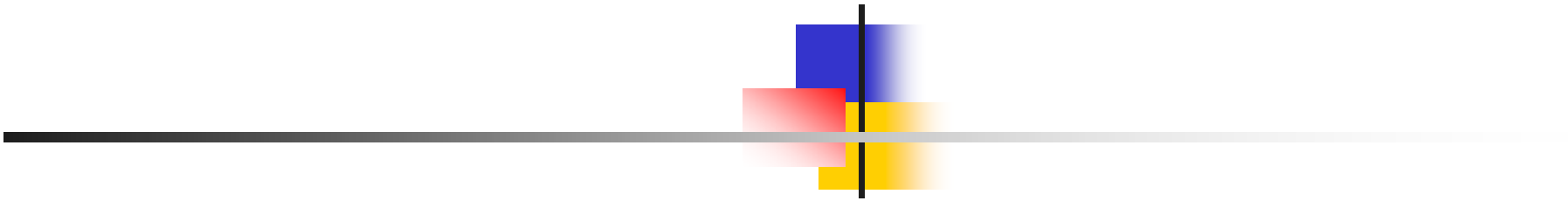
CSE398: Network Systems Design



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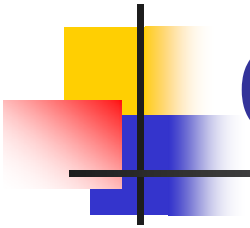
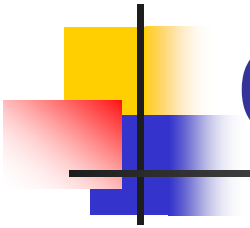


Outline

- Recap
  - Packet processing algorithms (Problem 5.11)
- Packet processing functions
- Summary and homework



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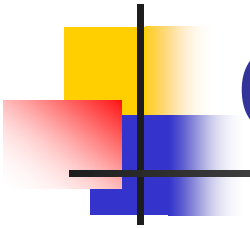
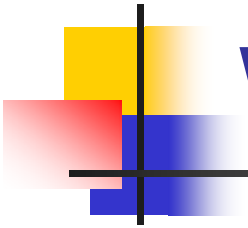


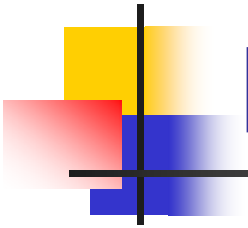
Goals

- Identify functions that occur in packet processing
- Devise set of operations sufficient for all packet processing
- Find an efficient implementation for the operations



What We Will Consider

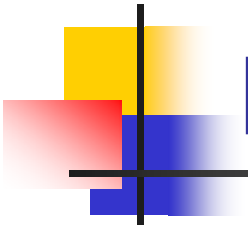
- Address lookup and packet forwarding
- Error detection and correction
- Fragmentation, segmentation, & reassembly
- Frame and protocol demultiplexing
- Packet classification
- Queueing and packet discard
- Scheduling and timing
- Security: authentication and privacy
- Traffic measurement and policing
- Traffic shaping



Recap

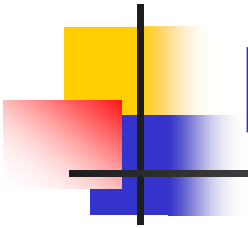
- Forwarding requires address lookup
  - Table driven
  - Cost depends on table size & lookup types
    - Exact match (typically layer 2)
    - Longest-prefix match (typically layer 3)
- Error detection and correction
  - Cost depends on packet size
- Fragmentation, segmentation, & reassembly
  - Cost is high due to memory & state management

Frame & Protocol Demultiplexing

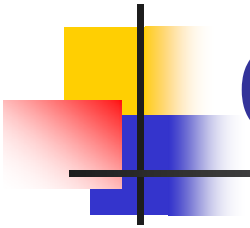


- Glue a protocol at one layer to a protocol at the layer above
- Type appears in each header
  - Ethernet header
    - IP <-> $(0800)_{16}$
  - IP header
    - TCP <-> 6; UDP <-> 17
- Cost of demultiplexing proportional to
  - Number of layers

Packet Classification

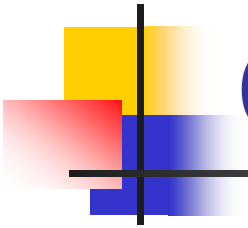


- An static example
  - A frame containing an IP datagram that carries a TCP segment
  - A frame containing an IP datagram that carries a UDP datagram
  - A frame containing an IP datagram that carries a ICMP message
  - A frame that contains something other than the above
- Alternative to demultiplexing
- Crosses multiple layers in one step
  - Achieves lower cost
- What could be a dynamic example?



Queueing and Packet Discard

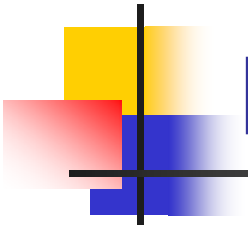
- General paradigm is store-and-forward
  - Incoming packet placed in a queue
  - Outgoing packet placed in a queue
- When the queue is full, choose a packet to discard
- Affects throughput of higher-layer protocols



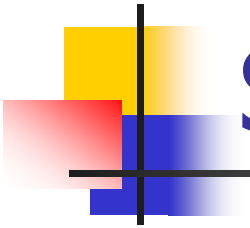
Queueing Priorities

- Multiple queues used to enforce priority among packets
- Incoming packet
  - Assigned priority as function of contents
  - Placed in appropriate priority queue
- Queueing discipline
  - Examines priority queues
  - Chooses which packet to send
  - Drop/discard mechanism: tail drop

Examples of Queueing Disciplines

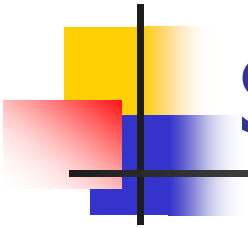


- Priority Queueing
  - Assign unique priority number to each queue
  - Choose packet from highest priority queue that is nonempty
  - Known as strict priority queueing
  - Can lead to starvation
- Weighted Round Robin (WRR)
  - Assign unique priority number to each queue
  - Process all queues round-robin
  - Compute N, max number of packets to select from a queue proportional to priority
  - Take up to N packets before moving to next queue
  - Works well if all packets equal size
- Weighted Fair Queueing (WFQ)
  - Make selection from queue proportional to priority
  - Use packet size rather than number of packets
  - Allocates priority to data amount of from a queue rather than number of packets



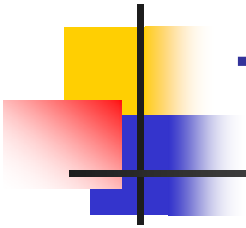
Scheduling

- Used to coordinate parallel and concurrent tasks
  - Processing on multiple packets
  - Processing on multiple protocols
  - Multiple processors
- A scheduler attempts to achieve fairness



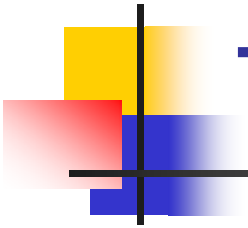
Security: Authentication & Privacy

- Authentication mechanisms
  - Ensure sender's identity
- Confidentiality mechanisms
  - Ensure that intermediaries cannot interpret packet contents
- Note: in common networking terminology, privacy refers to confidentiality
  - Example: Virtual Private Networks



Traffic Measurement and Policing

- Used by network managers
  - Often related to Service Level Agreement (SLA)
  - Can measure aggregate traffic or per-flow traffic
- Against hard boundaries
- Traffic profile
  - CBR
  - VBR: sustained data rate, …
  - ABR
  - UBR
- Cost is high if performed in real-time
  - Critical path



Traffic Shaping

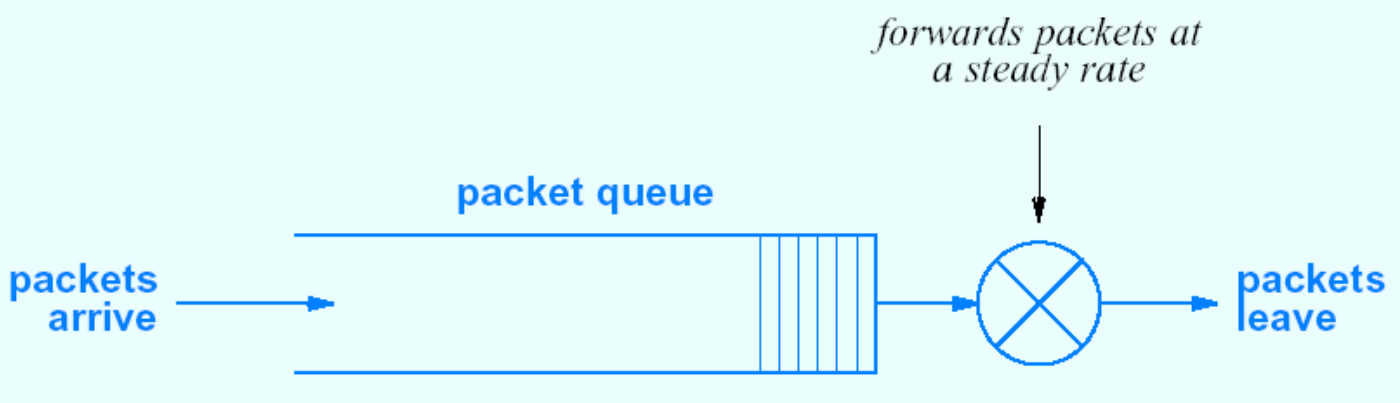
- Make traffic conform to statistical bounds
- Possibilities
  - Discard packets (seldom used) or delay packets
- Typical use
  - Smooth bursts and avoid packet trains

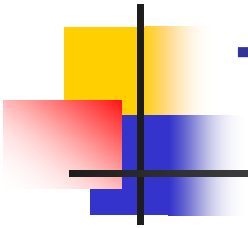
Traffic Shaping Examples

- Leaky bucket
  - Easy to implement
  - Popular
  - Sends steady number of packets per second
  - Rate depends on number of packets waiting
  - Does not guarantee steady data rate
- Token bucket
  - Sends steady number of bits per second
  - Rate depends on number of bits waiting
  - Achieves steady data rate
  - More difficult to implement

Illustration of Traffic Shaper

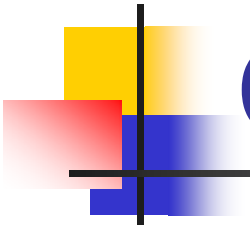
- Bursty input and steady output





Timer Management

- A fundamental piece of network systems
- Needed for multiple layers
  - Scheduling
  - Traffic shaping
  - Other protocol processing (e.g., retransmission)
- Cost
  - Depends on number of timer operations (e.g., set, cancel)
  - Can be high



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Homework (due on 02/28)

- 7.1. Problem 1 of Chapter 6 (Page 83).

- A question to be studied offline that does not need to be handed in.
  (a) Read RFC 3232 and related document and find the assigned Internet protocol numbers for ICMP, IGMP, RSVP, TCP, UDP, SIP.
  (b) Review Table 2 in a paper downloadable at:
  http://www.cse.lehigh.edu/~cheng/papers/COMCOM-xDSL.pdf