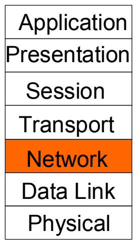
CSE 461 – Module 10

Introduction to the Transport Layer

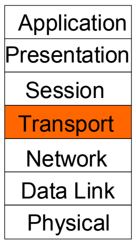
Last Time

- We finished up the Network layer
  - Internetworks (IP)
  - Routing (DV/ RIP, LS/ OSPF, BGP)
- It was all about routing: how to provide end-to-end delivery of packets.



This Time

- We begin on the Transport layer
- Focus
  - Process-to-process communication
    - Fast?
    - Reliable?
  - Impact on the network
    - Congestion control
- Topics
  - The Transport layer
  - Acknowledgements and retransmissions (ARQ)
  - Sliding windows

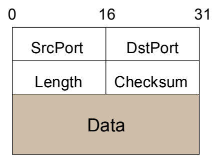


The Transport Layer

- Builds on the services of the Network layer
  - “TCP/ IP”
- Communication between processes running on hosts
  - Naming/ Addressing
- Stronger guarantees of message delivery make sense
  - This is the first layer that is talking “end-to-end”

Internet Transport Protocols

- UDP
  - Datagram abstraction between processes
  - With error detection



- TCP
  - Bytestream abstraction between processes
  - With reliability
  - Plus congestion control (later!)

UDP/IP Properties (User Datagram Protocol)

UDP

- Datagram oriented
- Lost packets
- Reordered packets
- Duplicate packets
- Limited size packets

IP

- Datagram oriented
- Lost packets
- Reordered packets
- Duplicate packets
- Limited size packets

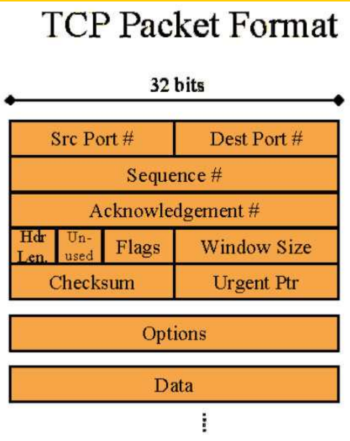
TCP/IP Properties (Transmission Control Protocol)

TCP
- Connection-oriented
- Reliable byte-stream delivery
  - In-order delivery
  - Single delivery
  - Arbitrarily long messages
- Synchronization
- Flow control
- Congestion control

IP
- Datagram oriented
- Lost packets
- Reordered packets
- Duplicate packets
- Limited size packets

M10.7

TCP Packet Format



16 bit window size gets
Cramped with large
Bandwidth x delay

16 bits --> 64K
BD ethernet: 122KB
STS24 (1.2Gb/s): 14.8MB

32 bit sequence number
must not wrap around faster
than the maximum packet
lifetime. (120 seconds)
-- 622Mb/s link: 55 seconds

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TCP End-to-End Properties

- TCP provides a full-duplex connection
  - Each side of a connection can send to the other
- Connection is a stream
  - Packet boundaries may not be visible to application
- Sliding window
  - Endpoints exchange window sizes
  - Packets carry sequence numbers
    - Actually, byte counts in the connection stream
  - Performance
  - Reliability (ARQ)

End-to-end Properties

- Performance
  - Sliding Window
    - Try to enable sender to put bandwidth *x* delay product bytes on the wire
- Reliability
  - Lost packets?
    - Sliding window performs flow control
    - Sliding window performs ARQ (Automatic Repeat Request)
  - Duplicate / out-of-order packets?
    - Sliding window receive (re-order) buffer

Network Property: Congestion Control

- TCP also implements congestion control
  - High level goal: keep from over-loading the bottleneck network link
  - Immediate goal: find the fastest transmission rate that doesn't overload the bottleneck
- Does it make sense to put congestion control in TCP?
  - Could it be in some other layer?
    - Would it make sense to apply it to UDP?
- Another goal: fairness
  - I'm not slowing down, you slow down…

TCP / UDP comparison

TCP	UDP
Reliable	Unreliable
Stream-oriented	Packet-oriented
Connection	Connectionless

TCP / UDP comparison

- Stream- vs. packet-oriented
  - Visible packet boundaries can act as "end of record" indicators to application
  - In a stream, if the application wants the notion of "records", it must embed them in the data
    - Example: lines in a text file
  - Since TCP doesn't know about app record boundaries, reading records can be cumbersome
    - Each read() operation returns whatever data happens to have arrived in the stream to this point

TCP / UDP comparison

- Connection vs. connectionless
  - UDP: "flexible" (or "you don't know who you're talking with")
    - Incoming data can be from anywhere
    - Outgoing data can go anywhere
    - *(Java API provides a connect() interface – filters packets before returning them to app)*
  - TCP: incoming/ outgoing packets are separated into "flows"
    - Provides a nice programming abstraction for many apps
    - How do I open a connection?
    - How do I close one?
    - How do I know when the other side has stopped listening/ sending