Chapter 3
Transport Layer

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Computer Networking: A Top Down Approach

7th edition
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Transport Layer 2-1
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
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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

<table>
<thead>
<tr>
<th>source port #</th>
<th>dest port #</th>
</tr>
</thead>
<tbody>
<tr>
<td>other header fields</td>
<td></td>
</tr>
<tr>
<td>application data (payload)</td>
<td></td>
</tr>
<tr>
<td>TCP/UDP segment format</td>
<td></td>
</tr>
</tbody>
</table>
Connectionless demultiplexing

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

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

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

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

DatagramSocket mySocket1 = new DatagramSocket (5775);

DatagramSocket mySocket2 = new DatagramSocket (9157);
```

Diagram showing the connectionless demultiplexing with source and destination ports.
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
Connection-oriented demux: example

three segments, all destined to IP address: B, dest port: 80 are demultiplexed to different sockets
Connection-oriented demux: example

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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!

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UDP: segment header

UDP segment format

<table>
<thead>
<tr>
<th>source port #</th>
<th>dest port #</th>
</tr>
</thead>
<tbody>
<tr>
<td>length</td>
<td>checksum</td>
</tr>
</tbody>
</table>

application data (payload)

32 bits

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....*
Internet checksum: example

dexample: add two 16-bit integers

\[
\begin{array}{cccccccccccccccc}
1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\
1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\
\hline
1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 1 \\
\end{array}
\]

\text{wraparound} \quad 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1

\text{sum} \quad 1 0 1 1 1 1 0 1 1 1 1 0 1 1 1 1 0 0

\text{checksum} \quad 0 1 0 0 0 1 0 0 0 1 1 0 0 0 0 0 1 1

\textbf{Note:} when adding numbers, a carryout from the most significant bit needs to be added to the result

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/