Chapter 3: Transport Layer

our goals:

- understand principles behind transport layer services:
  - multiplexing, demultiplexing
  - reliable data transfer
  - flow control
  - congestion control

- learn about Internet transport layer protocols:
  - UDP: connectionless transport
  - TCP: connection-oriented reliable transport
  - TCP congestion control
Chapter 3 outline

3.1 transport-layer services
3.2 multiplexing and demultiplexing
3.3 connectionless transport: UDP
3.4 principles of reliable data transfer

3.5 connection-oriented transport: TCP
  - segment structure
  - reliable data transfer
  - flow control
  - connection management

3.6 principles of congestion control
3.7 TCP congestion control
Transport services and protocols

- provide **logical communication** between app processes running on different hosts
- transport protocols run in end systems
  - send side: breaks app messages into **segments**, passes to network layer
  - rcv side: reassembles segments into messages, passes to app layer
- more than one transport protocol available to apps
  - Internet: TCP and UDP
Transport vs. network layer

- **network layer:** logical communication between hosts
- **transport layer:** logical communication between processes
  - relies on, enhances, network layer services

**household analogy:**

12 kids in Ann’s house sending letters to 12 kids in Bill’s house:

- hosts = houses
- processes = kids
- app messages = letters in envelopes
- transport protocol = Ann and Bill who demux to in-house siblings
- network-layer protocol = postal service
Internet transport-layer protocols

- reliable, in-order delivery (TCP)
  - congestion control
  - flow control
  - connection setup
- unreliable, unordered delivery: UDP
  - no-frills extension of “best-effort” IP
- services not available:
  - delay guarantees
  - bandwidth guarantees
Chapter 3 outline

3.1 transport-layer services
3.2 multiplexing and demultiplexing
3.3 connectionless transport: UDP
3.4 principles of reliable data transfer
3.5 connection-oriented transport: TCP
   - segment structure
   - reliable data transfer
   - flow control
   - connection management
3.6 principles of congestion control
3.7 TCP congestion control
Multiplexing/demultiplexing

**Multiplexing at sender:**
Handle data from multiple sockets, add transport header (later used for demultiplexing)

**Demultiplexing at receiver:**
Use header info to deliver received segments to correct socket
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 number

- host uses *IP addresses & port numbers* to direct segment to appropriate socket

TCP/UDP segment format:

- source port #
- dest port #
- other header fields
- application data (payload)
- 32 bits
Connectionless demultiplexing

- *recall:* created socket has host-local port #:
  ```java
  DatagramSocket mySocket1 = new DatagramSocket(12534);
  ```

- *recall:* when creating datagram to send into UDP socket, must specify
  - destination IP address
  - destination port #

- when host receives UDP segment:
  - checks destination port # in segment
  - directs UDP segment to socket with that port #

  IP datagrams with *same dest. port #*, but different source IP addresses and/or source port numbers will be directed to *same socket* at dest
Connectionless demux: example

```
DatagramSocket serverSocket = new DatagramSocket (6428);

source port: 6428
dest port: 9157

source port: 9157
dest port: 6428

DatagramSocket mySocket1 = new DatagramSocket (5775);

source port: ?
dest port: ?

DatagramSocket mySocket2 = new DatagramSocket (9157);

source port: ?
dest port: ?
```

Transport Layer 3-10
Connection-oriented demux

- TCP socket identified by 4-tuple:
  - source IP address
  - source port number
  - dest IP address
  - dest port number

- demux: receiver uses all four values to direct segment to appropriate socket

- server host may support many simultaneous TCP sockets:
  - each socket identified by its own 4-tuple

- web servers have different sockets for each connecting client
  - non-persistent HTTP will have different socket for each request
three segments, all destined to IP address: B, dest port: 80 are demultiplexed to different sockets
Connection-oriented demux: example

Transport Layer 3-13
Chapter 3 outline

3.1 transport-layer services
3.2 multiplexing and demultiplexing
3.3 connectionless transport: UDP
3.4 principles of reliable data transfer
3.5 connection-oriented transport: TCP
   - segment structure
   - reliable data transfer
   - flow control
   - connection management
3.6 principles of congestion control
3.7 TCP congestion control
UDP: User Datagram Protocol [RFC 768]

- “no frills,” “bare bones” Internet transport protocol
- “best effort” service, UDP segments may be:
  - lost
  - delivered out-of-order to app
- *connectionless*:
  - no handshaking between UDP sender, receiver
  - each UDP segment handled independently of others

- **UDP use:**
  - streaming multimedia apps (loss tolerant, rate sensitive)
  - DNS
  - SNMP

- **reliable transfer over UDP:**
  - add reliability at application layer
  - application-specific error recovery!
**UDP: segment header**

**UDP segment format**

- **source port #**
- **dest port #**
- **length**
- **checksum**

- **application data (payload)**

**length**, in bytes of UDP segment, including header

---

**why is there a UDP?**

- no connection establishment (which can add delay)
- simple: no connection state at sender, receiver
- small header size
- no congestion control: UDP can blast away as fast as desired
**UDP checksum**

**Goal:** detect “errors” (e.g., flipped bits) in transmitted segment

**sender:**
- treat segment contents, including header fields, as sequence of 16-bit integers
- checksum: addition (one’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.
  *But maybe errors nonetheless? More later....*
example: add two 16-bit integers

| 1 1 1 0 0 1 1 0 0 1 1 0 0 1 1 0 |
| 1 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 |

\[ \text{wraparound} \]

\[ 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 \]

\[ \text{sum} \]

\[ 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 0 0 \]

\[ \text{checksum} \]

\[ 0 1 0 0 0 1 0 0 0 1 0 0 0 0 1 1 1 \]

Note: when adding numbers, a carryout from the most significant bit needs to be added to the result.