The Transport Layer: Review

Smith College, CSC 249
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TCP Congestion Control

1. How does a sender sense congestion?
   -
2. How does a sender determine its sending rate?
   -
   -
3. What algorithm is used to change the send-rate?
   - Many phases and alternatives...

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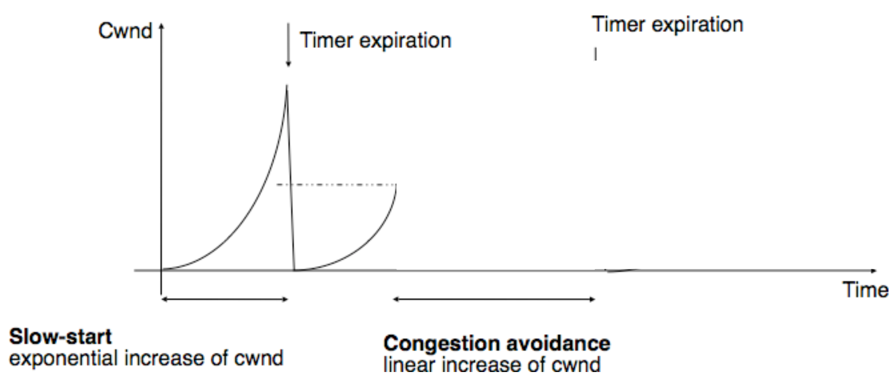
Reaction to Loss Events

- Exponential increase switches to linear increase when **CongWin** gets to the 'threshold' value (size)



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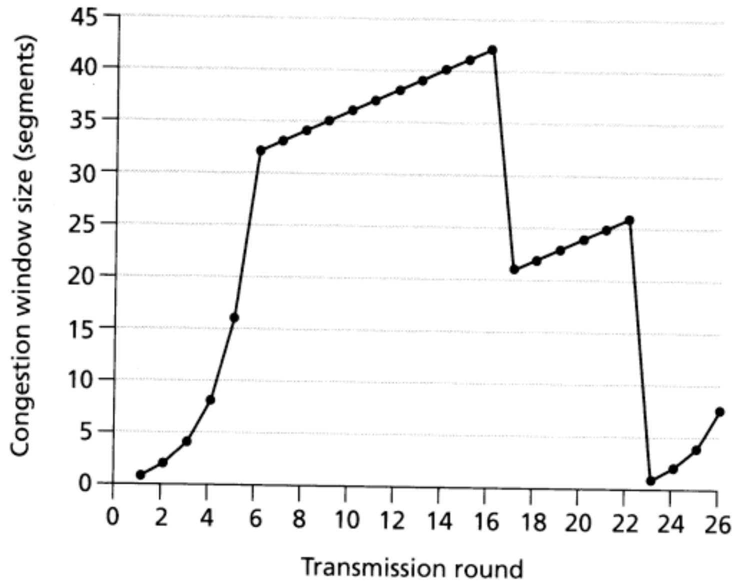
Identify everything on this graph



TCP Congestion Control Algorithm

Increase Sending Rate Phase Options:

1. When **CongWin** is below **Threshold**, sender in slow-start phase, window grows exponentially.
2. When **CongWin** is above **Threshold**, sender is in congestion-avoidance phase, window grows linearly.

Decrease Sending Rate Phase Options:

1. When a triple duplicate ACK occurs, **Threshold** set to **CongWin/2** and **CongWin** set to **Threshold**.
2. When timeout occurs, **Threshold** set to **CongWin/2** and **CongWin** is set to 1 MSS.

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TCP Congestion Control Algorithm

Three major phases / mechanisms:

1) Slow start – at 1 max segment size
   - But increase __________
2) Congestion Avoidance phase
   - AIMD = additive incr, multiplicative decr
   - Using cwnd and ssthresh
3) Fast Recovery
   - Increase of cwnd each round trip time
   - Slow start: _________
   - Congestion avoidance: _________

Summary TCP reaction to loss

- Loss indicated by timeout
  - **cwnd** set to 1 MSS
  - **ssthresh** set to **cwnd**/2
  - Window (**cwnd**) grows exponentially (slow start) to the threshold, then grows linearly
- Loss indicated by 3 duplicate ACKs
  - Network capable of delivering some segments, so…
  - **cwnd** is cut in half (=ssthresh)
  - Window grows linearly

Transport Layer Review

- The transport layer services are:
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Transport Layer Review

- The transport layer ***does not*** provide:
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Transport Layer Review

- Compare TCP and UDP (pros and cons?)
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Transport Layer Review

- TCP Connection Management includes
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Transport Layer Review

- Elements of TCP reliability:
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Transport Layer Review

- Elements of congestion control algorithm
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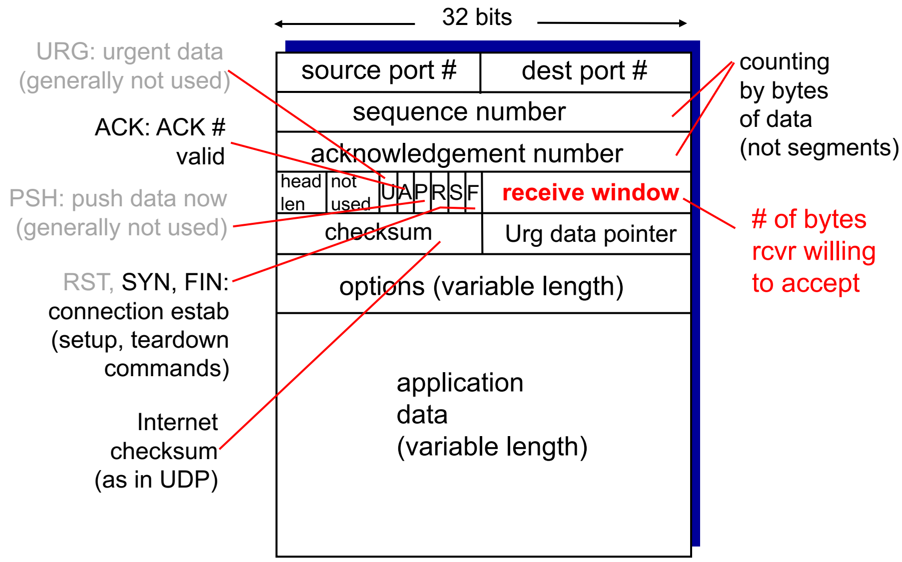
TCP Flow Control



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TCP flow control (quick & easy)

- Receiver "advertises" free buffer space by including **rwnd** value in TCP header of receiver-to-sender segments
  - **RcvBuffer** size set via socket options (typical default is 4096 bytes)
  - Many operating systems auto-adjust **RcvBuffer**
- Sender limits amount of un-ACKed ("in-flight") data to receiver's **rwnd** value
  - Guarantees receive buffer will not overflow

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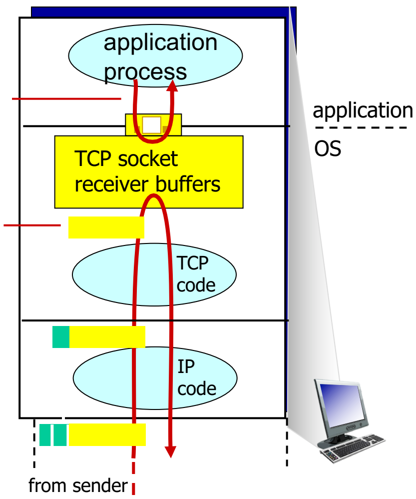
TCP flow control

The application may remove data from the TCP socket buffers ….

… slower than the TCP receiver is delivering it into the buffers (sender is sending)

flow control to the rescue!

receiver controls sender, so sender won't overflow receiver's buffer by transmitting too much, too fast



receiver protocol stack

Transport Layer Review

- Other questions?
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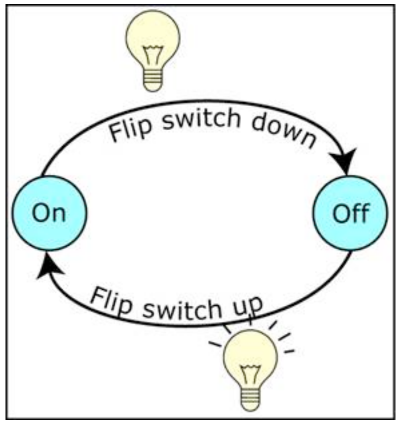
A fun tangent...
Finite State Machines



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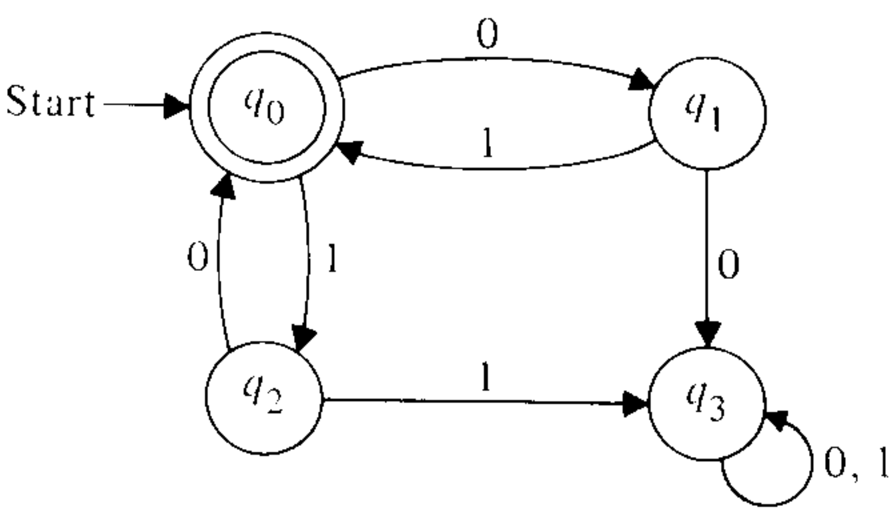
Finite State Machines



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TCP sender events:

(1) data received from application:

1. Create a segment and assign a SEQ number
   - SEQ # is byte-stream number of first data byte in segment
2. Start timer if it is not already running
   - Timer is for the oldest un-acked segment
   - Expiration interval: `TimeOutInterval`

(2) timeout:

1. Retransmit segment that caused the timeout
2. Restart the timer

(3) ACK received:

- For previously unacked segments
  1. update what is known to be acked
  2. start timer if there are outstanding segments

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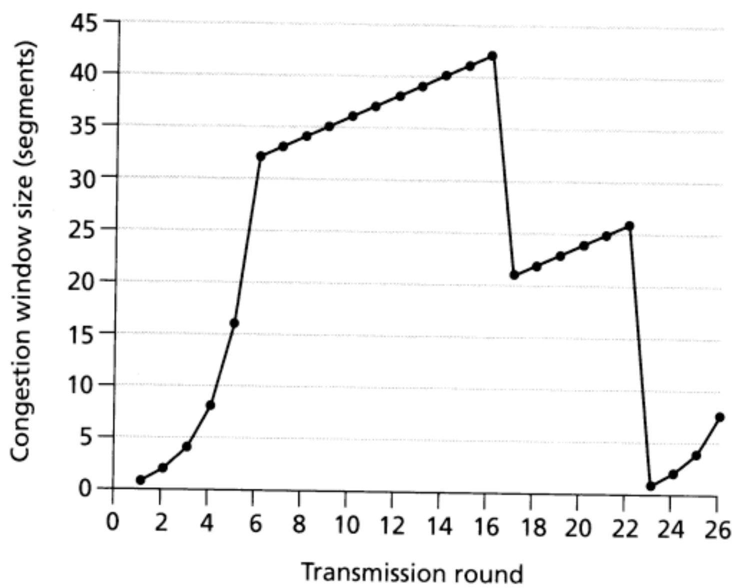
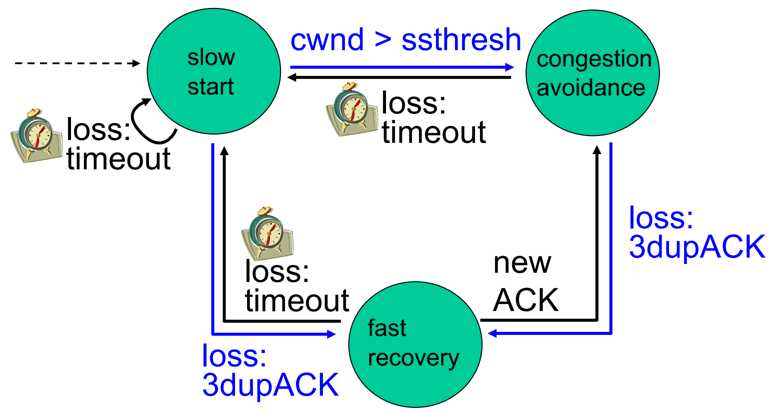
TCP Congestion Control



TCP Congestion Control: FSM



Transport Layer Summary

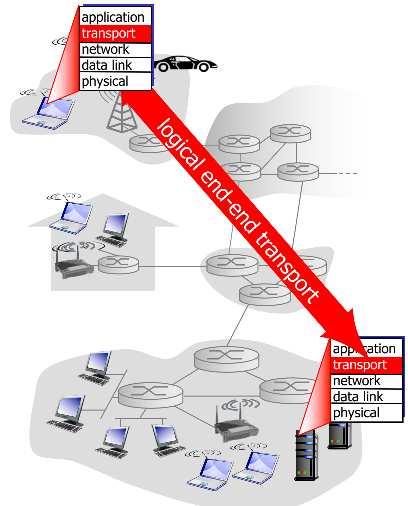
- TCP and UDP Services
- Encapsulation (create and attach header)
- Multiplexing and demultiplexing
- Checksum
- Connection management
- Reliable transport service
- Congestion control
- Detect loss and retransmit
  - Detect out-of-order and reorder
- Flow Control

Transport services and protocols

- Provide *logical communication, a virtual connection*

  …between application processes running on different hosts

  This is not a physical path including routers



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Introduction to the Network Layer

- Desired network layer services…
  - Actual network layer services
- Implemented in hosts and routers
- Two main network layer functions
- Three main network layer protocols

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Network Layer Services of IP?

- Guaranteed delivery?
- Guaranteed minimum delay?
- In-order datagram delivery?
- Guaranteed minimum bandwidth to flow?
- Restrictions on changes in inter-packet spacing?

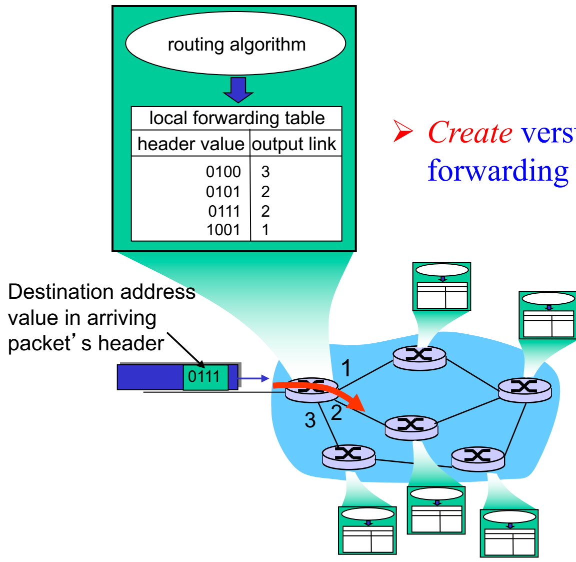
- IP Provides? → "Best-effort service"

Key Network-Layer Functions

1. *routing:* determine route taken by packets from source to destination
   - *Network-wide routing algorithms*

2. *forwarding:* move packets from router's input link to appropriate output link
   - *Internal to a single router*

Network Layer: Routing and Forwarding



- *Create* versus *use* the forwarding table

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Network Layer, Chapter 4

- Router 'switching fabric'
  - Hardware / electrical pathways within a router
- Forwarding – use the forwarding table to transmit, or forward, each packet to the correct output link, based on the destination IP address
- Routing – Create the forwarding tables
  - Decentralized vs. Centralized algorithms
  - Within an ISP vs. between ISPs
- Softward Defined Networks, SDN

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