Process-to-process communication

- We have a network. How to get between programs?
Transport layer functionality

• What functions should transport layer implement?

Multiplexing/demultiplexing

• Multiple processes operate on one computer
  – Interface address alone is not sufficient to distinguish
• Need to (de)multiplex traffic from different processes
• 5-tuple used for unique identification of connection
  – IP source address
  – IP destination address
  – Transport layer source port
  – Transport layer destination port
  – Transport layer protocol
UDP: bare bones protocol

- Ports, length, checksum
  - Checksum is optional

<table>
<thead>
<tr>
<th>Source port number</th>
<th>Destination port number</th>
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<tbody>
<tr>
<td>Length</td>
<td>Checksum</td>
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5-tuple example

- 5-tuple is reversed for return communication
- Destination port is associated with application layer protocol (e.g., 80 for HTTP)
- Operating system picks source port randomly

<table>
<thead>
<tr>
<th>sender (client)</th>
<th>receiver (server)</th>
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<tbody>
<tr>
<td>source IP</td>
<td>destination IP</td>
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<tr>
<td>source port</td>
<td>destination port</td>
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What functionality does TCP provide?

• Reliability
  – Recovery from errors in the network layer
• Flow control
  – Limit transmission rate to not overwhelm receiver
• Congestion control
  – Limit transmission rate to not overwhelm network
Reliable data transfer

• How can reliability be achieved?
  – Consider different assumptions for network layer

• Case 1: completely reliable network layer
  – Send segment

• Case 2: bit errors in network layer
  – Add error detection and ACK/NAK
  – Add sequence number to handle garbled ACK/NAK

• Case 3: bit errors and packet loss in network layer
  – Timer to trigger retransmission
  – “Stop-and-wait” protocol
Reliable data transfer

- Stop-and-wait has low performance
  - How can we increase throughput?
- Sliding window
  - Allow multiple segments “in-flight”

Sliding window example
TCP header

- Port numbers
- Sequence number
  - Position of data
- ACK number
  - Next expected data
- Checksum
- Flags for connection setup and teardown

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<td>Source port number</td>
<td>Destination port number</td>
<td>Sequence number</td>
<td>Acknowledgement number</td>
<td></td>
</tr>
<tr>
<td>Data offset</td>
<td>Reserved</td>
<td>PSH</td>
<td>ACK</td>
<td>SYN</td>
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