independent: UDP or TCP (or AAL5 or X.25)
SIP functionality

- call user
- re-negotiate call parameters
- manual and automatic forwarding
- call center: reach first (load distribution) or reach all (department conference)
- personal mobility (complements data link/IP mobility) ➔ change of terminal (PC, digital cordless, palmtop), location
- terminate and transfer calls

Service creation: Call Processing Language

- incoming and outgoing
- “if somebody is trying to call for the 3rd time, allow mobile”
- “try office and lab in parallel, if that fails, try home”
- “allow call to mobile if I’ve talked to person before”
- users and administrators
- not quite like cgi: multiple responses? timers?
- Tcl, Java?
Real-Time Streaming Protocol (RTSP)
remote-control streaming media ➤

- “rough” synchronization (fine-grained ➤ RTP sender reports)
- virtual presentations = synchronized playback from several servers ➤
  command timing
- load balancing using redirection at connect, during stream
- supports any session description
- device control ➤ camera pan, zoom, tilt
- caching: similar to HTTP, except “cut-through”

Open Operational Issues

- billing
- finding the nearest gateway to the Internet (➤ GLP)
- mapping E.164 (phone) numbers to IP addresses
- controlling phones through the Internet (PINT)
- 911 services
- CALEA
- anonymity and certified identity
Conclusion

• transition of separate circuit-switched ➞ IP-based applications
• packets from the inside out or the outside in?
• IP over ATM, Sonet, WDM?
• IPv6 or NATs?
• “the end of distance” or tiered IP service?