COMP 431
Internet Services & Protocols

The Transport Layer
Multiplexing, Error Detection, & UDP

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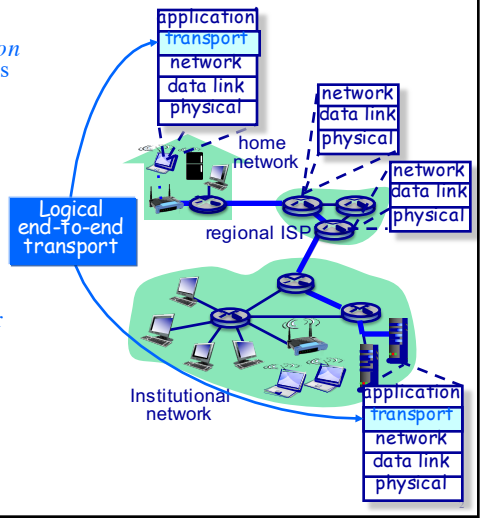
February 18, 2020

The Transport Layer
Transport services and protocols

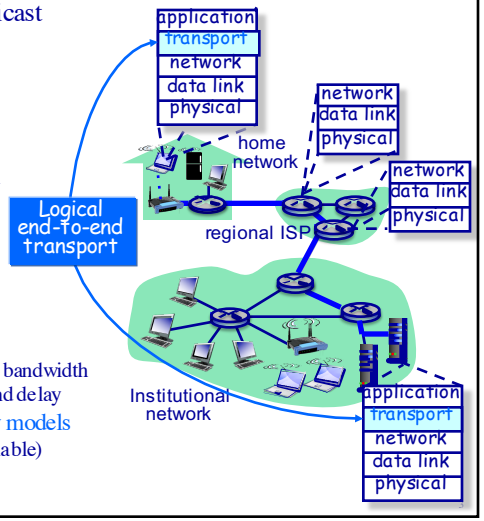
- Transport protocols:
  - Provide *logical communication* between application processes running on different hosts
  - Execute on the end systems (and *not* in the network)
- Transport *v.* network layer services:
  - *Network layer:* data transfer between end systems
  - *Transport layer:* data transfer between processes
    - Relies on, and enhances, network layer services



Transport Layer Protocols

Internet transport services

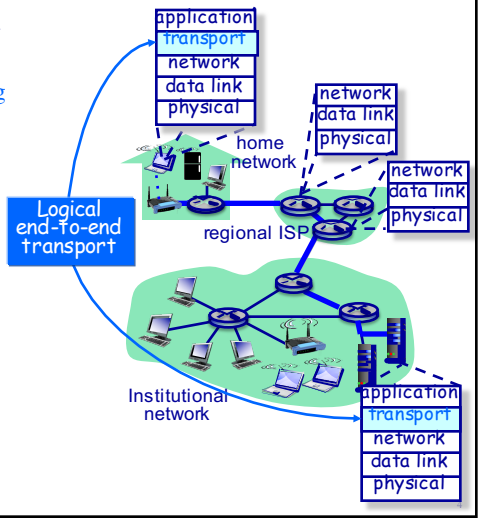
- TCP: Reliable, in-order, unicast delivery
  - » Congestion control
  - » Flow control
  - » Connection setup
- UDP: Unreliable, unordered ("best-effort"), unicast or multicast delivery
  - » (Minimal) error detection
- Services not available:
  - » Performance guarantees
    - ❖ No guarantees of available bandwidth
    - ❖ No guarantees of end-to-end delay
  - » Other (non-unicast) delivery models
    - ❖ Multicast (reliable *v.* unreliable)
    - ❖ Anycast



Transport Layer Protocols & Services

Outline

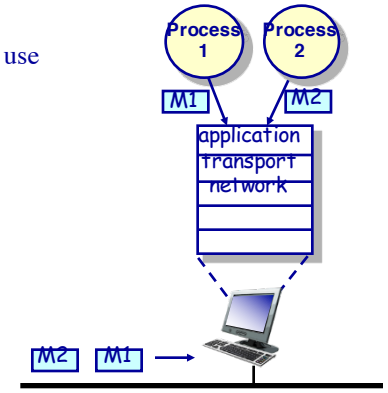
- Fundamental transport layer services
  - » Multiplexing/Demultiplexing
  - » Error detection
  - » Reliable data delivery
  - » Pipelining
  - » Flow control
  - » Congestion control
- Service implementation in Internet transport protocols
  - » UDP
  - » TCP



Fundamental Transport Layer Services

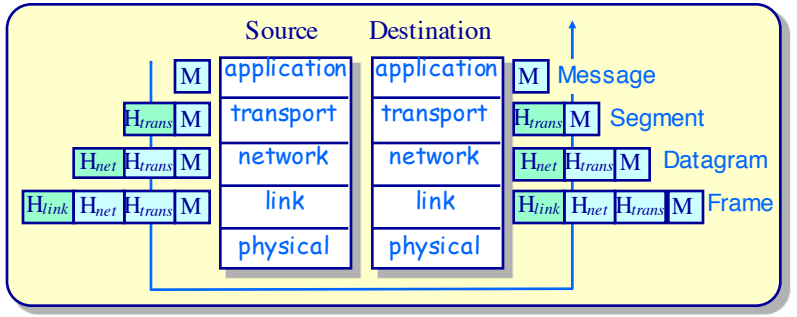
Multiplexing/Demultiplexing

- Each end-system has a single protocol "stack"
  - » The stack is shared between all applications using the network
- Multiplexing is the process of allowing multiple applications to use the network simultaneously
  - » (To send data into the network concurrently)
- Demultiplexing is the process of delivering received data to the appropriate application



Multiplexing/Demultiplexing

Review: Protocol layering in the Internet

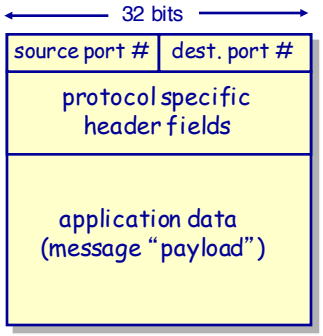


- At the sender, each layer takes data from above
  - » May subdivide into multiple data units at sending layer
  - » Adds header information to create new data unit
  - » Passes new data unit to layer below
- The process is reversed at the receiver

Multiplexing/Demultiplexing

Multiplexing

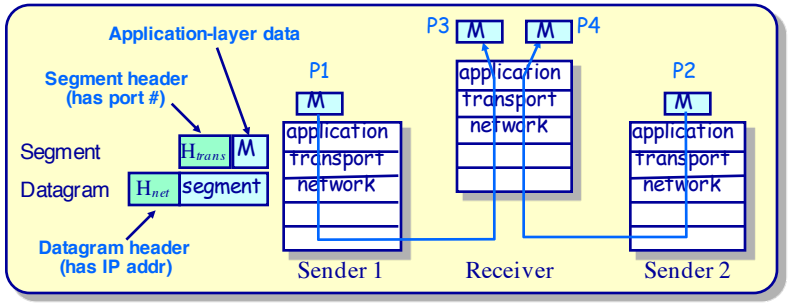
- Gathering data from multiple application processes, enveloping data with header (later used for demultiplexing)
- Based on IP addresses and sender and receiver port numbers
  - » Source and destination port numbers carried in each segment
  - » (Recall: well-known port numbers for specific applications)



TCP/UDP segment format

Multiplexing/Demultiplexing

Demultiplexing



- Demultiplexing is the process of delivering received segments to the correct application-layer process
  - » IP address (in network-layer datagram header) identifies the receiving machine
  - » Port number (in transport-layer segment header) identifies the receiving process

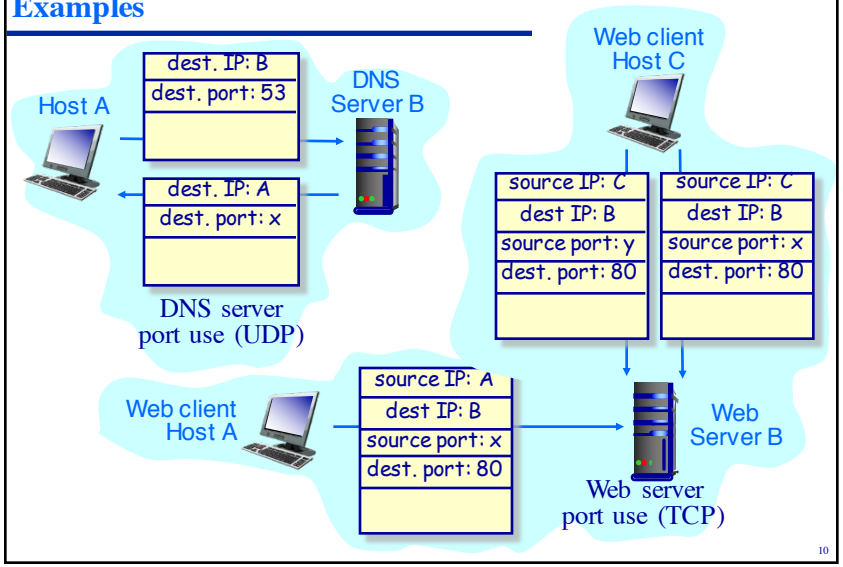
Multiplexing/Demultiplexing

Transport protocol specific demultiplexing

- Demultiplexing actions depend on whether the transport layer is connectionless (UDP) or connection-oriented (TCP)
- UDP demultiplexes segments to the *socket*
  - » UDP uses 2-tuple
    <*destination IP addr*, *destination port nbr*>
    to identify the socket
  - » Socket is "owned" by some process (allocated by OS).
- TCP demultiplexes segments to the *connection*
  - » TCP uses 4-tuple
    <*source IP addr*, *source port nbr*, *destination IP addr*, *destination port nbr*>
    to the identify connection
  - » Connection (and its socket) is owned by some process

Multiplexing/Demultiplexing

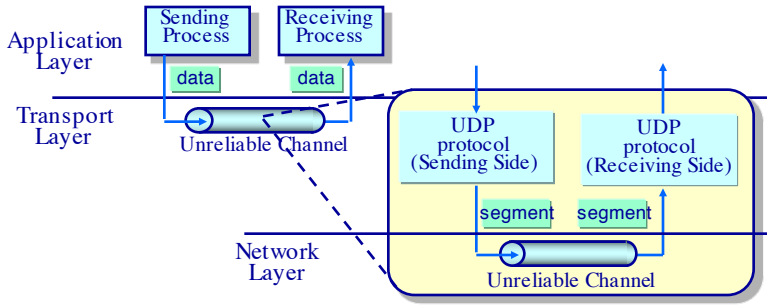
Examples



Fundamental Transport Layer Services

"Best Effort" Delivery

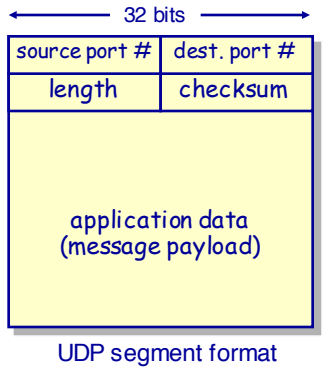
- Goal: Provide error detection and multiplexing but no delivery guarantees
  - » The characteristics of the underlying network layer will determine the reliability of data delivery



Internet Transport Protocols

User Datagram Protocol (UDP) [RFC 768]

- No frills, "bare bones" Internet transport protocol
- Best effort service — UDP segments may be:
  - » Lost
  - » Delivered out of order to the application
  - » Delivered multiple times to the application
- "Connectionless"
  - » No handshaking between UDP sender, receiver
  - » Each UDP segment handled independently of others



UDP segment format

Length field is length in bytes, of UDP segment (including header)

User Datagram Protocol (UDP)

Is unreliable, unordered communications useful?

- Who uses UDP?
  - » Often used for streaming multimedia applications
  - » Loss tolerant
  - » Rate sensitive
- Other UDP uses (why?):
  - » DNS
  - » SNMP
  - » Routing protocols

Why use UDP?

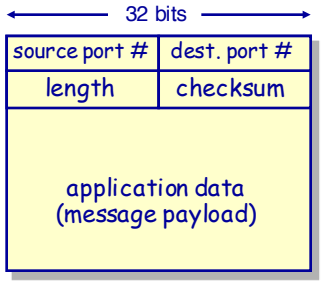
- No connection establishment (which can add delay)
- Simple: no connection state at sender, receiver
- Small segment header
- No congestion control: UDP can blast away as fast as desired

- Reliable transfer over UDP still possible
  - » Reliability can always be added at the application layer
  - » (Application-specific error recovery)

User Datagram Protocol (UDP)

Checksum computation

- The UDP checksum allows the receiver to detect errors in transmitted segment
  - » Errors are "flipped" bits
- Sender computation:
  - » Treat segment contents as a sequence of 16-bit integers
  - » Sum the segment's contents, place the 1's complement of the sum into the checksum field
- Example:
  - » Sum of segment = 1010101110011011
  - » Checksum = 0101010001100100



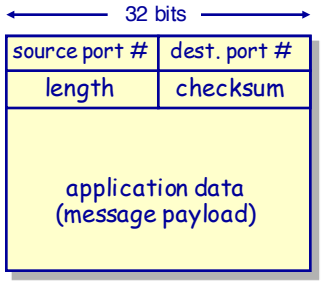
UDP segment format

"Theorem:"
segment sum + checksum =
1111111111111111

User Datagram Protocol (UDP)

Checksum computation

- Receiver computation:
  - » Compute checksum of received segment (including received checksum)
  - » Compare value to all 1's
  - » If equal — No error detected, segment "OK"
  - » If not equal —Error detected, now what?!
    - ❖ Retransmit?
    - ❖ Discard?
    - ❖ Deliver?



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