

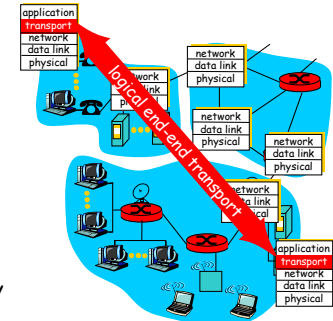
# Transport Layer Overview

Kai Shen

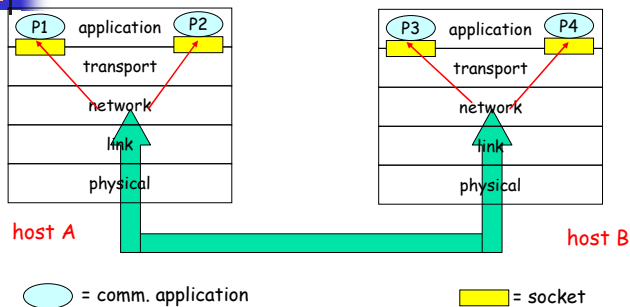
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# Transport-layer Overview

- **Network layer:** host-to-host logical communication between *hosts*.
- **Transport layer:** logical communication between *applications*.
  - multiple comm. applications can reside in one host.
  - comm. applications can be a Web browser/server, a FTP client/server, etc.
- Transport layer: end-host-only implementation.



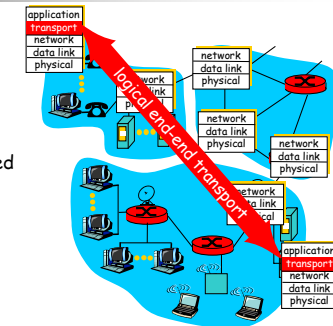
# Multiplexing/demultiplexing



P1 on host A is communicating with P3 on host B; while at the same time, P2 on host A is communicating with P4 on host B.

# Transport-layer Service Model

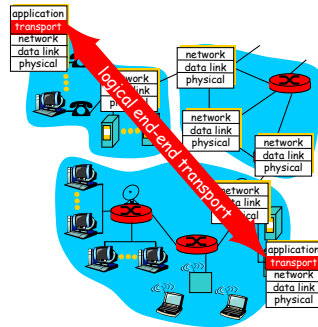
- **Transport layer:** logical communication between *applications*.
  - multiplexing/demultiplexing
- Additional services:
  - reliable data transfer (guaranteed arrival, no error, in-order)
  - flow control (keep sender from overrunning receiver): good for myself
  - congestion control (keep sender from overrunning network): good for the community
  - delay/bandwidth guarantee
  - ...



Why not these features at network layer?

## Internet Transport-layer Protocols

- UDP:
  - multiplexing/demultiplexing
  - error detection
- TCP:
  - multiplexing/demultiplexing
  - error detection
  - reliable data transfer
  - flow control
  - congestion control
- services not available:
  - delay guarantees
  - bandwidth guarantees
  - why?



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## Internet Transport-layer Protocols (cont.)

- What is a *connection*?
  - logical relationship among data segments between the same pair of comm. end-points
  - allow for shared resources, basis for services such as in-order delivery, flow control, et al.
- UDP is *connectionless*:
  - each UDP segment handled independently of others
  - datagram-based service
- TCP is *connection-oriented*:
  - TCP segments between the same pair of comm. end-points are considered as belonging to a connection
  - stream-based service

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## Outline

- Overview of transport-layer services/protocols
- **Multiplexing and demultiplexing**
- Connectionless transport: UDP
- Principles of reliable data transfer
- Connection-oriented transport: TCP
  - reliable data transfer
  - flow control
  - connection management
- Principles of congestion control
- Congestion control in TCP

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## How multiplexing/demultiplexing works?



IP packet format

- **using port numbers**
  - each IP packet has source IP address, destination IP address
  - each IP packet carries a transport-layer segment
  - each segment has source, destination port number
- **dest. IP address** for routing to the host; **IP addresses and port numbers** for going to appropriate socket in the dest. host.

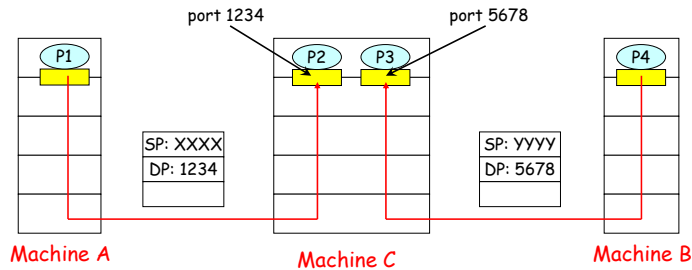
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## UDP Demultiplexing: An Example

- UDP socket identified by port number



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## TCP Demultiplexing (Connection-oriented)

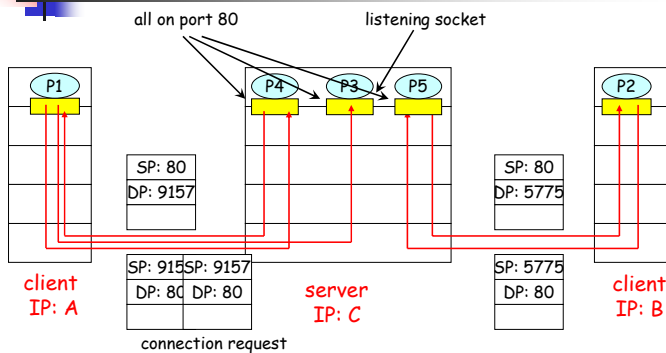
- TCP socket identified by 4-tuple:
  - (source IP address, source port number, dest IP address, dest port number)
  - recv host uses all four values to direct segment to appropriate socket
- Why?
  - each socket corresponds to a TCP connection
    - ⇒ Server at a port may support multiple simultaneous TCP connections/sockets
- Web server (on default port 80) has multiple sockets, one for each connecting client

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## TCP Demultiplexing: An Example



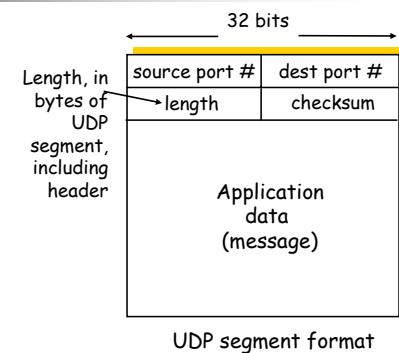
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## UDP: User Datagram Protocol

- UDP is connectionless
- UDP does
  - multplexing/demultiplexing
  - simple error detection
- UDP does not do
  - reliable data transfer, flow control, congestion control ...



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## UDP Checksum

**Goal:** detect "errors" (e.g., flipped bits) in transmitted segments

### 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.

Why are there error detections in transport, network, and link layers?

## What is good about UDP?

- TCP features may not be needed by some applications
- less overhead:
  - no connection establishment (which can add delay)
  - small segment header
  - no congestion control: UDP can blast away as fast as desired (may not be good for others, but not bad for my own connection 😊)
- simple: no connection state at sender, receiver

## UDP: More

- Often used for streaming multimedia apps
  - loss tolerant
  - rate sensitive
- In general, UDP is used when TCP features are not important
- What if you want features not in UDP while the full TCP is overkill?
  - implemented at application-level
  - flow control and loss recovery in some multimedia apps

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