Characteristics of Packet-Switched Networks; Protocols

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1 Administrivia

Announcements

Assignment

Read 2.1–2.3.

From Last Time

The Internet's edge and core.

Outline

1.

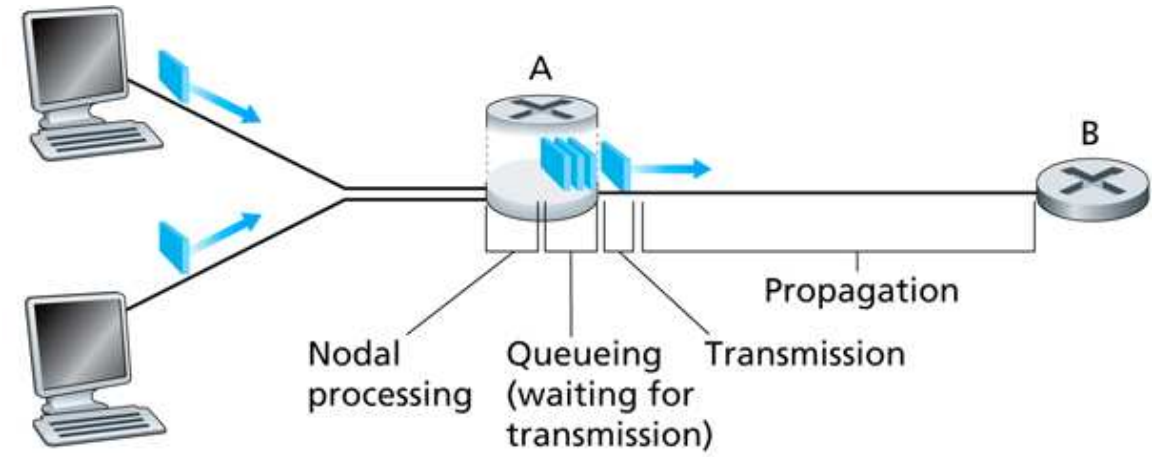
Coming Up

Introduction to application layer, HTTP and FTP.

2 Packet-Switched Network Characteristics

2.1 Delay

Packet transmission delay model:



Nodal delay (one switch):

$$d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

Delay components:

1. Processing delay: integrity checking, routing, etc.

2. Queuing delay: Waiting in output buffer prior to transmission. Variable.

3. Transmission delay: Getting the *entire* packet "out the door."

   Let packet contain L bits and link transmission rate be R b/s. Transmission delay is then L/R.

4. Propagation delay: Time for one bit to traverse the medium between two switches.

End-to-end delay with n switches along the route:

$$\sum_{i=1}^{n} d_{\text{nodal}_i}$$

Using `traceroute` to see the route between two hosts:

```
bluebird:~
% traceroute www.google.com
traceroute to www.google.com (64.233.169.147), 30 hops max, 40 byte packets
 1  10.67.1.1 (10.67.1.1)  1.383 ms  1.552 ms  1.674 ms
 2  66.240.10.65 (66.240.10.65)  30.927 ms  232.192 ms  250.335 ms
 3  at-8-0-0-16-br01.whm.comcastcommercial.net (66.240.7.165)
    67.405 ms  122.690 ms  140.896 ms
 4  ge-6-0-cr01.whm.comcastcommercial.net (208.39.140.9)
    49.226 ms  85.665 ms  104.371 ms
 5  ge-5-2-113.hsa1.Baltimore1.Level3.net (4.78.140.13)
    159.112 ms  177.257 ms  195.600 ms
 6  so-6-1-0.mp1.Baltimore1.Level3.net (4.68.112.65)
    213.743 ms  257.386 ms  266.623 ms
 7  ae-2-0.bbr1.Washington1.Level3.net (4.68.128.201)
    275.783 ms  249.083 ms  247.324 ms
 8  ae-1-69.edge1.Washington1.Level3.net (4.68.17.16) 238.350 ms  229.374 ms
    ae-3-89.edge1.Washington1.Level3.net (4.68.17.144)  219.795 ms
 9  GOOGLE-INC.edge1.Washington1.Level3.net (4.79.228.38) 210.880 ms
    GOOGLE-INC.edge1.Washington1.Level3.net (4.79.231.6) 202.249 ms
    GOOGLE-INC.edge1.Washington1.Level3.net (4.79.228.38) 193.167 ms
10  64.233.175.169 (64.233.175.169)  184.294 ms
    64.233.175.171 (64.233.175.171)  175.361 ms  166.344 ms
11  72.14.232.21 (72.14.232.21)  157.196 ms  10.448 ms  160.945 ms
12  yo-in-f147.google.com (64.233.169.147)  26.664 ms  6.023 ms  16.402 ms
```

BTW, Level 3 is a Tier 1 ISP.

2.2 Queuing Delay and Packet Loss

If packets arrive more quickly at the switch than we can send them, we have a couple problems:

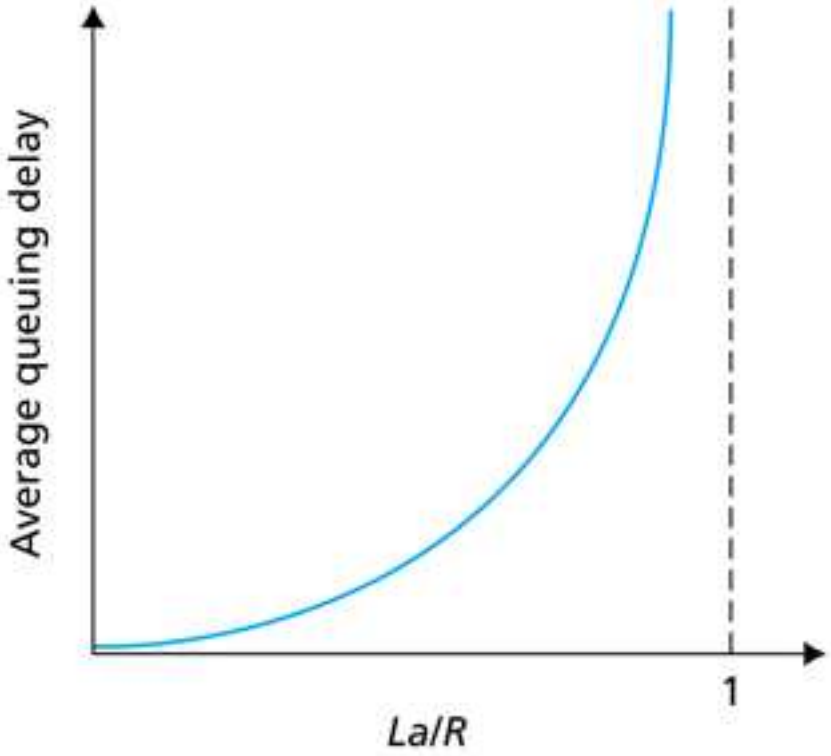
1. Packets will begin to queue up in the switch's buffers — increasing queueing delay.

2. If the buffer fills completely, packets will be dropped — lost forever.

Traffic intensity is a metric used to describe queuing delay:

$$\frac{La}{R},$$

where a is the packet arrival rate, per second.



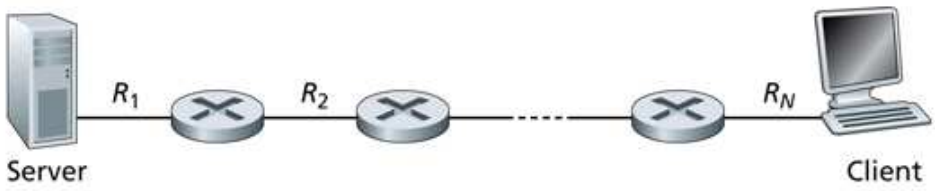
2.3 Throughput and Latency

Two throughput measures:

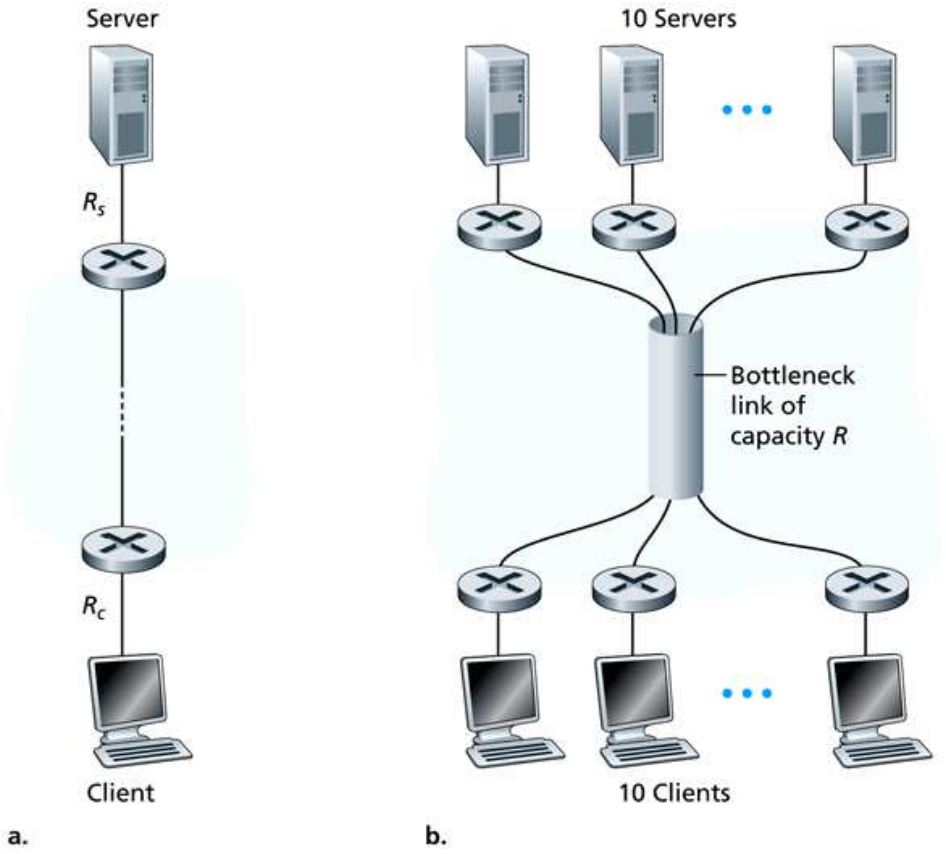
1. Instantaneous throughput — throughput at a particular instant.
2. Average throughput.

   Transferred 5 MB MP3 file in 12 sec.: $(5 * 2^{20} * 8)/30 = 1.4$ mb/s.

The "slowest" link determines the overall throughput — the bottleneck:



Internet resources are shared:



Latency: How long it takes the first bit to make it from end-to-end.

Rules of thumb:

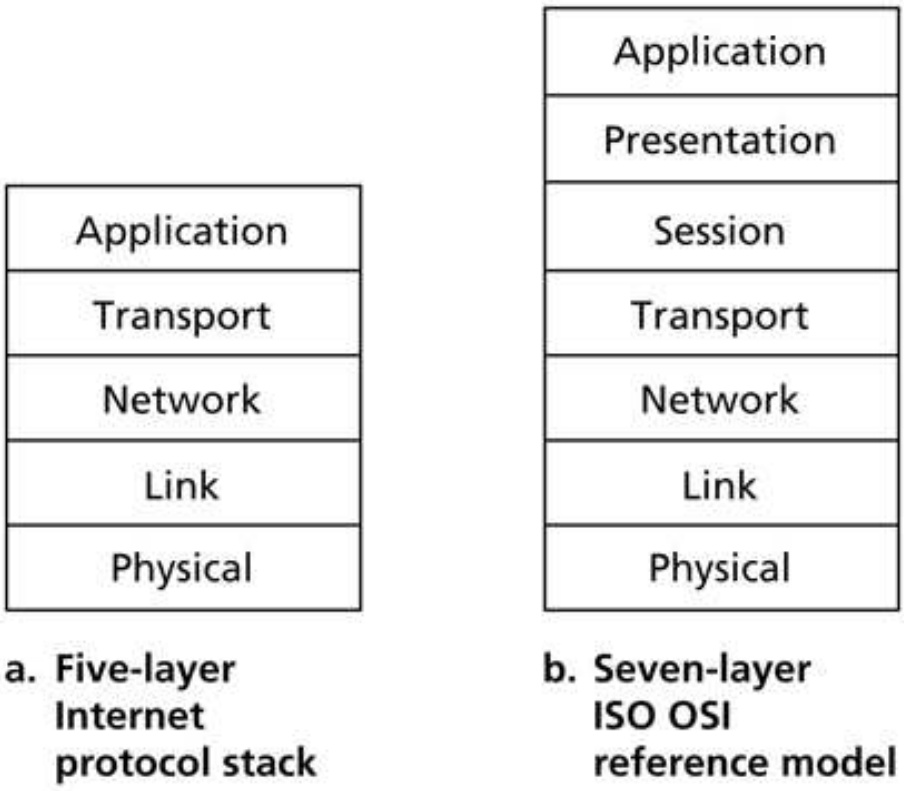
1. Latency matters for realtime applications: gaming, telephony. Throughput may or may not matter — low-fi audio, no; video, yes.

2. Throughput usually matters for file transfer.

3. Neither particularly matter for email; maybe IM.

3 Protocol Layers and Models

Protocols (services) are layered on top of each other:



Characteristics:

1. Only the physical layers on two hosts communicate directly.

2. Higher layers communicate through lower layers — abstraction.

   Think of two heads of state communicating through their ministers, and the ministers communicating through under-secretaries.

3. Going down, layers add headers with information specific to that layer (nested envelopes).

4. Going up, layers examine and discard headers.

Layer synopses:

1. Application layer: What ordinary think of the Internet as: HTTP, SMTP, FTP, etc.

   Unit of exchange: message.

2. Transport layer: message transport service between hosts.

   (a) TCP: connection-oriented service; guaranteed delivery; segmentation of messages; congestion control.

   (b) UDP: connectionless service; delivery not guaranteed; no congestion control.

   Unit of exchange: segment.

3. Network layer: segment delivery service.

   IP protocol. No guarantee of delivery. Routing services occupy this layer.

   Unit of exchange: datagram.

4. Link layer: delivery of datagrams between two adjacent nodes.

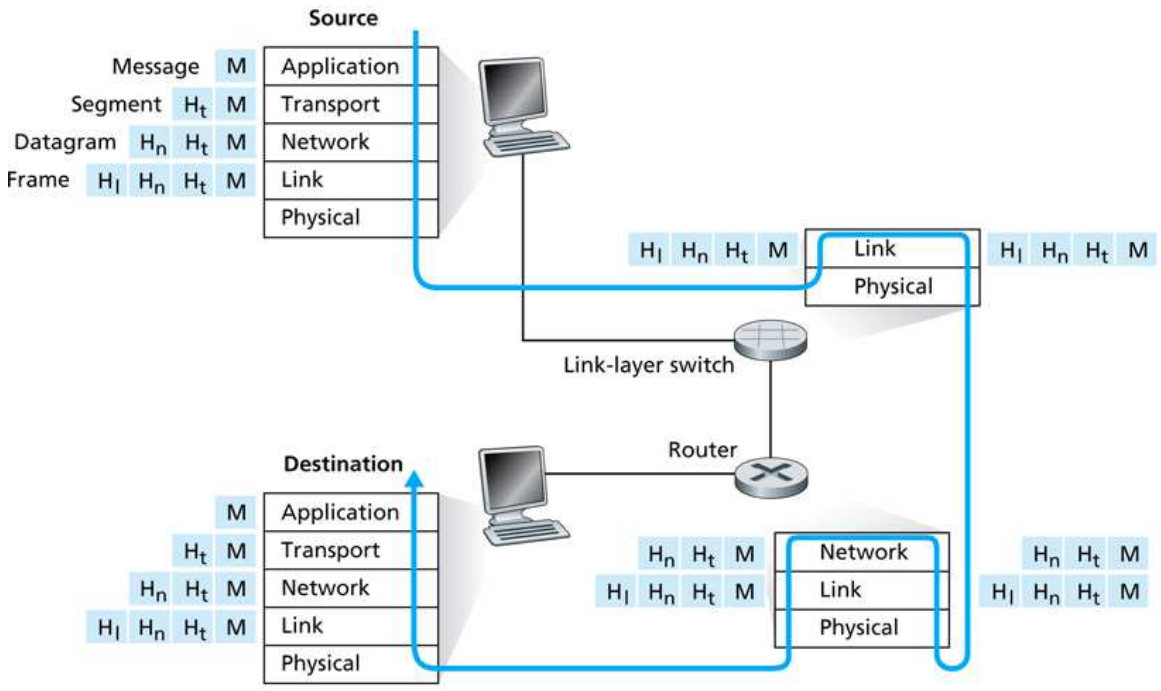
   Sometimes delivery is guaranteed. The mediums between links may vary.

   Unit of exchange: frame.

5. Physical layer: move frames from one node to the next.

   Unit of exchange: bit.

TCP/IP example:



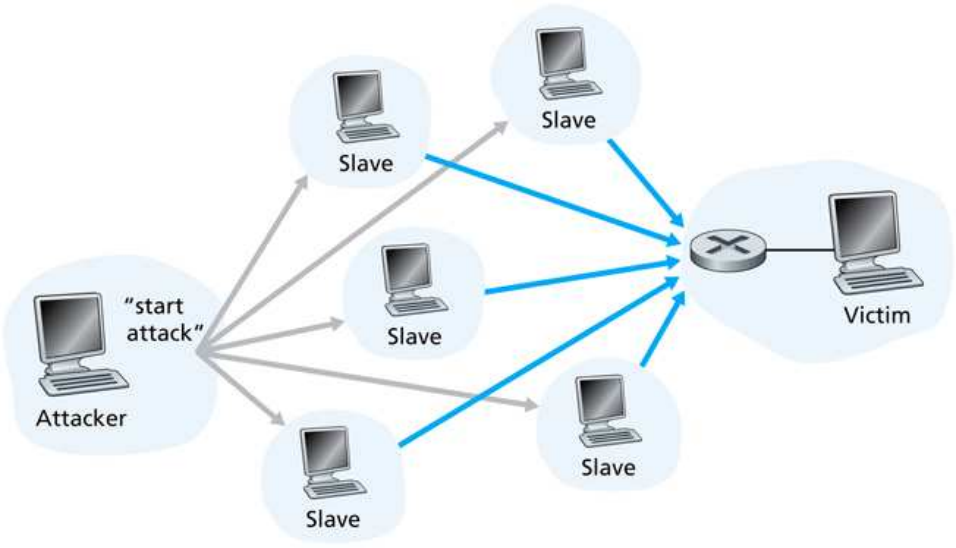
4 Security

The "bad guys" can:

1. use viruses, worms, malware on web sites, etc. to take control of hosts.

   Botnets.

2. attack Internet infrastructure. DDOS attack:



3. Read, modify, or delete packets.

4. Masquerade as legitimate hosts.

   Hosts files, DNS cache poisoning attacks.

5 History

1. The original "Internet" in 1969 consisted of four nodes.

   Today? According to the Internet Systems Consortium, 433,193,199 hosts were reachable in Jan. 07. This is a gross undercount.

2. An early IMP (router):

3. A modern "router," the Linksys WRT54GL (Linux):