CMSC 417

Computer Networks

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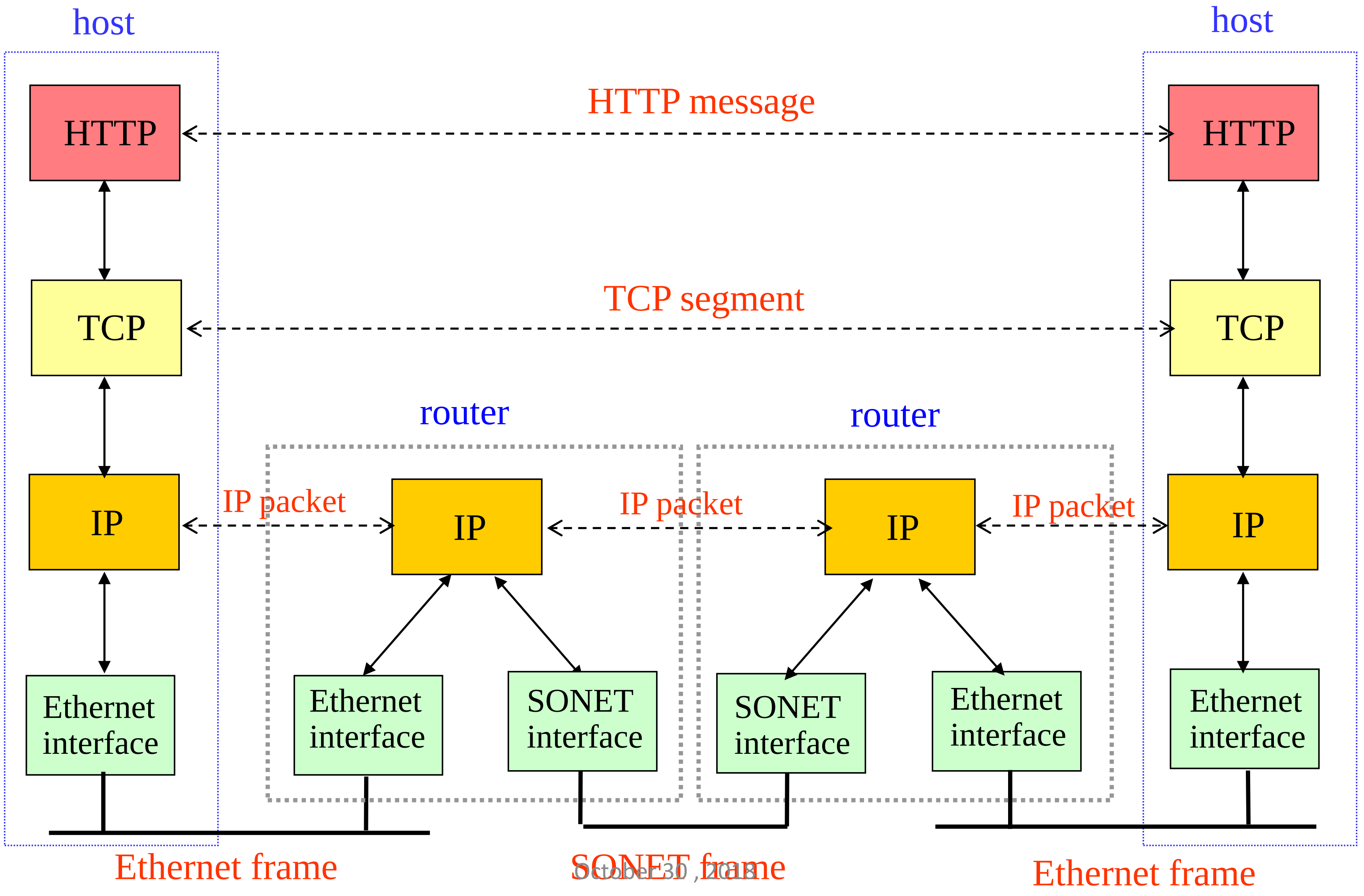
Message, Segment, Packet, and Frame



TCP Congestion Control

- Congestion – a function of total number of packets in the network, and where they are
- First step – detection
  - Is packet loss an indication of congestion??
  - All TCP algorithms assume timeouts are caused by congestion
- Initial steps
  - When connection is established – use suitable window size
    - Loss will not occur due to buffers at receiver
- Two issues
  - Network Capacity
  - Receiver Capacity

TCP Congestion Control

- Network Capacity and Receiver Capacity
- Maintain two windows
  - Receiver window
  - Congestion window
  - Use the min (Receiver window and Congestion window)
- Initially
  - Sender sets congestion window to MSS (Max Seg Size)
  - If acked add one more MSS – 2 now
  - Repeat for each acked MSS
  - Congestion window grows exponentially
  - If timeout – go back to previous window size
  - SLOW START

Internet Congestion Control

- Use a Threshold – initially 64 KB
- When a timeout occurs set threshold to half the current congestion window and reset congestion window to 1 MSS
- Use slow start till the threshold is reached
- Then successful transmissions grow congestion window linearly

TCP Congestion Control (1)

TCP uses AIMD with loss signal to control congestion

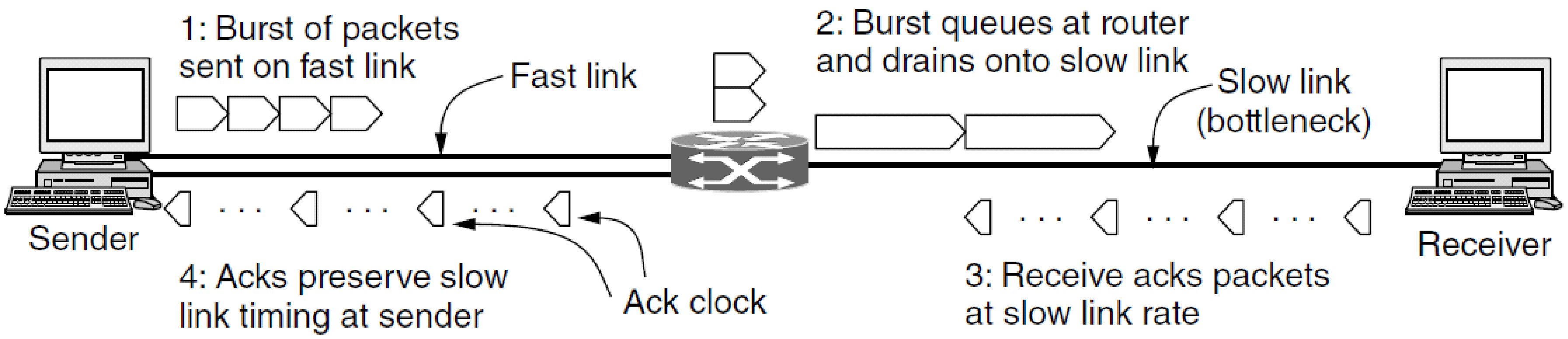
- Implemented as a <u>congestion window</u> (cwnd) for the number of segments that may be in the network
- Uses several mechanisms that work together

Name	Mechanism	Purpose
ACK clock	Congestion window (cwnd)	Smooth out packet bursts
Slow-start	Double cwnd each RTT	Rapidly increase send rate to reach roughly the right level
Additive Increase	Increase cwnd by 1 packet each RTT	Slowly increase send rate to probe at about the right level
Fast retransmit / recovery	Resend lost packet after 3 duplicate ACKs; send new packet for each new ACK	Recover from a lost packet without stopping ACK clock

TCP Congestion Control (2)

Congestion window controls the sending rate

- Rate is cwnd / RTT; window can stop sender quickly
- ACK clock (regular receipt of ACKs) paces traffic and smoothes out sender bursts

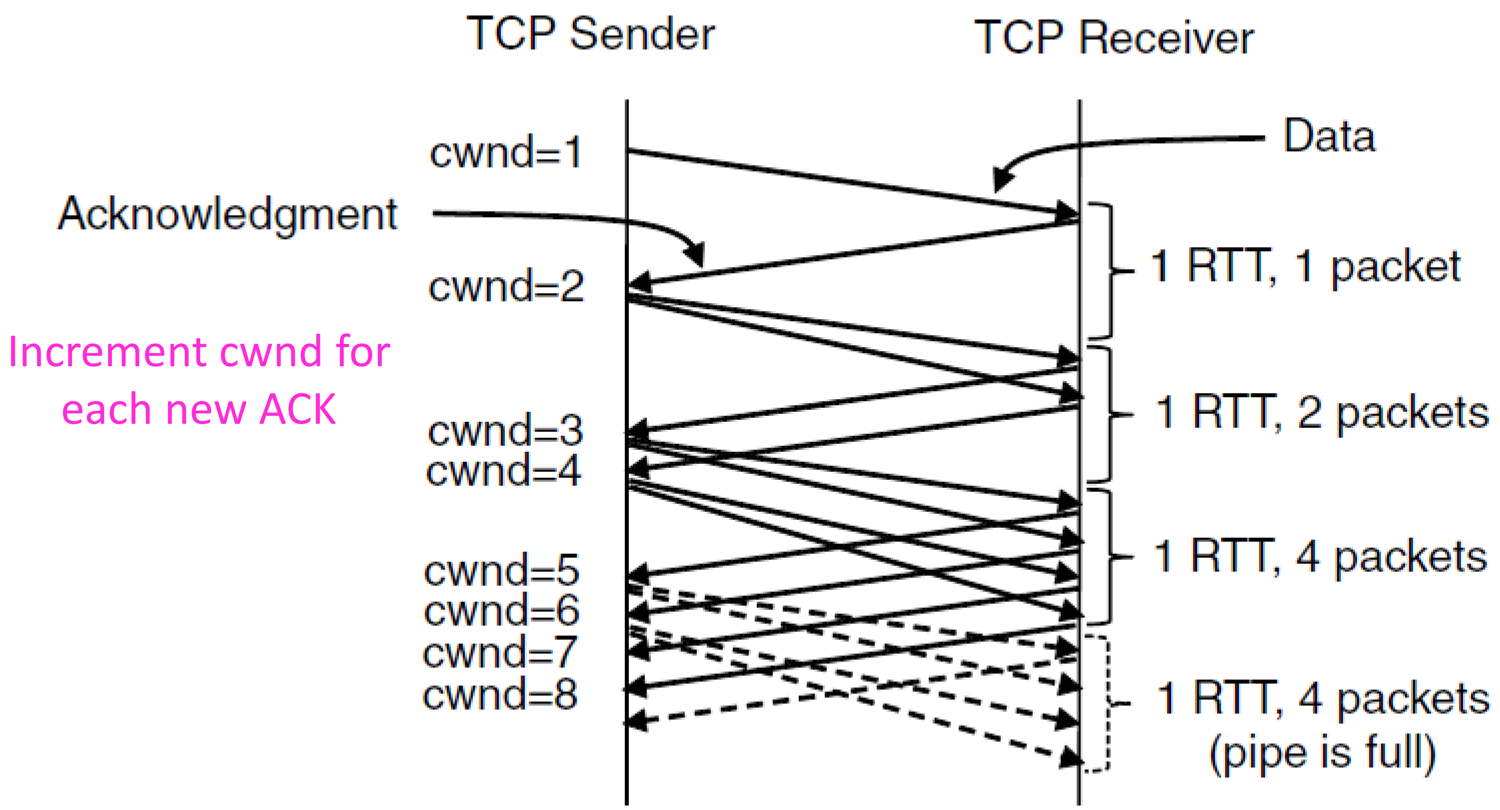


ACKs pace new segments into the network and smooth bursts

TCP Congestion Control (3)

Slow start grows congestion window exponentially

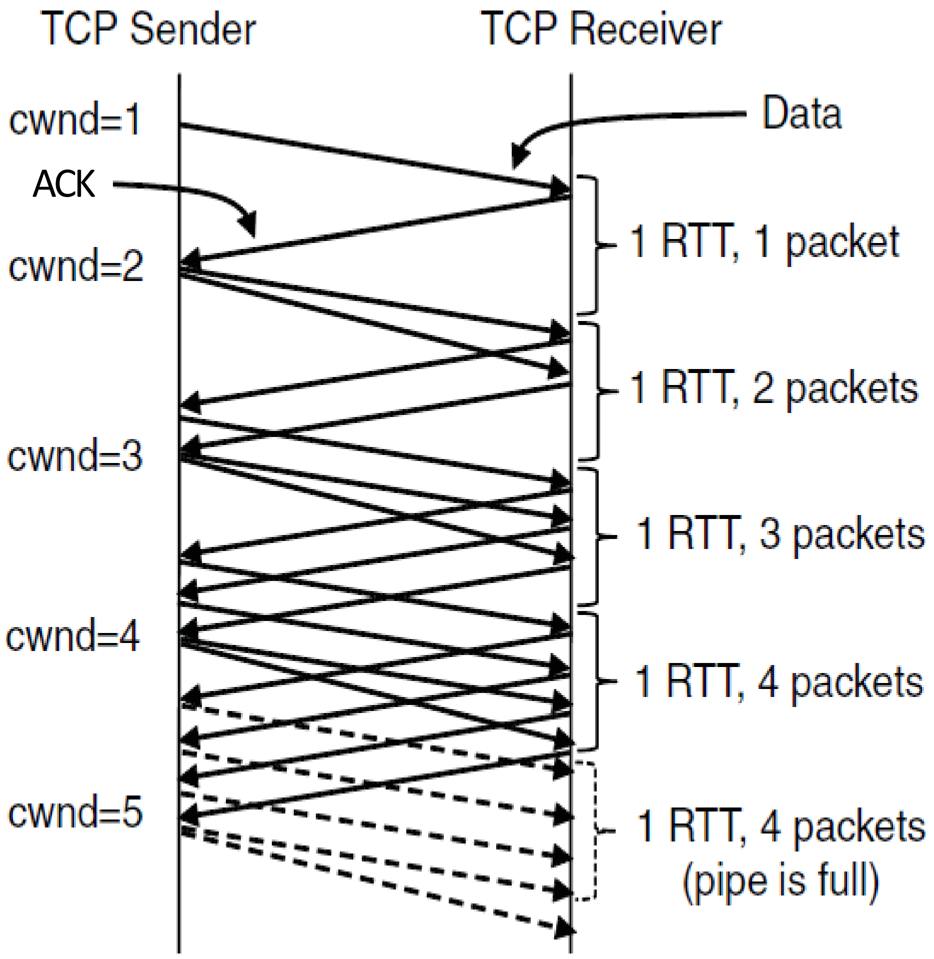
- Doubles every RTT while keeping ACK clock going



TCP Congestion Control (4)

Additive increase grows cwnd slowly

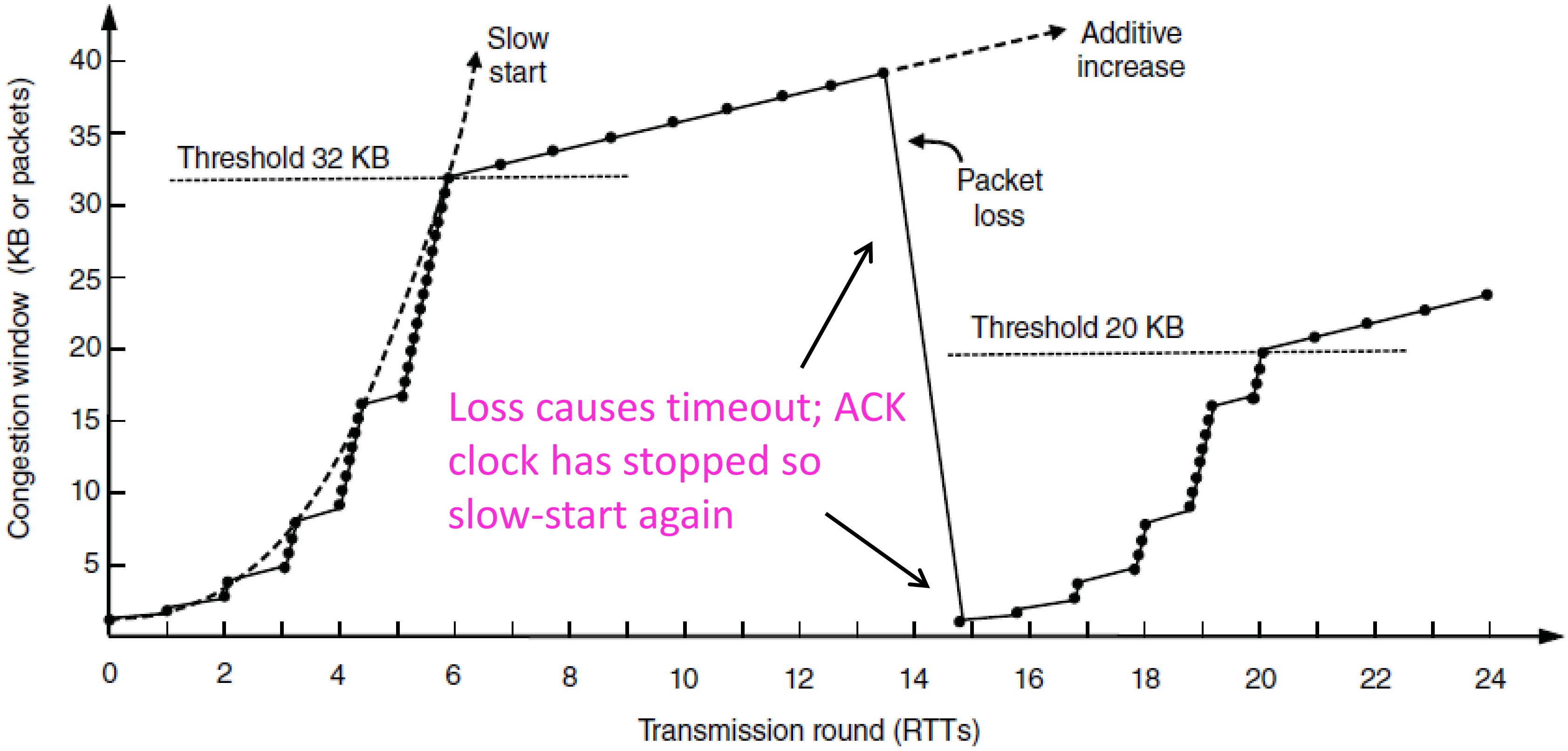
- Adds 1 every RTT
- Keeps ACK clock



TCP Congestion Control (5)

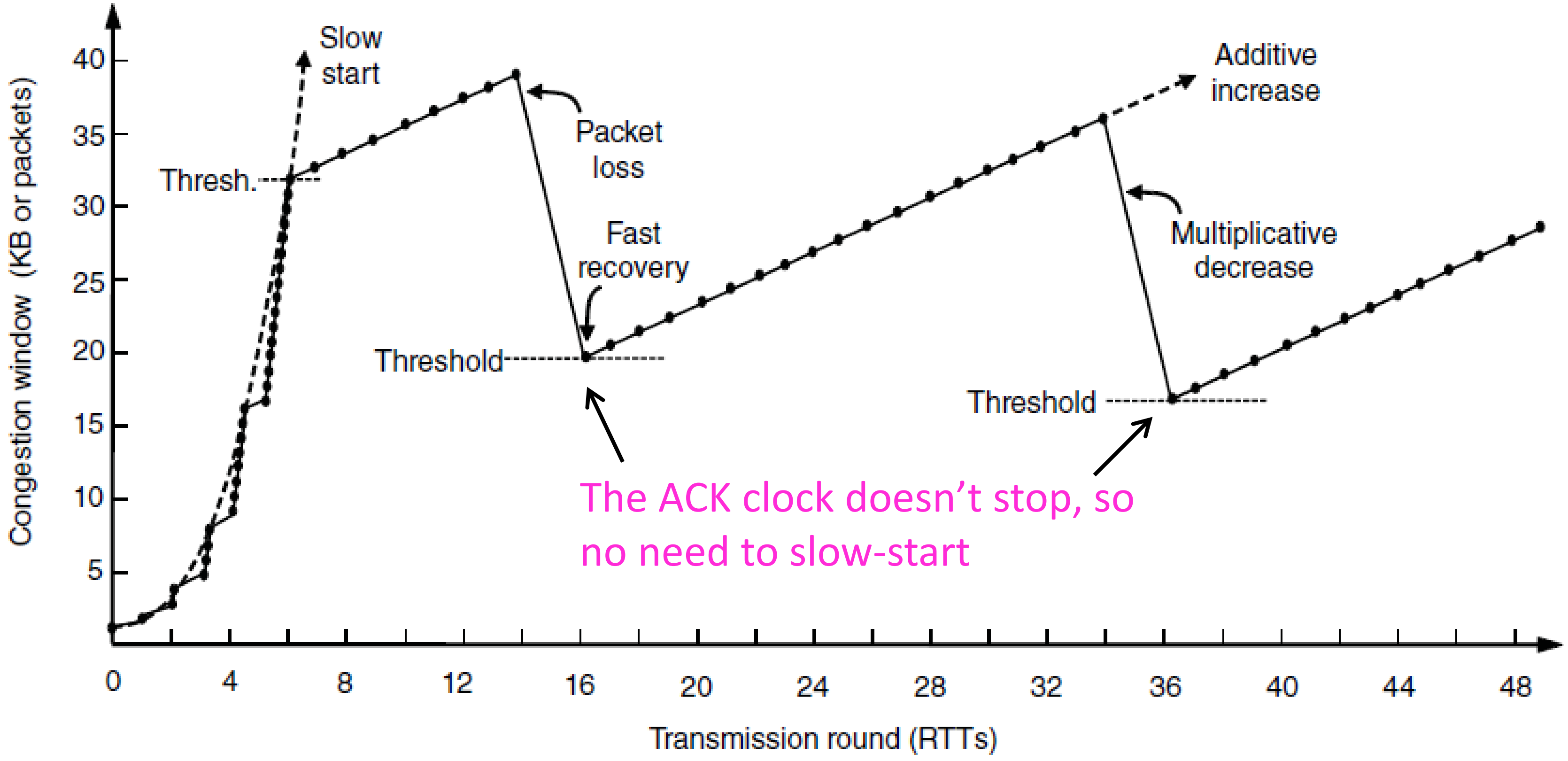
Slow start followed by additive increase (TCP Tahoe)

- Threshold is half of previous loss cwnd



TCP Congestion Control (6)

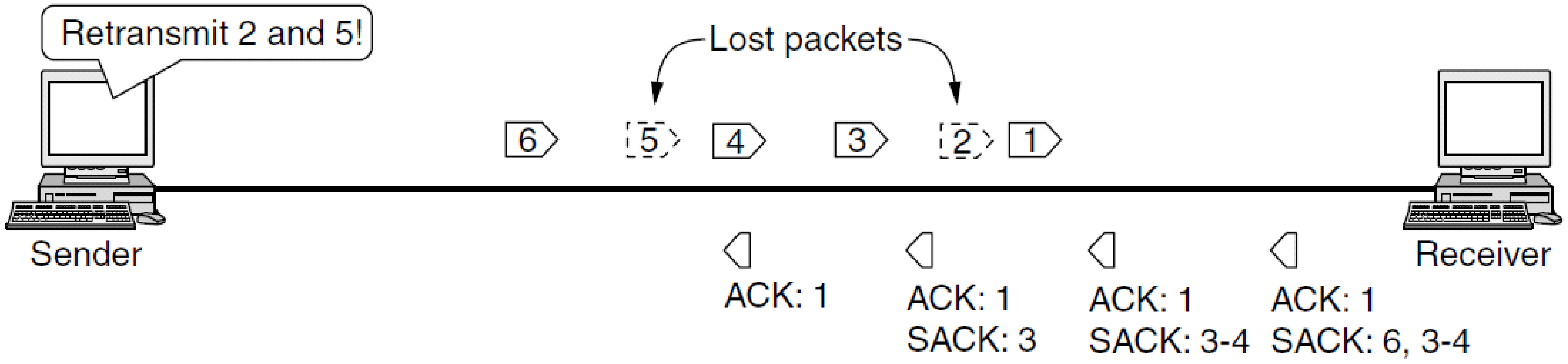
- With fast recovery, we get the classic sawtooth (TCP Reno)
  - Retransmit lost packet after 3 duplicate ACKs
  - New packet for each dup. ACK until loss is repaired



TCP Congestion Control (7)

SACK (Selective ACKs) extend ACKs with a vector to describe received segments and hence losses

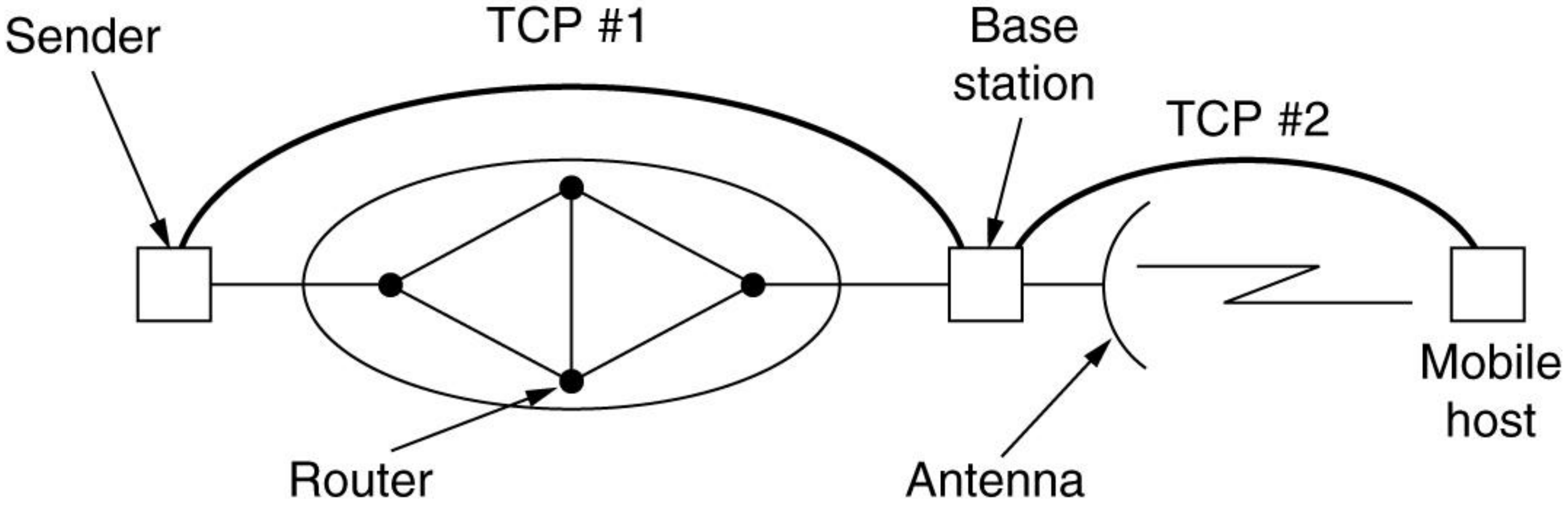
- Allows for more accurate retransmissions / recovery



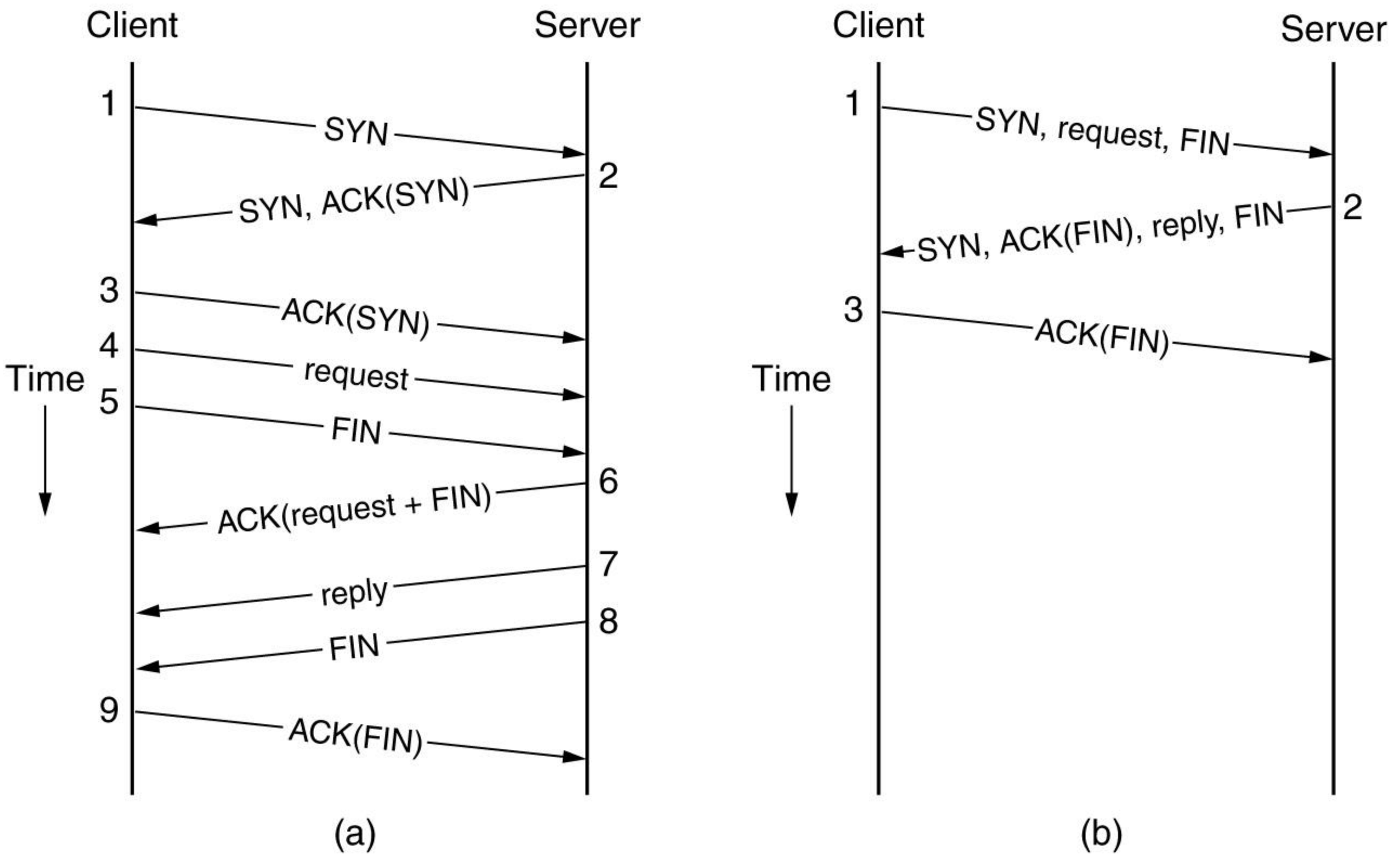
No way for us to know that 2 and 5 were lost with only ACKs

Wireless TCP and UDP

Splitting a TCP connection into two connections.



Transactional TCP



(a) RPC using normal TPC.

(b) RPC using T/TCP.

Performance Issues

Many strategies for getting good performance have been learned over time

- Performance problems »
- Measuring network performance »
- Host design for fast networks »
- Fast segment processing »
- Header compression »
- Protocols for “long fat” networks »

Performance Problems

Unexpected loads often interact with protocols to cause performance problems

- Need to find the situations and improve the protocols

Examples:

- Broadcast storm: one broadcast triggers another
- Synchronization: a building of computers all contact the DHCP server together after a power failure
- Tiny packets: some situations can cause TCP to send many small packets instead of few large ones

Host Design for Fast Networks

Poor host software can greatly slow down networks.

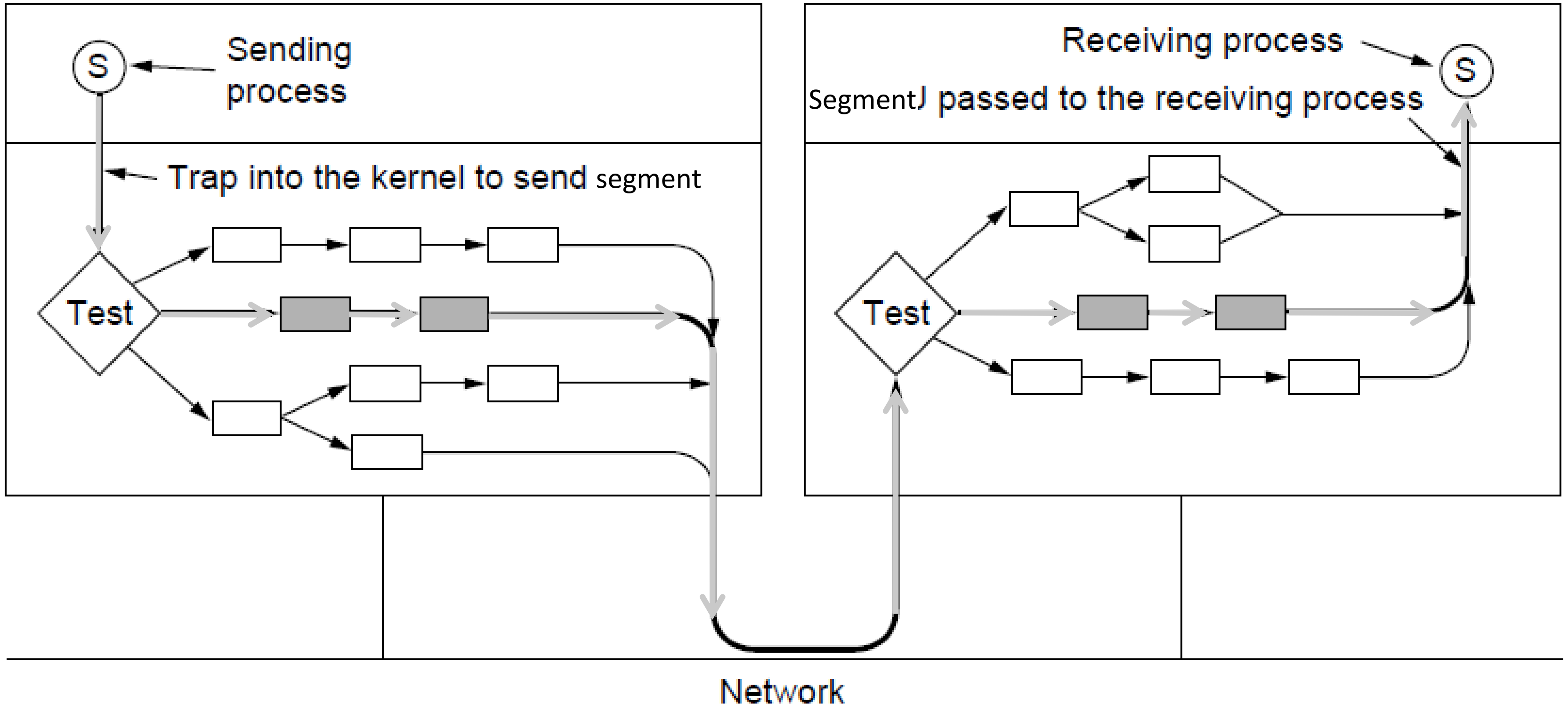
Rules of thumb for fast host software:

- Host speed more important than network speed
- Reduce packet count to reduce overhead
- Minimize data touching
- Minimize context switches
- Avoiding congestion is better than recovering from it
- Avoid timeouts

Fast Segment Processing (1)

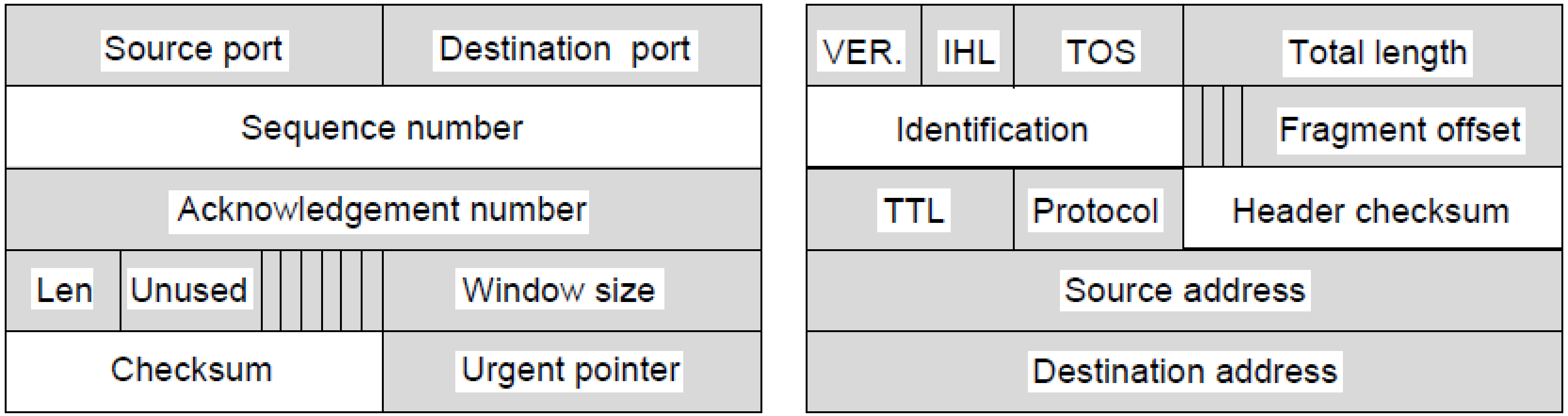
Speed up the common case with a fast path [pink]

- Handles packets with expected header; OK for others to run slowly



Fast Segment Processing (2)

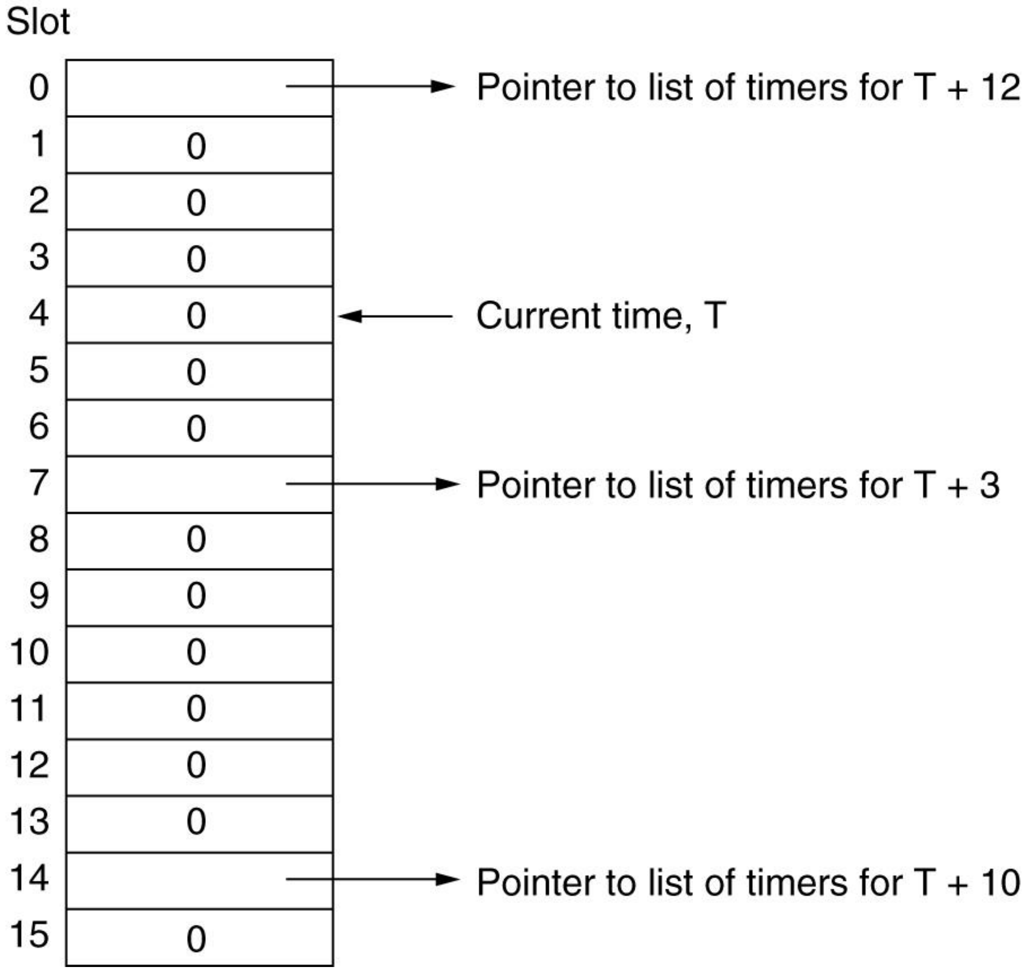
Header fields are often the same from one packet to the next for a flow; copy/check them to speed up processing



TCP header fields that stay the same for a one-way flow (shaded)

IP header fields that are often the same for a one-way flow (shaded)

Fast TPDU Processing (3)



A timing wheel.

Header Compression

Overhead can be very large for small packets

- 40 bytes of header for RTP/UDP/IP VoIP packet
- Problematic for slow links, especially wireless

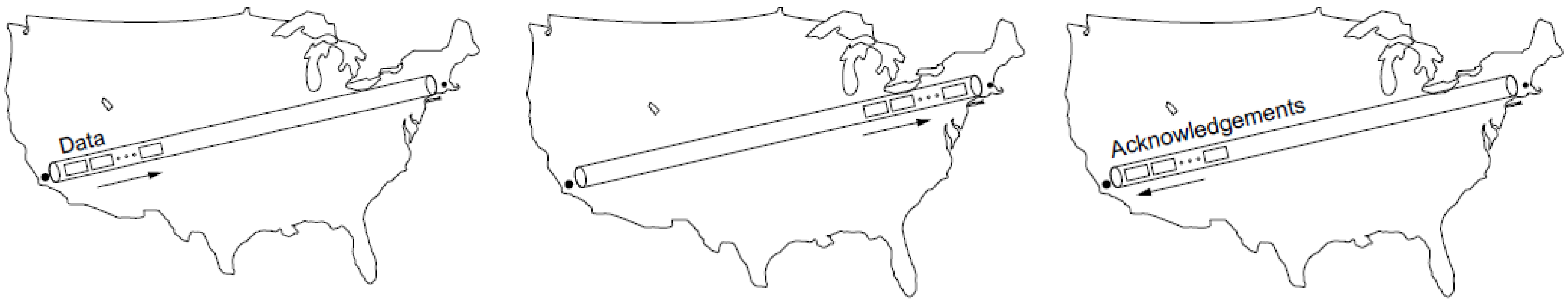
Header compression mitigates this problem

- Runs between Link and Network layer
- Omits fields that don’t change or change predictably
  - 40 byte TCP/IP header → 3 bytes of information
- Gives simple high-layer headers and efficient links

Protocols for “Long Fat” Networks (1)

Networks with high bandwidth (“Fat”) and high delay (“Long”) can store much information inside the network

- Requires protocols with ample buffering and few RTTs, rather than reducing the bits on the wire



Starting to send 1 Mbit San Diego → Boston

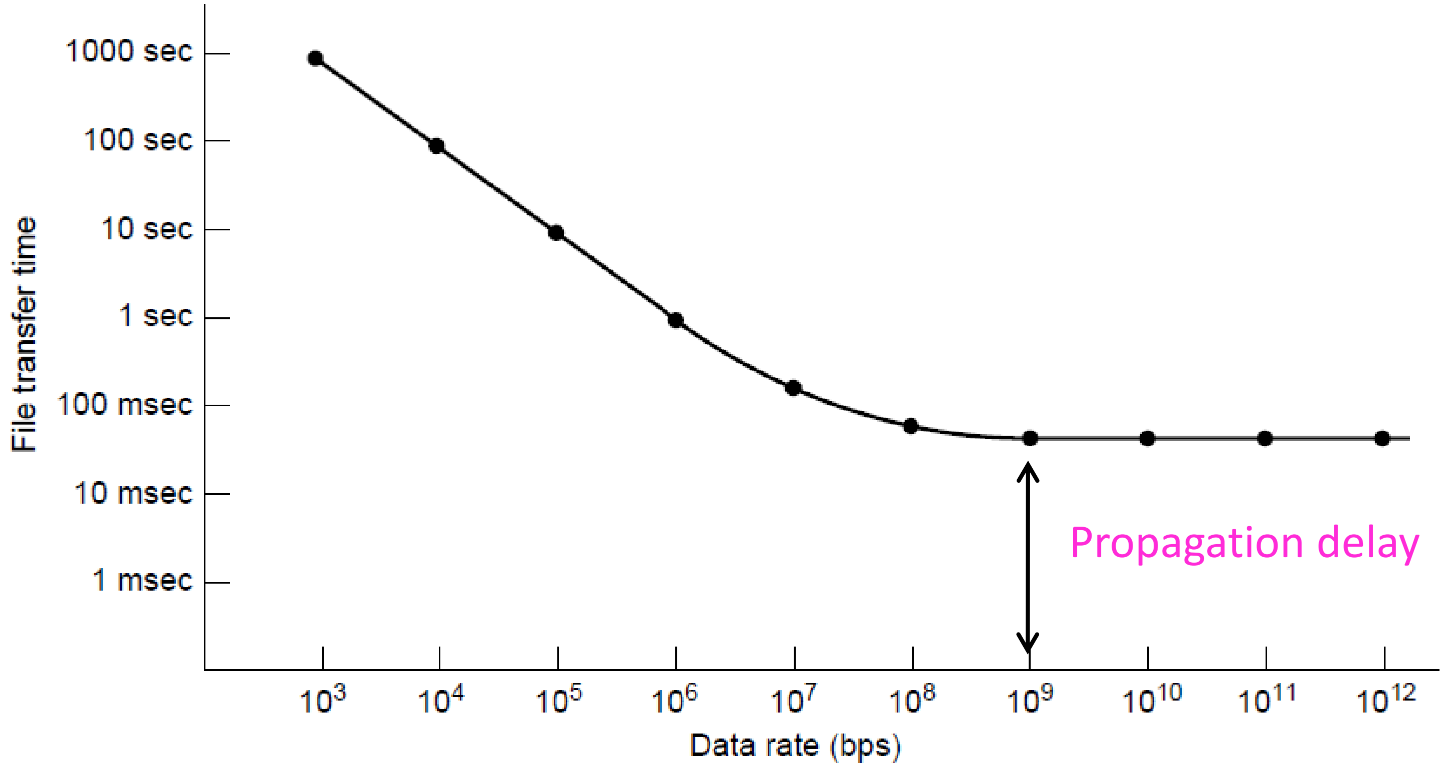
20ms after start

40ms after start

Protocols for "Long Fat" Networks (2)

You can buy more bandwidth but not lower delay

- Need to shift ends (e.g., into cloud) to lower further



Minimum time to send and ACK a 1-Mbit file over a 4000-km line

Delay Tolerant Networking

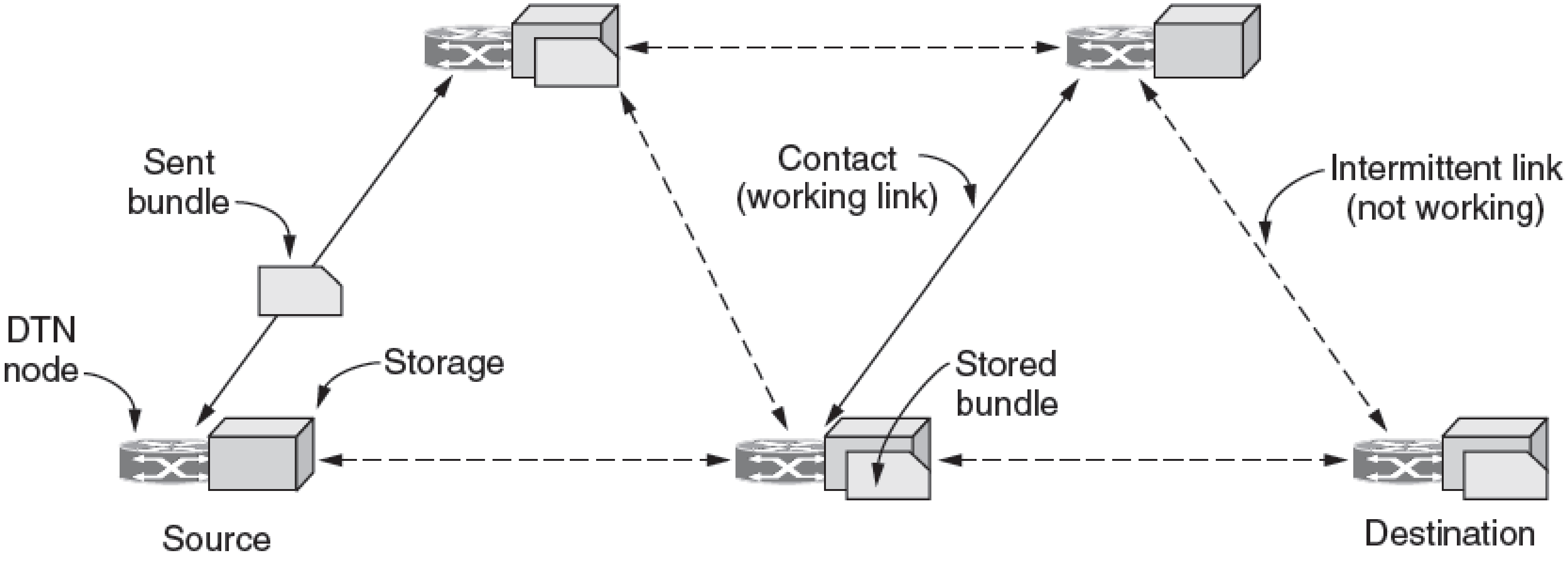
DTNs (Delay Tolerant Networks) store messages inside the network until they can be delivered

- DTN Architecture »
- Bundle Protocol »

DTN Architecture (1)

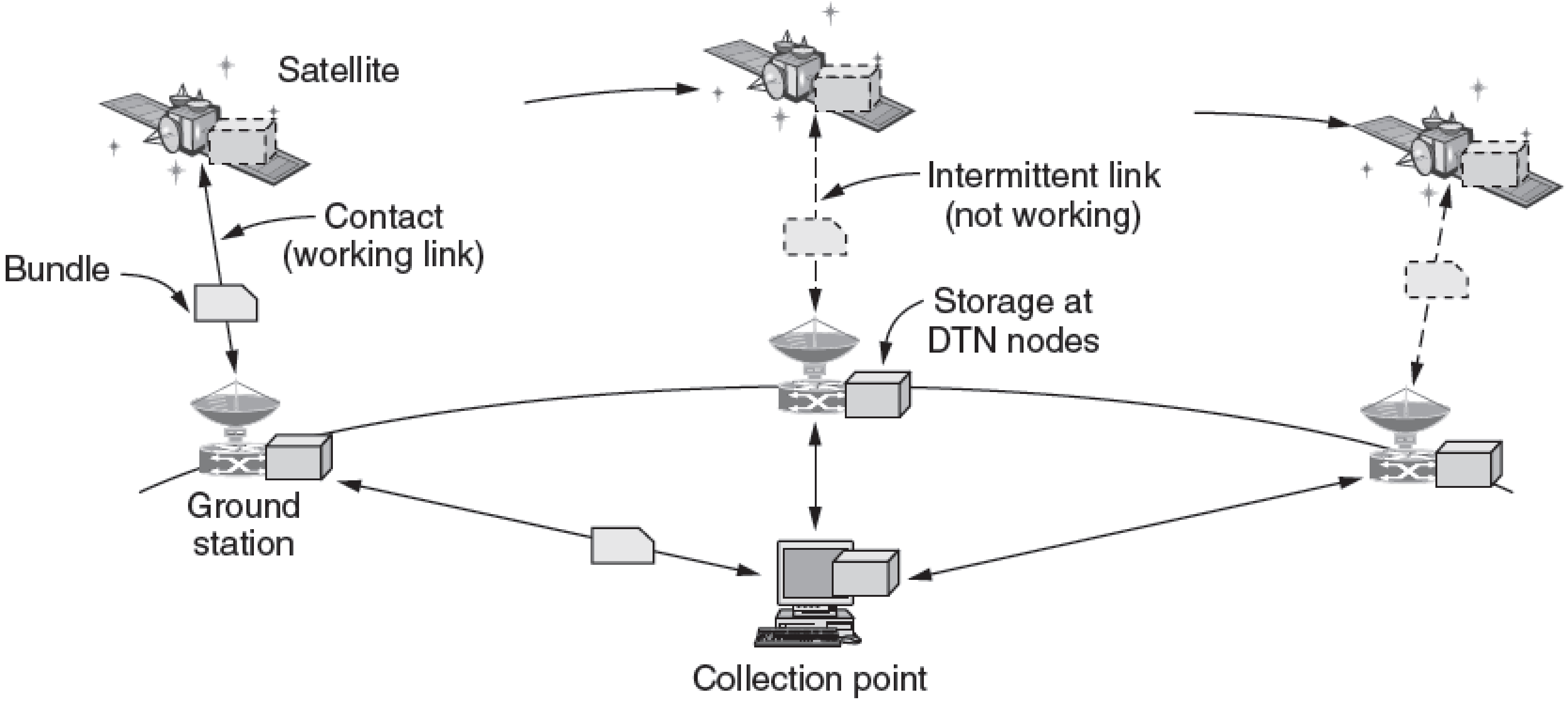
Messages called <u>bundles</u> are stored at DTN nodes while waiting for an intermittent link to become a contact

- Bundles might wait hours, not milliseconds in routers
- May be no working end-to-end path at any time



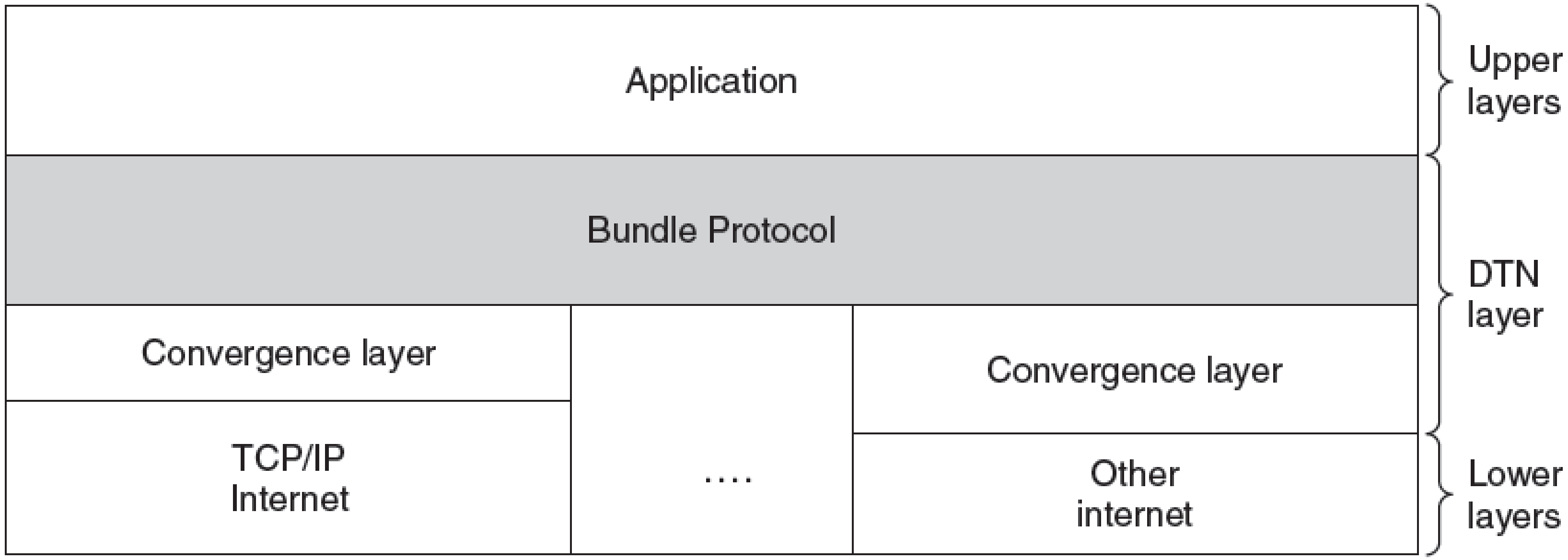
DTN Architecture (2)

Example DTN connecting a satellite to a collection point



Bundle Protocol (1)

The Bundle protocol uses TCP or other transports and provides a DTN service to applications



Bundle Protocol (2)

Features of the bundle message format:

- Dest./source add high-level addresses (not port/IP)
- Custody transfer shifts delivery responsibility
- Dictionary provides compression for efficiency