Transport Layer and UDP

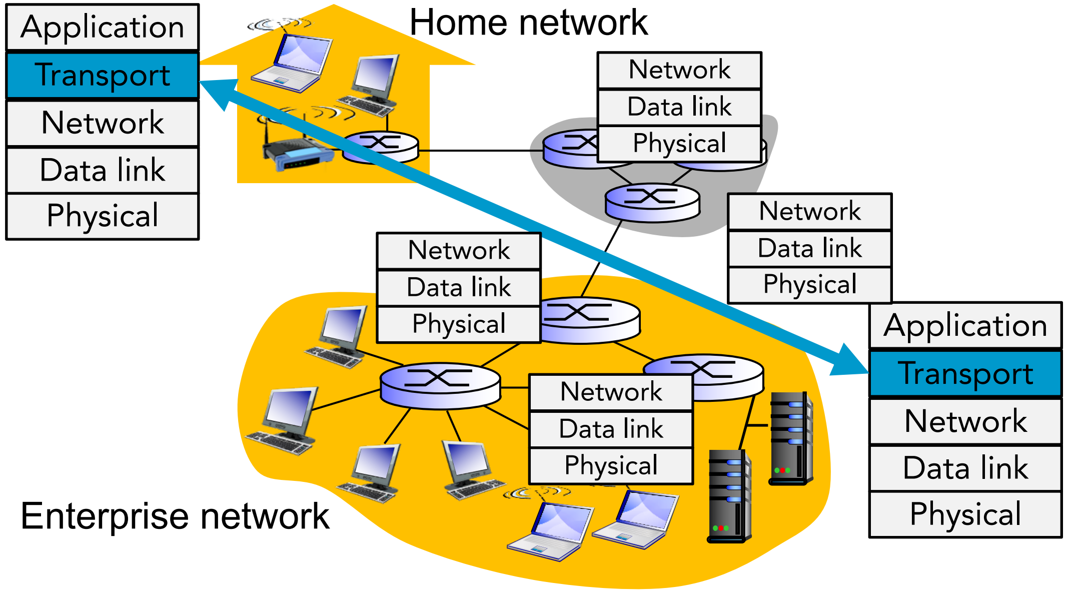
To do …

- ☐ Transport Layer – The Basics
- ☐ The Simplest Transport Layer Protocol - UDP

Northwestern

Transport-Layer Service

- A transport-layer protocol provides for *logical* communication between app processes running in different hosts
  - From the app's perspective, as if the nodes were directly connected
- Implemented at end hosts, not in routers
  - Converts app-layer packets into segments by
    - Possible breaking messages into smaller chunks
    - Adding some headers
  - Segments are given to the network layer …



Transport and Network Layer

- Transport-layer protocols – logical communication between processes running in different hosts
- Network-layer … between hosts
  - *Subtle but important difference*
- Clearly, the services a transport-layer protocol can provide is constrained by what the underlying network-layer service offers
  - *No delay or bandwidth guarantees from network? …*
- Constrained is not the same as completely determined …
  - E.g., A reliable transport on an unreliable network

Transport Layer in the Internet

- Internet transport-layer protocols – UDP and TCP
- What do they get from IP, the network-layer protocol?
  - An unreliable, best-effort service
    - i.e., best effort = no guaranteed segment delivery
    - No guaranteed integrity of data in the segments
- What do they offer
  - Extending host-to-host delivery to process-to-process – transport-layer multiplexing/demultiplexing
  - Integrity checking with error-detection fields in the header

TCP and UDP

  - Reliable data transfer, using flow control, seq #, acks, timers
  - Congestion control (for the general good) ensuring every connection in a congested link gets an equal share of bw

Only TCP

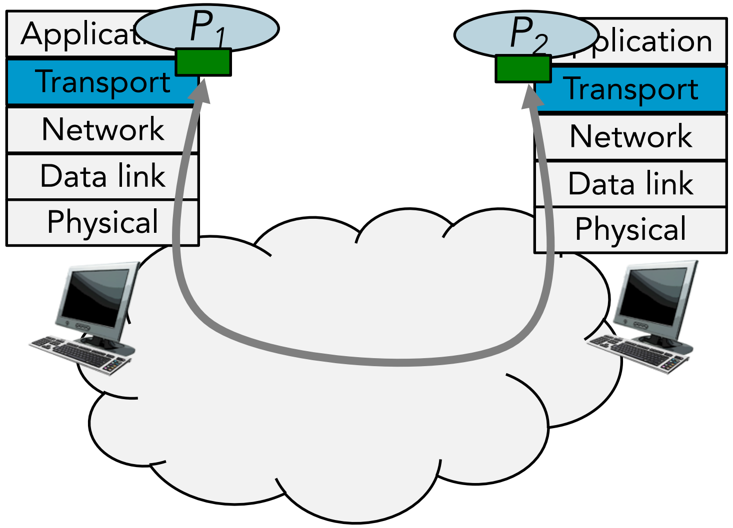
Transport Layer in the Internet

- UDP – User Datagram Protocol
  - Unreliable, connectionless service
  - Extending IP service “between hosts” to “between processes” – transport-layer multiplexing
  - Basic error checking
  - No setup costs, no transmission delays above IP
- TCP – Transmission Control Protocol
  - Reliable, connection-oriented service
  - Transport-layer multiplexing + basic error checking
  - Besides API provides abstraction of a stream of bytes, hiding
    - Message sizes, lost messages, duplication and ordering, flow control and congestion avoidance

Multiplexing/Demultiplexing

- Multiple processes, one connection (let’s imagine)
  - How can you tell which process each segment belongs to?
- Transport layer in the receiving host delivers data to a socket
  - Each socket has a unique identifier
  - Each segment has fields to identify the receiving socket – a destination port number

  → demultiplexing



- On the other end, gather data chunks from different sockets, encapsulate them into segments with header info, and pass them to the network layer → multiplexing

Connectionless Multiplexing

- To create a UDP socket

```
clientSocket = socket(AP_INET, SOCK_DGRAM)
```

  - Get back a socket # (between 1024 and 65535, currently not in use) or we can associate it with a specific port # with bind

```
clientSocket.bind((‘’, 19157)
```

- On the client side, let the transport layer assign a port #
- A UDP port is fully identified by a two-tuple consisting of a destination IP address and a destination port #
  - The source address acts as a return address

UDPServer.py and UDPClient.py

Server

```
from socket import *
serverPort = 12000
serverSocket = socket(AF_INET, SOCK_DGRAM)
serverSocket.bind(('', serverPort))
print("The server is ready to receive")
while True:
       message, clientAddress = serverSocket.recvfrom(2048)
       modifiedMessage = message.decode().upper()
       serverSocket.sendto(modifiedMessage.encode(), clientAddress)
```

Return address to be used …

Here for replies

Client

```
from socket import *
serverName = 'localhost'
serverPort = 12000
clientSocket = socket(AF_INET, SOCK_DGRAM)
message = input('Input lowercase sentence: ')
clientSocket.sendto(message.encode(), (serverName, serverPort))
modifiedMessage, serverAddress = clientSocket.recvfrom(2048)
print(“From Server:”, modifiedMessage.decode())
clientSocket.close()
```

Connection-oriented Multiplexing

- A TCP socket is identified by a four-tuple <src IP, src port, dst IP, dst port>
  - Demultiplexing happens based on the four values
- Server has a ‘welcoming socket’ to wait for connection-establishment requests from clients

```
serverPort = 12000
serverSocket = socket(AF_INET, SOCK_STREAM)
serverSocket.bind(('', serverPort))
```

- When it receives a request, it creates a new socket for that client

```
while True:
        connectionSocket, addr = serverSocket.accept()
```

TCPServer.py and TCPClient.py

Server

```
from socket import *
serverPort = 12000
serverSocket = socket(AF_INET, SOCK_STREAM)
serverSocket.bind(('', serverPort))
serverSocket.listen(1)
print("The server is ready to receive")
while True:
        connectionSocket, addr = serverSocket.accept()
        message = connectionSocket.recv(1024).decode()
        modifiedMessage = message.upper()
        connectionSocket.send(modifiedMessage.encode())
        connectionSocket.close()
```

A welcoming socket to wait for connections

Create a new socket for this client; use IP and port of src, port of dst and its own IP to identify it

Client

```
from socket import *
serverName = 'localhost'
serverPort = 12000
clientSocket = socket(AF_INET, SOCK_STREAM)
message = input('Input lowercase sentence: ')
clientSocket.connect((serverName, serverPort))
clientSocket.send(message.encode())
modifiedMessage = clientSocket.recv(1024)
print('From server: ', modifiedMessage.decode())
clientSocket.close()
```

Create a socket and send a connection-establishment request

UDPClient.py and TCPClient.py

UDP Client

```
from socket import *
serverName = 'localhost'
serverPort = 12000
clientSocket = socket(AF_INET, SOCK_DGRAM)
message = input('Input lowercase sentence: ')
clientSocket.sendto(message.encode(), (serverName, serverPort))
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clientSocket.close()
```

TCP Client

```
from socket import *
serverName = 'localhost'
serverPort = 12000
clientSocket = socket(AF_INET, SOCK_STREAM)
message = input('Input lowercase sentence: ')
clientSocket.connect((serverName, serverPort))
clientSocket.send(message.encode())
modifiedMessage = clientSocket.recv(1024)
print('From server: ', modifiedMessage.decode())
clientSocket.close()
```

UDPServer.py and TCPServer.py

UDP Server

```
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serverPort = 12000
serverSocket = socket(AF_INET, SOCK_DGRAM)
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TCP Server

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from socket import *
serverPort = 12000
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```
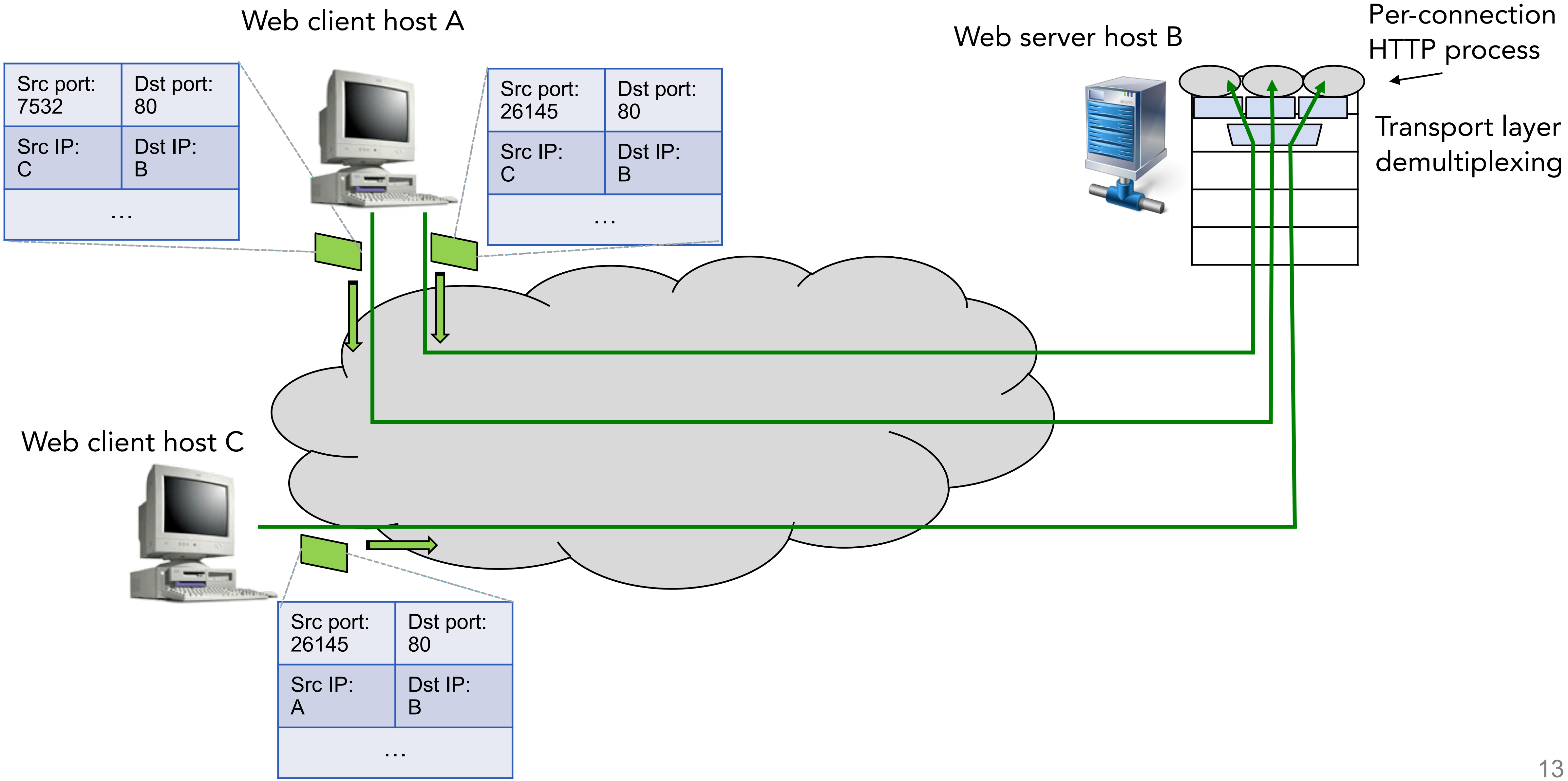

Demultiplexing – Two Clients Connected to a Web Server



Web client host A

Src port: 7532	Dst port: 80
Src IP: C	Dst IP: B
…	

Src port: 26145	Dst port: 80
Src IP: C	Dst IP: B
…	

Web server host B

Per-connection HTTP process

Transport layer demultiplexing

Web client host C

Src port: 26145	Dst port: 80
Src IP: A	Dst IP: B
…	

Connectionless Transport – UDP

- User Datagram Protocol [RFC 768] – As little as possible from a transport-level protocol
  - Nearly the same as IP
  - Just allowing multiple applications on a host to share one network
  - Plus some error checking

- Multiplexing/demultiplexing …
  - Takes application msgs, attaches src/dst port numbers for multiplexing
  - Pass the resulting segment to the network layer
  - No handshaking between src/dst – connectionless
  - On arrival, use dst port to deliver the segment to the correct app
- One example application – DNS

Why Would You Want to Use UDP? *Why not TCP?!*

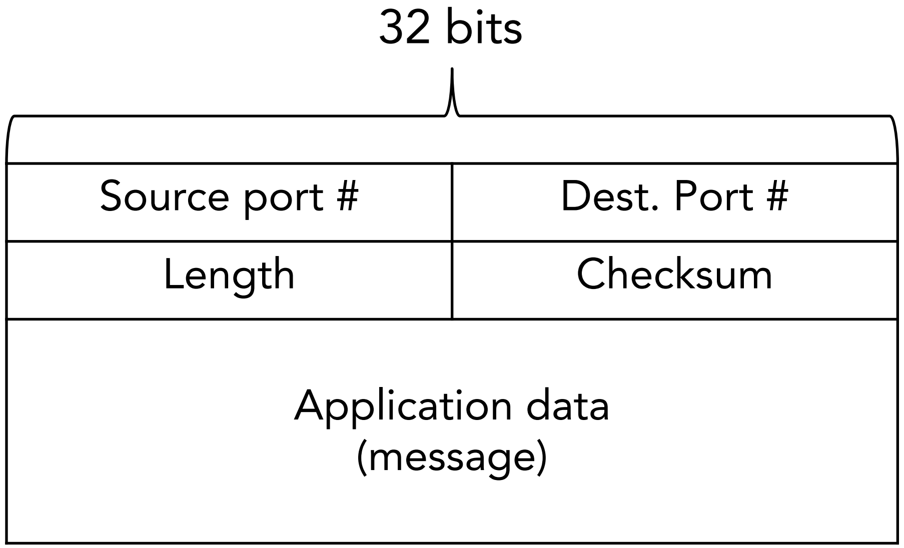
- *Finer app-level control over what data is sent and when* – UDP just passes on whatever the app gives it; TCP has a congestion control mechanism that throttle the sender, a potential problem for real-time applications
- *No connection establishment* – TCP three-way handshake introduces delay in setting a connection
- *No connection state* – TCP keeps connection state that includes receive and send buffers, congestion control parameters and sequence and ack number parameters → constrains scalability
- *Small packet header overhead* – TCP segment has 20B of header in every segment, vs 8B in UDP

How do Processes Learn Each Others' Ports?

- Client initiates the exchange so, just include that and the server will learn the client's port
- How does the client learn of the server's port?
  - A common approach – a well-known port, e.g., DNS in port 53 (in a Unix mach, look at /etc/services)
  - Another option is a "port mapper", with a well-known port answering questions like 'what port should I use to reach x?'

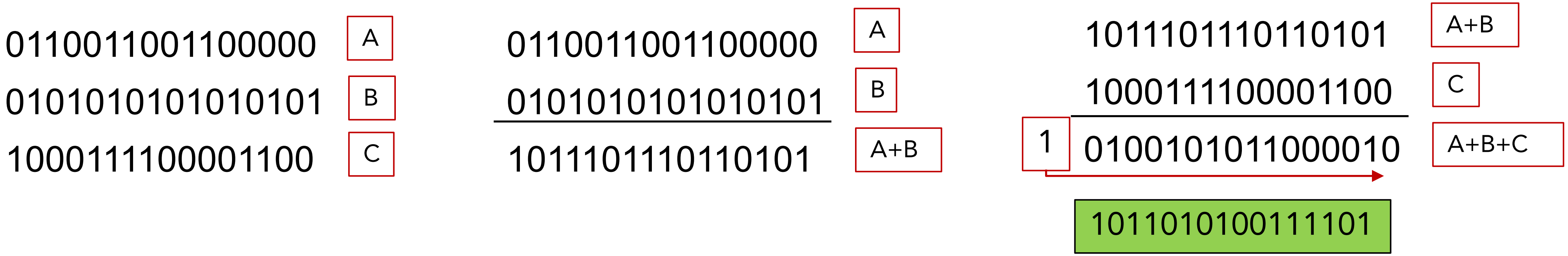
UDP Segment Structure

- Not much needed, four fields each of two bytes
- *Source* and *destination ports* as discussed
- *Length* – number of byes in header+data Needed since the size of data field may be different from one segment to the next
- *Checksum* to check if the segment has been altered in transfer



Checksum is a simple way to detect data corruption

- Break the data into sequence of 16-bit integers
- Do the 1s complement of the sum
  - Add the integers
  - Wrap the carry-out bits to the least-significant position
  - Finally, invert the result (0 to 1, 1 to 0)



0110011001100000 A
0101010101010101 B
1000111100001100 C

0110011001100000 A
0101010101010101 B
1011101110110101 A+B

1011101110110101 A+B
1000111100001100 C
1 0100101011000010 A+B+C

1011010100111101

Checksum is a simple way to detect data corruption

- *Why do you need error detection here?*
  - Many link-layer protocols have it already
  - Yeah, but not all
  - And the error could be introduced when the segment is stored in a router's memory
- An example of the end-to-end principle*
- Notice there's no "recovery" by checksum, just detection
  - Discard the bad segment or pass it on with a warning

* J. Saltzer, D. Reed and D. Clark, End-to-End Arguments In System Design, ACM TOCS, 2(4), 1984
http://web.mit.edu/Saltzer/www/publications/endtoend/endtoend.pdf

Recap

- Providing comm. services to applications – the transport layer
- At least, multiplexing/demultiplexing for communication processes – this + some checking = UDP
- A good basis for reliable data transfer and TCP …