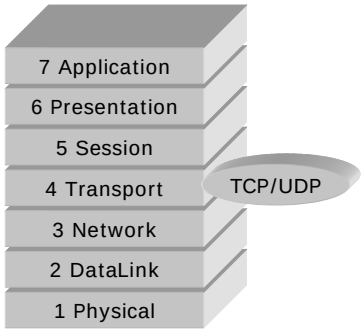
Where Are We?



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Transport vs Network Layer

- Network layer:
  - Provides host-to-host communication
  - Source and destination addresses are computers (attachment points)
  - *Machine-to-machine* networking
  - Datagrams
- Transport layer:
  - Logical communication between processes
  - Relies on and enhances the services provided by the network layer
  - Segment: Unit of data exchanged between transport layer entities

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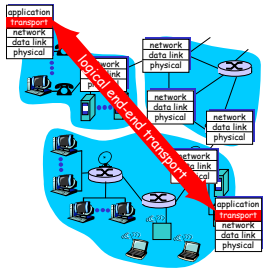
Transport Layer Services and Protocols

- Provide *logical communication* between application processes running on different hosts
  - Application-to-application communication
- Need extended addressing mechanism to identify applications
- Called end-to-end
- Optionally provide:
  - Reliability
  - Flow control
  - Congestion control



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TCP/IP Transport Layer Protocols

- UDP (User Datagram Protocol):
  - Unreliable, unordered delivery
  - Transport layer extension of ``best-effort'' IP; connectionless
- TCP (Transmission Control Protocol):
  - Reliable, ordered delivery
  - Connection-oriented
- Services not available:
  - Delay guarantees
  - Bandwidth guarantees

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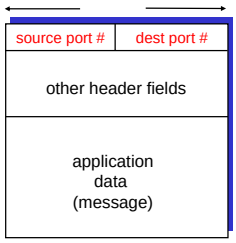
Ports

- A *connection* is identified by 2 end-points
  - An end-point is an *IP address* and an associated *port*
  - There can be many connections coming through a single port
  - Cannot use OS or application related quantity (process ID, task number, job name)
- TCP/IP uses numeric port numbers
  - Identifies which service within the host machine you wish to connect to
- The standard defines ports for both
  - UDP and TCP for common applications
- Other port numbers are available for private use
  - Both communicating machines must agree on what port numbers mean what

Multiplexing

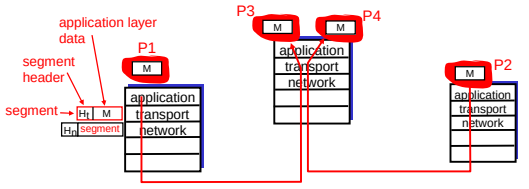
- Multiplexing:
  - Gathering data from multiple application processes, enveloping data with header (later used for demultiplexing)
  - Based on sender, receiver port numbers, IP addresses
    - * Source, destination port numbers in each segment
    - * Recall: well-known port numbers for specific applications



TCP/UDP segment format

Demultiplexing

- Delivering received segments to correct application layer processes



How Demultiplexing Works

- Host receives IP datagrams
  - Each datagram has source IP address, destination IP address
  - Each datagram carries one transport layer segment
  - Each segment has source, destination port numbers
- Host uses IP addresses and port numbers to direct the segment to the appropriate application/process

User Datagram Protocol (UDP)

- In TCP/IP protocol suite, using IP to transport datagram (similar to IP datagram)
- Allows an application to send datagram to other application on the remote machine
- Delivery and duplicate detection are not guaranteed
- Connectionless; each UDP segment handled independently of others
- Low overhead: Faster than TCP
- RFC 768

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UDP Characteristics

- **End-to-end**: An application sends/receives data to/from another application
- **Connectionless**: Application does not need to preestablish communication before sending data; application does not need to terminate communication when finished
- **Message-oriented**: Application sends/receives individual messages (UDP datagram), not packets
- **Best-effort**: Same best-effort delivery semantics as IP, i.e. a message can be lost, duplicated, and corrupted
- **Arbitrary interaction**: Application communicates with many or one other application(s)
- **Operating system independent**: Identifying applications does not depend on OS

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The Need for 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
- Often used for streaming multimedia applications

- Loss tolerant, rate sensitive

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UDP Header

- **Source port (16 bits):** Port number of the sender
- **Destination port (16 bits):** Port number of the intended recipient; UDP software uses this number to demultiplex a datagram to the appropriate higher-layer software
- **Length (16 bits):** Length of the entire UDP datagram, including header and data
- **Checksum (16 bits):** Checksum of entire datagram (including data and pseudo header)

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UDP Checksum

- Goal: Detect ``errors'' (e.g., flipped bits) in transmitted segment
- Sender:
  - Treat segment contents as sequence of 16-bit integers
  - Checksum: Addition (1's complement sum) of segment contents
  - Sender puts checksum value into UDP checksum field
- Receiver:
  - Compute checksum of received segment
  - Check if computed checksum equals checksum field value
    - * NO: Error detected
    - * YES: No error detected

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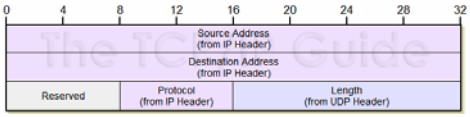
UDP Checksum and Pseudo Header

- UDP uses a pseudo header to verify that the UDP message has arrived at both the correct machine and the correct port



- Prepended to the real UDP message
- Computed over the combination of the pseudo header and the real UDP message
- The pseudo header is used only for this calculation and is then discarded; it is not actually transmitted
- Destination creates the same pseudo header when calculating its checksum to compare to the one transmitted in the UDP header

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Connectionless Demultiplexing

- Socket: An abstraction that provides an interface for processes to specify and access a connection point (TCP or UDP)
- UDP socket identified by two-tuple:
  - (dest IP address, dest port number)
- When host receives UDP segment:
  - Checks destination port number in segment
  - Directs UDP segment to socket with that port number
- IP datagrams with different source IP addresses and/or source port numbers directed to same socket

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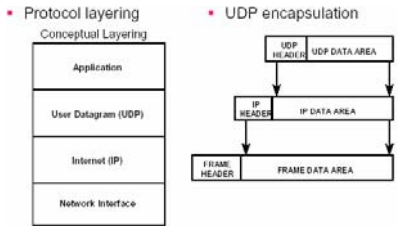
Encapsulation and Layering

- UDP segment is encapsulated into an IP datagram
- IP datagram in turn is encapsulated into a physical frame for actually delivery



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