ECE 356/COMPSI 356
Computer Network Architecture

Final Review

Monday December 9th, 2019

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One of the Course Goals: Understand the Technology You Use Every Day

- Client-server communications
  - Physical layer packet exchange
  - TCP session
  - HTTP request/response mechanisms
- Behind-the-scenes support mechanisms for end-to-end communications
  - Intra-domain and inter-domain routing
  - Queuing policies
  - Congestion avoidance
- Wireless communications, security, multimedia, sending e-mails, …

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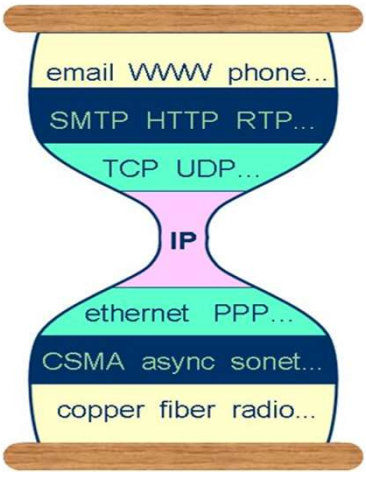
Key Network Architectures Principle

- **Protocol stack: layering**
  - Each protocol is implemented independently
  - Each protocol is responsible for a specific subtask
  - Protocols are grouped in a hierarchy
- Protocol *peer* and *service* interfaces
- Encapsulation and decapsulation
  - Each layer adds its own header



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Axioms of Computer Networking

- Networks are error-prone
  - Bit errors
  - Buffer constraints
- Networks are shared
  - Multiple access
  - Congestion control
  - Resource allocation
- Networks are not secure

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Final: Expectations

- Fundamental concepts
- Key algorithms / protocols

Course Grading

- Final: **20%**
- In-class quizzes: 5%
- Homeworks: 20%
- Labs: 40%
- Midterm: 15%

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Final Policy

- Date, location: on Duke Hub
  - December 15th, 7 – 10 PM, HH 125
- Covers all lectures, with an emphasis on post-midterm material
  - Includes the invited lecture
- Closed book/notes
- No Internet
- Allowed:
  - One two-sided hand-written page, written by you (letter-size)
  - A calculator

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You Need to Know The Material Covered in Class

- Will not ask questions on material covered in the book but not in class
- Will ask questions on lecture materials not covered in the book

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Additional Study Materials

- HW1, HW2, HW3 solutions
- Lab2, Lab3 concepts and materials
  - If you are working in a group, please make sure to understand the parts done by your lab partner
- In-class quiz answers
  - Make sure you understand everything you did not get right
- Midterm and makeup midterm solutions
  - Make sure you understand everything you did not get right
  - Note that final emphasizes post-midterm materials

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What We've Learned: Physical Layer Through IP

- Please review October 14th midterm review lecture
- IP protocol
  - Hierarchical addressing
  - CIDR notation, e.g., 128.143.137.144/**24**
  - Longest prefix match
- ARP

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What We've Learned: Routing

- Please review October 9th routing wrap-up lecture
- Also routing material on midterm, Lab 3
- Intra-domain routing
  - Link state routing
  - Distance vector routing
- Inter-domain routing

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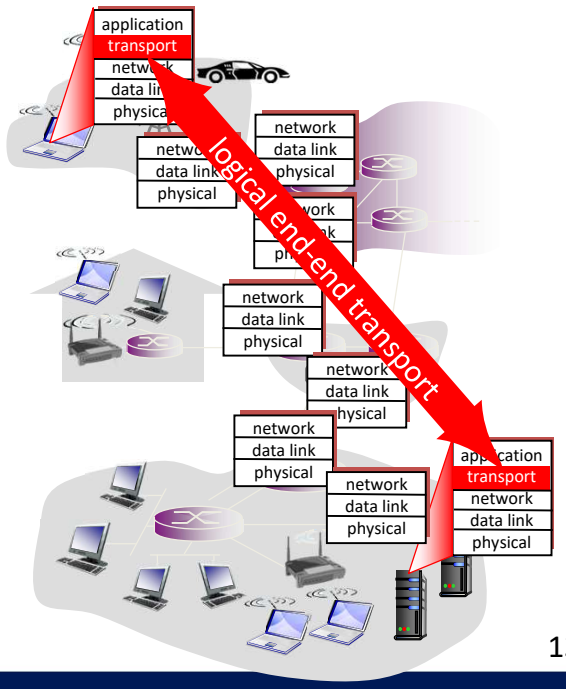
What We've Learned: Transport Protocols

- Transport control is needed because of best-effort nature of IP
- Transport protocols are **end-to-end**



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What We've Learned: UDP

- A bare-bones protocol that only provides
  - Demultiplexing by port numbers
  - Checksumming of data
- Has important advantages
  - HW exercises on TCP vs. UDP for different scenarios
- DNS, RIP, some multimedia applications run over UDP

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What We've Learned: TCP

- TCP provides **reliable unicast** service
  - Without gaps
  - Without duplication
  - In sequence
- Mechanisms:
  - TCP connection establishment and termination
  - Reliable data transfer
  - TCP flow control

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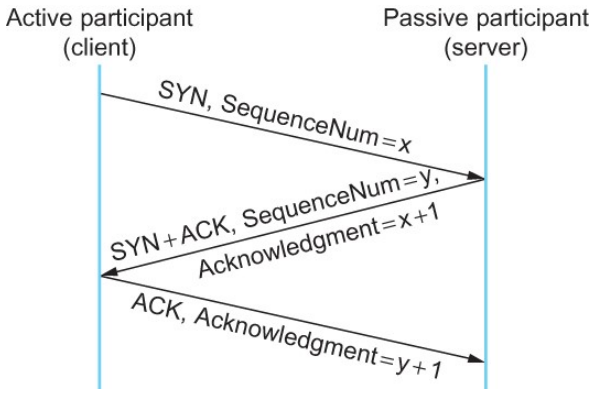
What We've Learned: TCP Connection Establishment

- TCP connection needs to be set up and torn down
  - Allocate and deallocate resources on both ends of the communication
- Mechanism: three-way handshake



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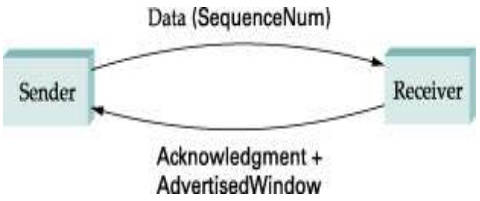
What We've Learned: TCP Flow Control

- Receiver controls sender so sender won't overflow receiver's buffer by transmitting too much, too fast
- Buffer space *explicitly signaled* in segment headers
  - Highly dynamic



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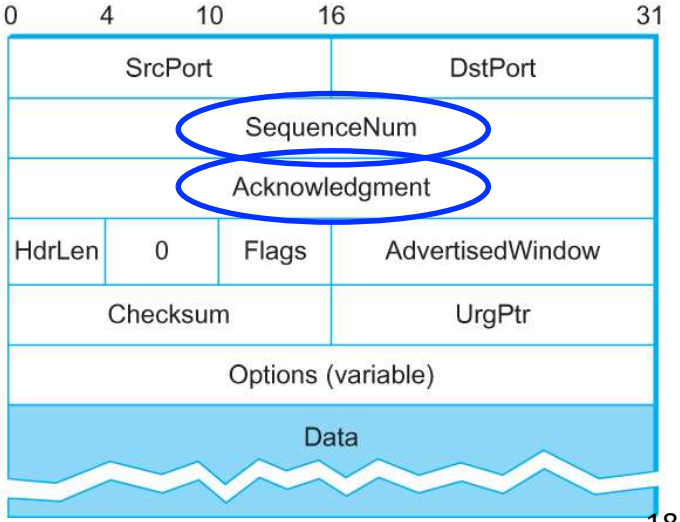
What We've Learned: TCP Reliable Data Transfer (1/2)

- Sequence numbers and acknowledgements
  - SequenceNum identifies the first byte in the segment
  - Acknowledgement contains the next SequenceNum that a host is expecting



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What We've Learned: TCP Reliable Data Transfer (2/2)

- Acknowledgements, timeouts, retransmissions
  - Cumulative acknowledgements
  - Timeouts set to a sender-estimated **estimated RTT + a safety margin**
  - Retransmissions triggered by:
    - Timeout events
    - Duplicate ACKs – *fast retransmit* mechanism

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What We've Learned: Congestion

- Congestion: "*Too many sources sending too much data too fast for network to handle*"
- Manifestations:
  - Long delays (queuing in router buffers)
  - Lost packets (buffer overflow at routers)
- Congestion control is different from flow control

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What We've Learned: TCP Congestion Control

- Each sender limits the rate at which it sends traffic into its connection, as a function of *perceived network congestion*
  - Congestion is inferred by the sender
- **Packet loss** is the congestion signal
- Receiving acknowledgements is a signal that all is well

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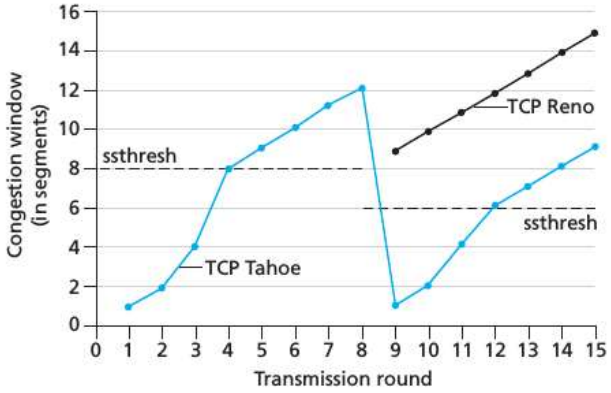
What We've Learned: Congestion Control Algorithm Components

- Slow start
- Congestion avoidance
- Fast recovery
- In-depth HW2 exercise on this



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What We've Learned: Queuing

- **Router-enforced** resource allocation
  - Scheduling policy: which packet gets sent
  - Drop policy: which packet gets dropped
- Default queueing approach: FIFO with drop tail
- Priority queuing: multiple FIFO queues for packets with different priority levels
  - May starve low-priority packets
- Fair queuing: a queue for each flow
  - Shares available bandwidth fairly between the flows

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What We've Learned: Router-Based Congestion Avoidance (1/2)

- **Congestion avoidance** rather than reaction to congestion
- Routers can *explicitly* notify sources about congestion
  - DECbit, Explicit Congestion Notification (DECbit)
- Random Early Detection (RED)
  - Routers *implicitly* notify sources by dropping packets
  - Drop packets at random, as a function of the level of congestion
  - Probability to drop flow's packet is ~ proportional to the flow's share of bandwidth

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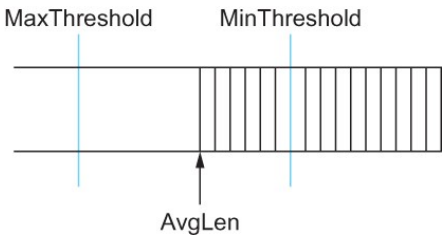
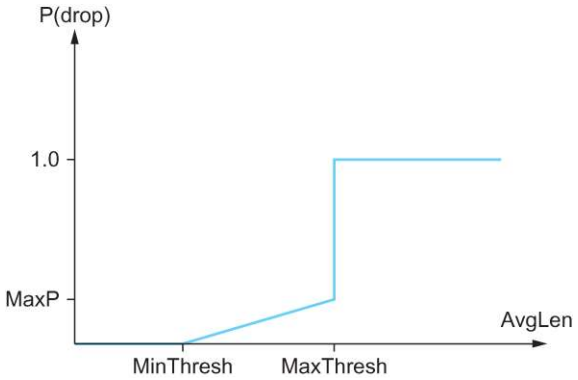
What We've Learned: Router-Based Congestion Avoidance (2/2)

- Two thresholds for different packet drop policies



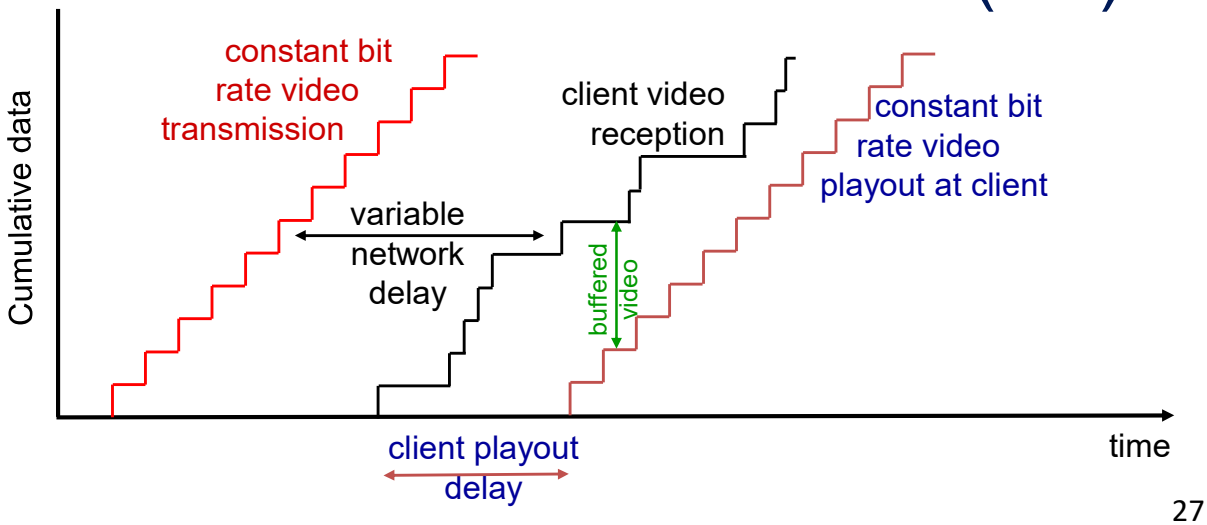


Drop probability function for RED

What We've Learned: Multimedia Communications (1/2)

- A large and ever-growing portion of Internet traffic
- Different categories of multimedia:
  - *Streaming* stored audio and video
  - Conversational voice and video over IP: **highly delay-sensitive**
  - Streaming live audio and video

What We've Learned: Multimedia Communications (2/2)



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What We've Learned: DNS

- Map an easy-to-remember name to an IP address
- Needs to be very fast
- *Distributed database* implemented in hierarchy of many *name servers*
- Rely on a 3-level server hierarchy, plus local servers
  - Root servers
  - Top-level domain servers (TLD)
  - Authoritative servers
- Uses caching to reduce client latency and network loads

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What We've Learned: HTTP

- Web's application layer protocol
- Client downloads a webpage consisting of multiple objects
  - Multiple objects can be handled in *persistent* and *non-persistent* manner
- Stateless
- Uses cookies to keep state

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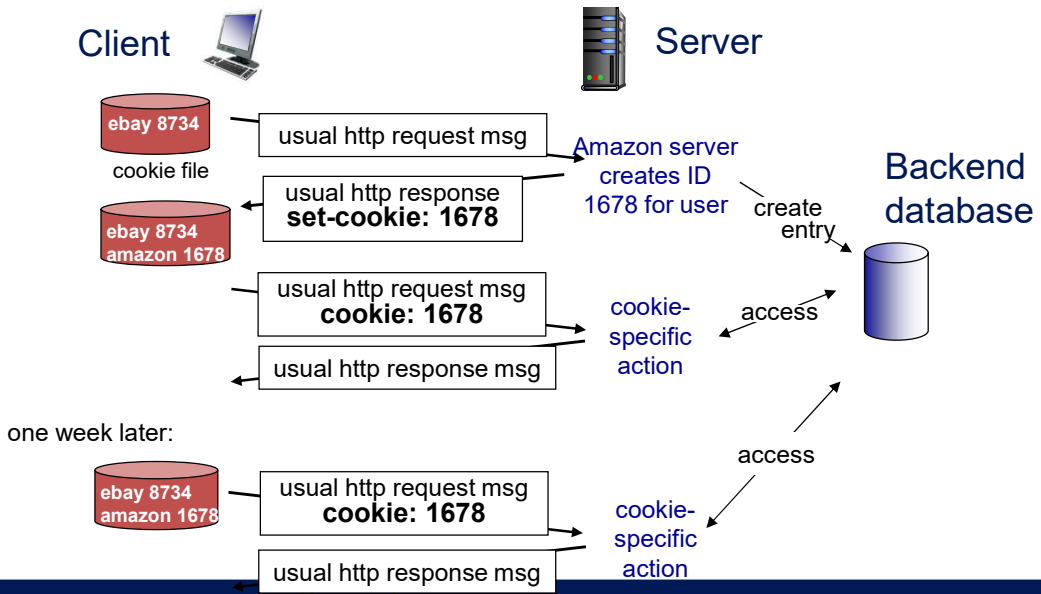
Cookies: An Example



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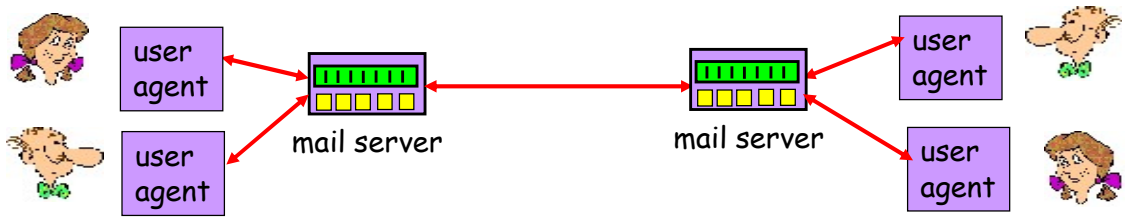
What We've Learned: Web Mail



- Role of user agents and mail servers
- Role of SMTP and mail access protocols
  - **SMTP:** delivery/storage to receiver's server
  - Mail access protocols: retrieval from server
    - HTTP is an option for mail access

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What We've Learned: Network Security

- Symmetric and *public key* cryptography
  - Combining both: **session key** approach
- Message integrity approaches
  - Message authentication code
  - Digital signature
- Role of certification authorities
- Secure Socket Layer (SSL)
  - Handshaking mechanism
  - Encryption, integrity verification

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Good luck on finals!