# Network Security: Network Review and Firewalls

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# Secure Communications

- Alice can send message to Bob; only Bob can read
- Bob knows for sure that Alice sent it
- Alice can't deny she sent the message
- but the basic communication is insecure:
  - wiretapping
  - switches and routers
  - redirection
  - storage
  - . . .
- ↔ storage security

# Security is analog, not binary…

- there is no perfect security
- cost of inconvenience vs. cost of breach
- how long does it have to stay secret?
- how sophisticated is the adversary?
- value of information + value of service (DOS)
- physical security + cryptographic
- difference: attack from anywhere, automated (“script kiddies”)
- most problems are not crypto problems
- wire/fiber-tapping is hard

# Terminology

**bad guy:** avoid ‘hacker’; *Trudy* = intruder, impostor

**secret key:** = symmetric = receiver and transmitter share secret key, nobody else

**public key:** = asymmetric = two keys, one public, one private (secret)

**privacy:** protect communications from all but intended recipients ≈ confidentiality ↔ privacy laws

## Dramatis Personae

usually computers:

**Alice:** first participant

**Bob, Carol, Dave:** second, third, fourth participant

**Eve:** evesdropper

**Mallory, Trudy:** malicious active attacker

**Trent:** trusted arbitrator

**Walter:** warden; guarding Alice and Bob in some protocols

**Peggy:** prover

**Victor:** verifier

## Kaufman Notation

<table>
<tr><th></th><th></th></tr>
<tr><td>$\oplus$</td><td>ex-or, exclusive or</td></tr>
<tr><td>$|$</td><td>concatenation (e.g., ”joe” $|$ ”secret” = ”joesecret”)</td></tr>
<tr><td>$K\{\text{message}\}$</td><td>encrypted with key $K$</td></tr>
<tr><td>$\{\text{message}\}_{\text{Bob}}$</td><td>encrypted with public key of Bob</td></tr>
<tr><td>$[\text{message}]_{\text{Bob}}$</td><td>signed by Bob = using his private key</td></tr>
</table>

# Network Primer

| layer | name | who | e.g., | PDU |
|---|---|---|---|---|
| 7 | application | E-E | SMTP | message |
| 6 | presentation | E-E | MIME | |
| 5 | session | E-E | ? | |
| 4 | transport | E-E | TCP | packet |
| 3 | network | router | IP | packet |
| 2 | data link | bridge, switch | Ethernet | frame |
| 1 | physical | repeater | Ethernet over coax | bit stream |

# Network Services

(Almost) any layer:

**error checking:** checksum, drop bad packets

**reliability:** retransmission (ARQ, ”ack”) or forward error correction (redundancy)

**ordering:** ensure delivery order

**multiplexing:** several upper-layer entities → one lower-layer entity (e.g.,: telephony)

**inverse multiplexing:** spread single message over several channels

**flow control:** avoid overrunning slow receiver

**congestion control:** avoid overrunning slow network

**encryption, authentication:** obviously…

# Directory Services

- need (network-layer) address to communicate
- more memorable, different assignment:
  - unique identifier
  - locator
  - name (administrative, “John Smith”, www.)
- directory service: translation between addresses
- scalability ➠ tree, hiearchy
- e.g.,: clinton@whitehouse.gov
- needed for security: public key
- needs to be secured

# Network Security Layers

**Physical layer:** blackening

**Data link layer:** wireless Ethernet encryption (802.11 WEP at 11 Mb/s), PPP authentication

**Network layer:** IPsec

**Transport layer:** secure socket layer (TLS, “https:”)

**Application:** email (PGP, S/MIME), $x$-over-TLS, HTTP authentication, SHTTP, Kerberos

**infrastructure:** DNS, routing, resource reservations, . . .

# Security Approaches

- Application security
- OS security
- Network infrastructure security
- Procedural and operational security

# Application Security

- application software security (e.g., buffer overruns)
- path encryption via secure application protocols (ssh)
- isolating critical applications on single-purpose hosts

# Host/OS Security

- OS software integrity (most attacks on non-patched OS)
- user-level access control (AAA, tokens)
- block unneeded services (finger, ftp, DNS)
- path encryption via IPsec
- device-level access control (MAC, IP, DNS) in servers, routers, Ethernet switches
- e.g., host firewalling (such as TCP wrappers, IP chains)

# Network Infrastructure Security

- service-blocking perimeter (port)
- device-ID perimeter (IP address)
- path encryption perimeter
- path isolation via routers and switches
- path isolation via separate infrastructure (“air gap”)

# Procedural and Operational Security

- policies and education on safe computing practices
- desktop configuration management
- proactive probing for vulnerabilities
- intrusion detection

# Top-level Domains

2 letters: countries

3 letters: independent of geography (except edu, gov, mil)

| domain | usage | example | domains (8/00) |
|---|---|---|---|
| com | business (global) | research.att.com | 17,050,817 |
| edu | U.S. 4 yr colleges | cs.columbia.edu | 5,673 |
| gov | U.S. non-military gov’t | whitehouse.gov | 730 |
| mil | U.S. military | arpa.mil | |
| org | non-profit orgs (global) | www.ietf.org | 248,489 |
| net | network provider | nis.nsf.net | 2,806,721 |
| us | U.S. geographical | ietf.cnri.reston.va.us | |
| uk | United Kingdom | cs.ucl.ac.uk | 194,686 |
| de | Germany | fokus.gmd.de | 262,708 |

# Replicated Services

- load sharing
- availability
- same information?
- replay: change password to different server

# Packet Switching

- circuit switching: fixed-rate, reserved bit stream between parties for duration of communications (“wire”)
- packet switching: chop application messages into packets ($<$ few kB, with upper bound):
  - interleaving from different sources
  - error recovery on single unit
  - flexible bandwidth

➠ encryption on messages or packets

# Network Components

**link:** connection between components, including wireless ➠ point-to-point (modem), multiple access (Ethernet)

**router, switch:** forward packets

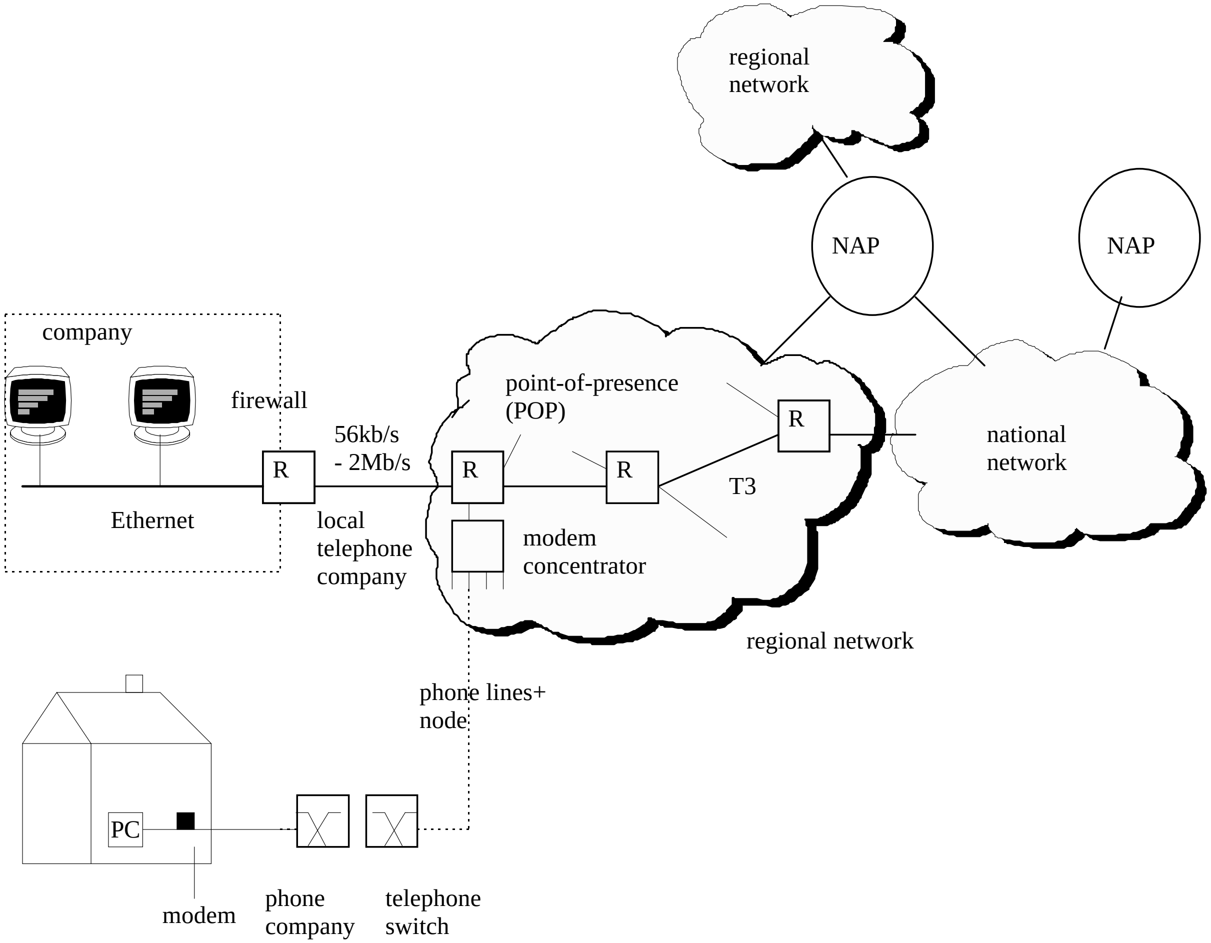
**node:** router (= intermediate system), host (= end system)

**clients:** access resources and services

**servers:** provide resources and services (may also be client)

**dumb terminal:** no local processing

# Network Access and Interconnection



# Destinations

- interconnect local networks (links) of different technology
- router:

  1. get packet from source link, strip link layer header
  2. find outgoing interface based on destination network address
  3. find next link-layer address
  4. wrap in link layer header and send

# Internet Names and Addresses

| | example | organization |
|---|---|---|
| MAC address | 8:0:20:72:93:18 | flat, permanent |
| IP address | 132.151.1.35 | topological (mostly) |
| Host name | www.ietf.org | hierarchical |
| User name | clinton@whitehouse.gov | multiple |

host name $\overset{\mathrm{DNS,many-to-many}}{\longrightarrow}$ IP address $\overset{\mathrm{ARP,1-to-1}}{\longrightarrow}$ MAC address

addresses can be forged ➠ check source

# Tempest

- every device is a radio transmitter
- e.g., TV scanning
- Europe: find unlicensed TV receivers
- *control zone*

# Threats for a Corporate/Campus Network

- unauthorized access to hosts (clients, servers)
- disclosure & modification of network data
- denial-of-service attacks

# Threats for the Internet/ISP

- propagate false routing entries (“black holes”, `www.citibank.com` ⟶ `www.mybank.az`)
- domain name hijacking
- link flooding
- configuration changes (SNMP)
- packet intercept

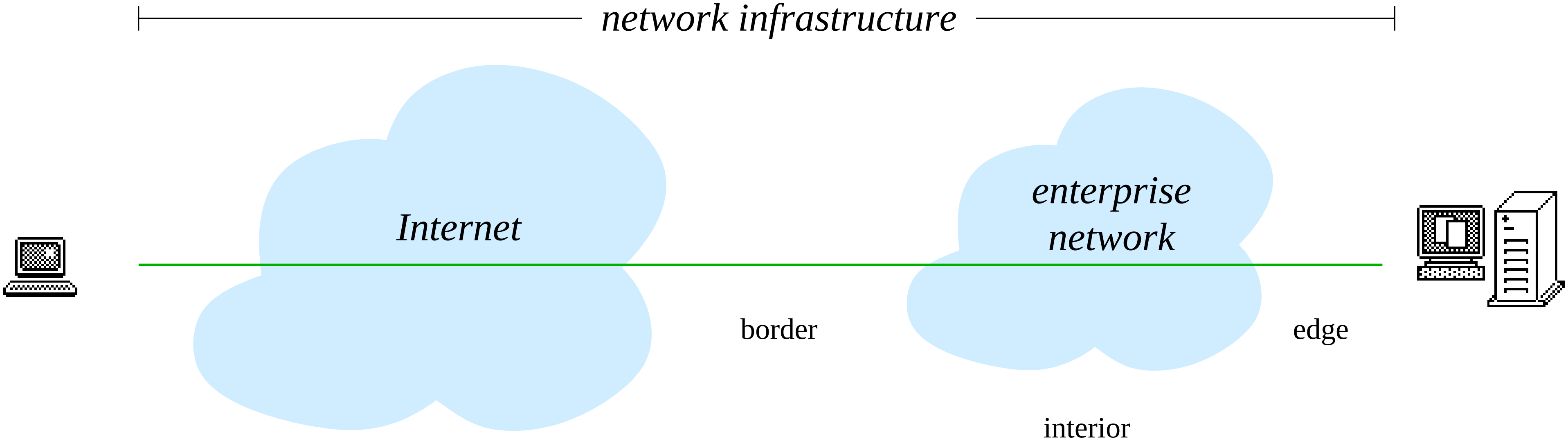
# Application-Layer Threats

- only limited ability of network intervention possible
- shoulder-surfing
- rogue applications emailing out confidential files
- viruses, mail bombs, email attachments, . . .

# General Strategies

- hardening the OS and applications
- encrypting sensitive data
- reduce size of target ⟶ disable unneeded services
- limit access of attacker to target systems

# Network Infrastructure



# Trust Model

- perimeter defense: defines *trust zone*
- most attacks are from the *inside*
- traveling users: virtual private networks – danger!
- “extranets” for vendors, suppliers, . . .
- internal hosts may not be managed or under control of network operator
- defense in depth

# Firewalls

- computer between internal (“intranet”) and external network
- = policy-based packet filtering
- watch single point rather than every PC
- limit in/out services, restrict incoming packets
- can’t prevent people walking out with disks

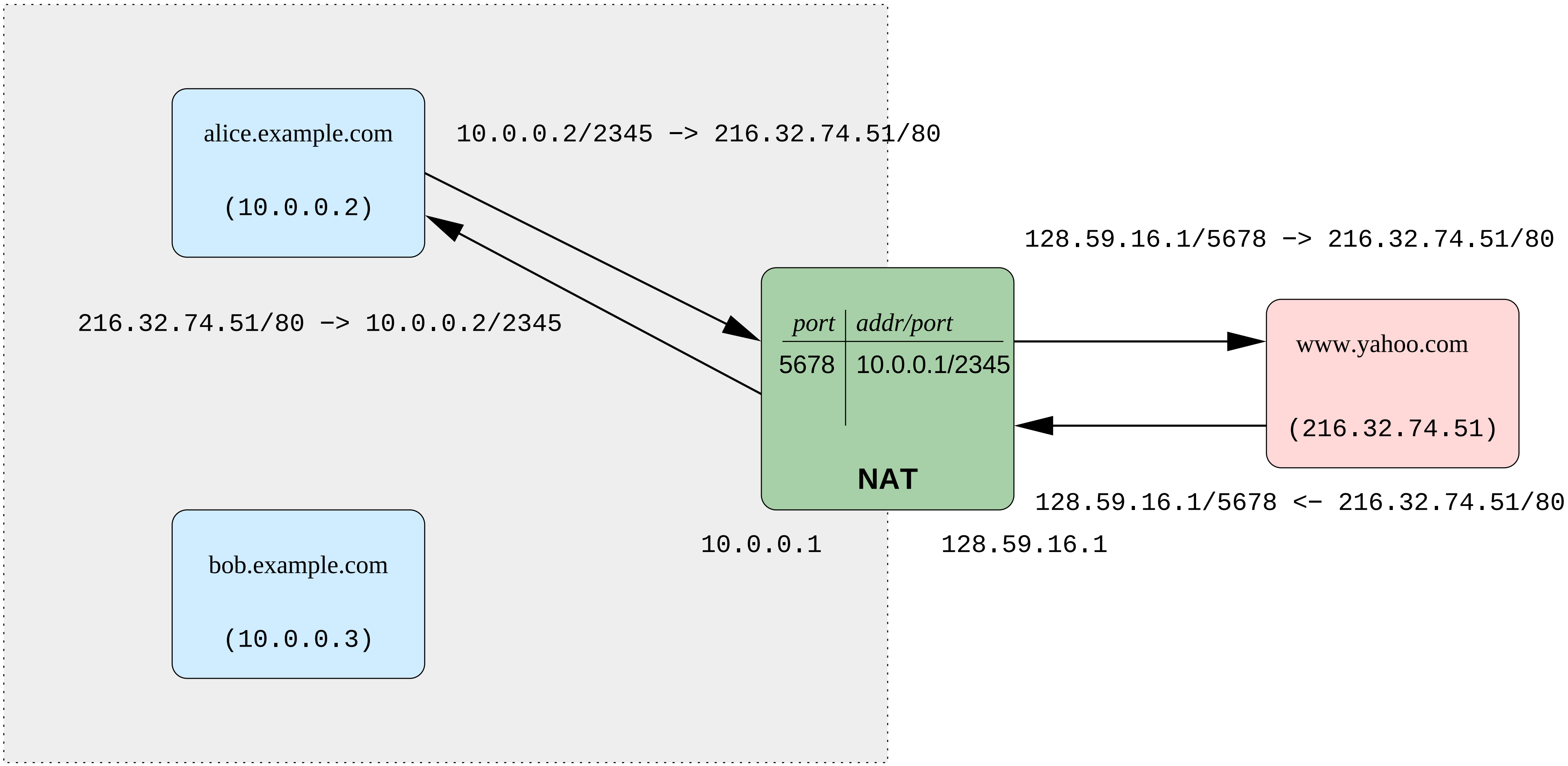
**packet filter:** restrict IP addresses (*address filtering*), ports

**connection filter:** only allow packets belonging to authorized (TCP) connections

**encrypted tunnel:** tunnel = layer same layer inside itself ➠ virtual network: connect intranets across Internet

**NA(P)T:** network address (and port) translator are *not* firewalls, but can prevent all incoming connections

# Network Address Translation



alice.example.com

(10.0.0.2)

10.0.0.2/2345 -> 216.32.74.51/80

216.32.74.51/80 -> 10.0.0.2/2345

bob.example.com

(10.0.0.3)

| *port* | *addr/port* |
|---|---|
| 5678 | 10.0.0.1/2345 |

NAT

10.0.0.1

128.59.16.1

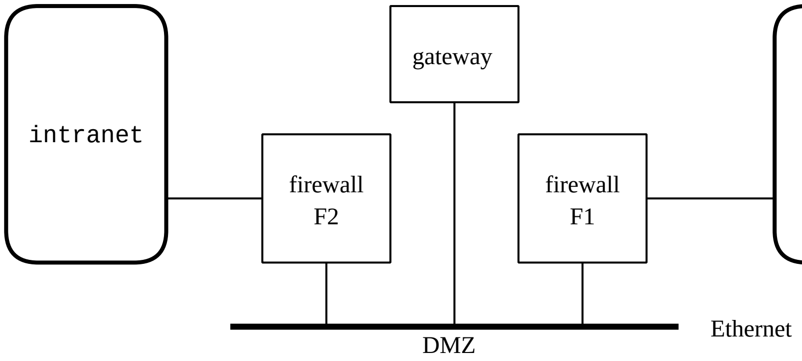
128.59.16.1/5678 -> 216.32.74.51/80

www.yahoo.com

(216.32.74.51)

128.59.16.1/5678 <- 216.32.74.51/80

# Application Gateway



- firewall $F_x$: only to/from gateway
- may only allow email, file transfer
- hard to restrict large file transfers

# Key Escrow

- key broken into pieces, $\oplus$’ed
- need all key pieces ➠ need collusion
- doesn’t prevent “bad guys” from using other cryptography
- useful in corporate environment: accidental key loss

# Viruses

**trojan horse:** looks innocent, does something nasty

**virus:** inserts copy of itself into another program

**worm:** replicates across network

**trapdoor:** undocumented high-priviledge access to program

**logic bomb:** triggered at some time instant or event

Carriers:

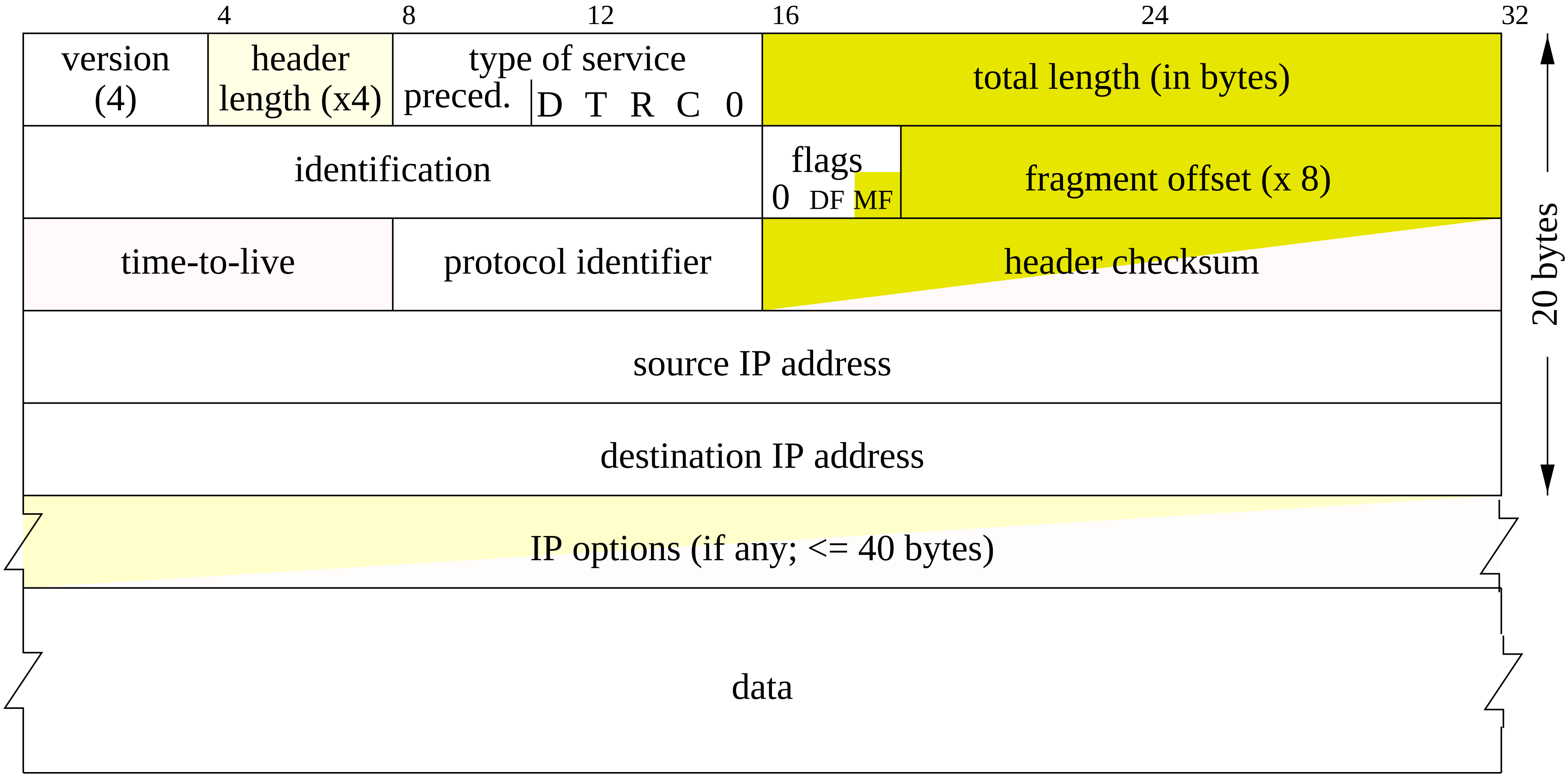
- only programs ➠ “Good Times” hoax
- but: PostScript is program
- but: Word is a program

## Virus Prevention

- signatures (➠ hash)
- but: polymorphic virus
- checksum files securely
- limit activity (*sandboxing*) ➠ Java
- run a non-Windows operating system . . .

also: some may do physical damage (EEPROM, tape, video monitor, speaker)

# IPv4



version (4)

header length (x4)

type of service
preced. D T R C 0

total length (in bytes)

identification

flags
0 DF MF

fragment offset (x 8)

time-to-live

protocol identifier

header checksum

source IP address

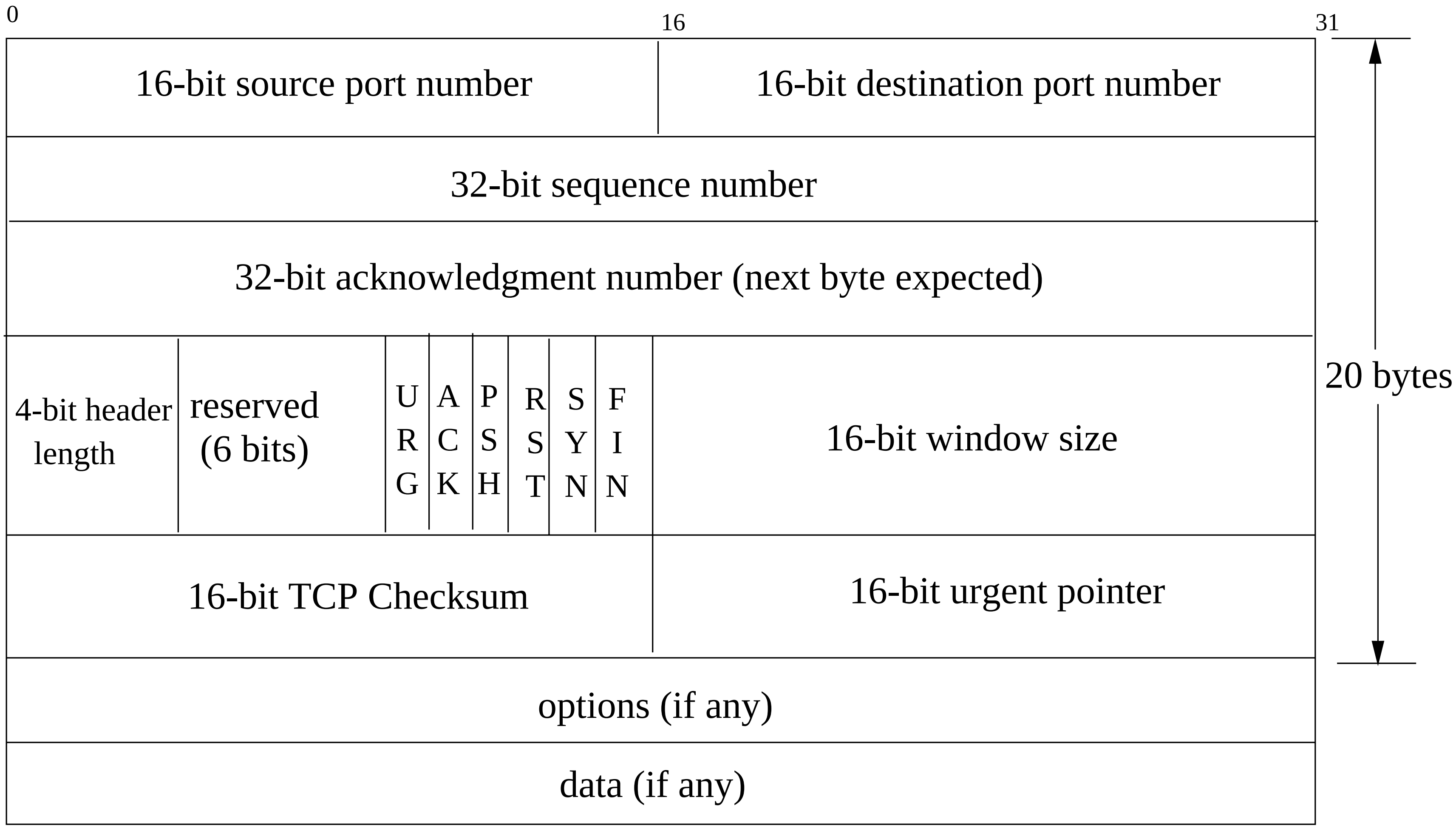
destination IP address

IP options (if any; <= 40 bytes)

data

🟥 modified by router 🟨 modified by fragmentation

# TCP



0

16

31

16-bit source port number

16-bit destination port number

32-bit sequence number

32-bit acknowledgment number (next byte expected)

4-bit header length

reserved (6 bits)

URG

ACK

PSH

RST

SYN

FIN

16-bit window size

16-bit TCP Checksum

16-bit urgent pointer

options (if any)

data (if any)

20 bytes

# Denial of Service (DOS) Attacks

Source: exploit legitimate behavior + bugs with “strange” packet formats.

**mailbombing:** send auto-generated email to victim

**smurf:** Perp sends ICMP echo (ping) traffic to IP broadcast address (directed broadcast), all of it having a spoofed source address of a victim. Prevention:

- disable directed broadcast;
- source address filtering on egress/ingress;
- compare source address of a packet against the routing table to ensure the return path of the packet is through the interface it was received on.
- “An ICMP Echo Request destined to an IP broadcast or IP multicast address MAY be silently discarded.”

**fraggle:** same, UDP echo packets;

**LAND attack:** spoofed packet(s) with the SYN flag set – if they contain the same destination and source IP address as the host, the victim’s machine could hang or reboot;

**Tear drop:** overlapping (fragmented) packets;

**SYN flood:** send lots of TCP SYN packets that occupy OS resources;

**crash server:** large URLs, malformed packets, . . .

# Distributed Denial-of-Service Attacks

E.g.: Stacheldraht, Trinoo, Tribe Flood Network

- compromise victim system, typically via buffer overflow
- clients (control handlers via TCP), handlers (control agents via TPC or ICMP ECHO_REPLY), agents (send data)
- handler-to-agent communication is encrypted
- handlers instruct agents to start DOS:
  - SYN flood
  - ICMP flood
  - UDP flood
  - Smurf

# Military Security Model

Access controls:

**discretionary:** owner gives out rights

**nondiscretionary:** policy fixed

- security levels: unclassified $<$ confidential $<$ secret $<$ top secret
- compartments ➠ “need to know”
- read up is illegal
- write down is illegal (➠ root can’t write to user!)

# Covert Channels

- smuggle information without detection, but with noise – “steganography”
- timing ➠ system loading
- (printer) queues
- create out-of-bounds file: can’t read vs. doesn’t exist
- error messages
- related application: additive “noise” in pictures, music, videos for fingerprinting (example: Secure Digital Music Initiative (SDMI), assumes trusted player)

# Orange Book

- military security, linear, documentation/testing

  **D:** none

  **C1:** discretionary security (Unix); prevent OS writing

  **C2:** ACL, no dirty disks, auditing (e.g., Windows NT 4.0, Solaris 2.6)

  **B1:** security labels for users, processes, devices

  **B2:** avoid Trojan horse; security level change notification; security kernel; covert channels

  **B3:** ACL with exceptions; alarms; secure crashing

  **A1:** verified design

# Legal Issues

Patents:

- interesting things are patented (17 years)
- but some are royalty-free (DES), at least for non-commercial use (IDEA)
- public key requires license (until 2000) from RSA (4,405,829, issued September 29, 1983)

# Export Controls

Modified policy as of Jan. 2000

- classically, encryption = munitions
- book ok, disk not
- export license: DOD ➠ DOC for export to government
- no export to Cuba, Iran, Iraq, Libya, North Korea, Sudan or Syria
- technical review for export to non-government
- “retail products” can now be exported to any end user
- open source do not need review, but deposit source code
- <64 bit encryption (including DES) mostly o.k. for export (Wassenaar agreement)
- USA, Australia, New Zealand, France, and Russia control export
- import always ok