Networks

What is a Network

Adopted from material in “Computer Networking: A Top Down Approach” by Kurose and Ross and slides developed by William Conner

What is a Network

Sections 1.1-1.3

What is a Network?

Collection of interconnected devices that exchange information

- Public switched telephone network
- Internet
- Cellular network
- Ad hoc wireless network

Examples of other networks (including technical and non-technical)?

Networked Devices

PSTN

- Landline phone
- Telephone exchange

Internet

- PCs and servers
- Router

Cellular

- Smartphone
- Cell tower

Examples of other devices?

Communication Links

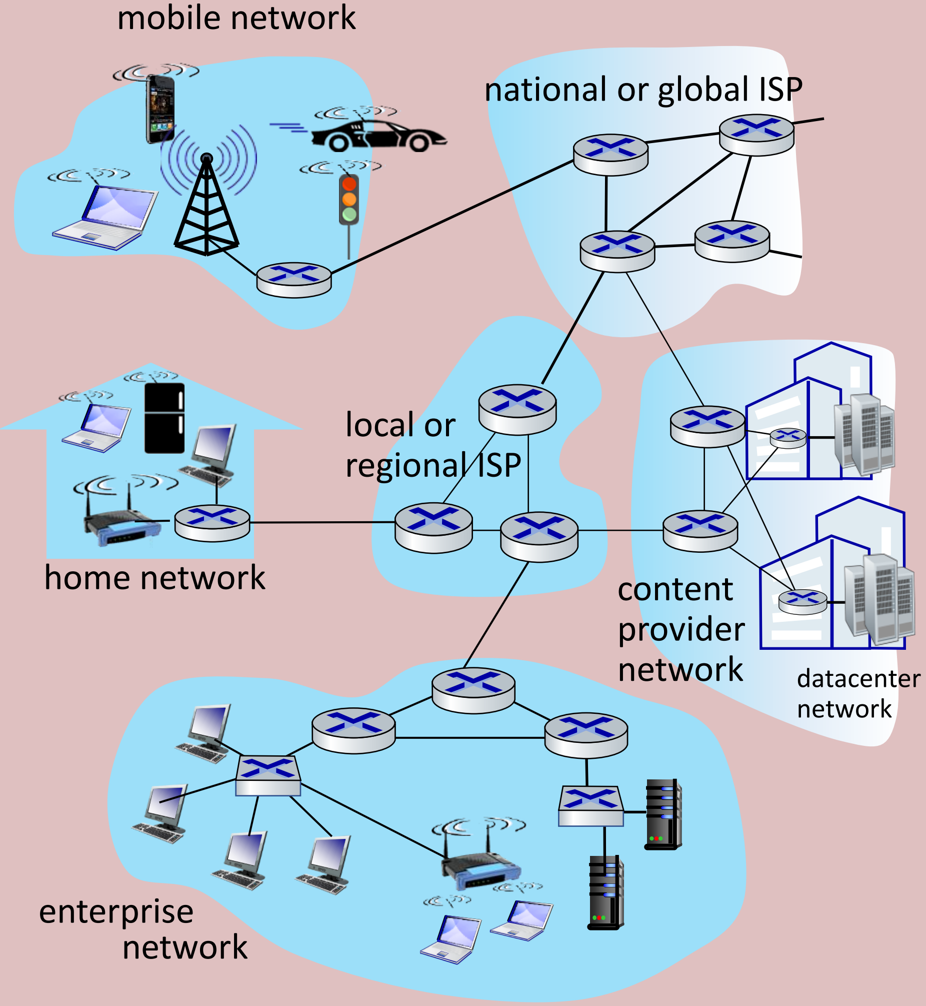
- Fiber optic cable (glass fiber)
- Coaxial cable (copper)
- Twisted pair (copper)
- Terrestrial and satellite radio

Network Components

- Network edge: end hosts (devices)
- Access network: wired (or wireless) communication links to core
- Network core: routers

Network Components

Core vs. access network?



Network Types

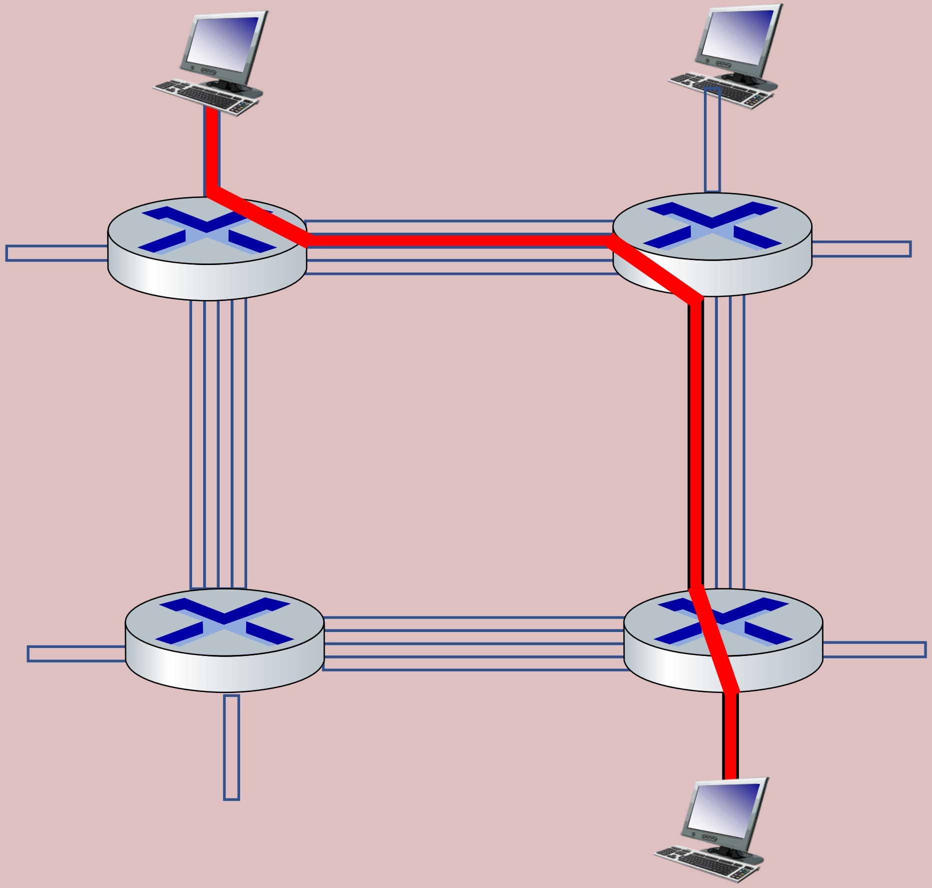
- Two major categories

- Connection-oriented networks modelled after telephone system (call is analogous to a circuit)

- Connectionless networks modelled after the postal system (letter is analogous to a packet)

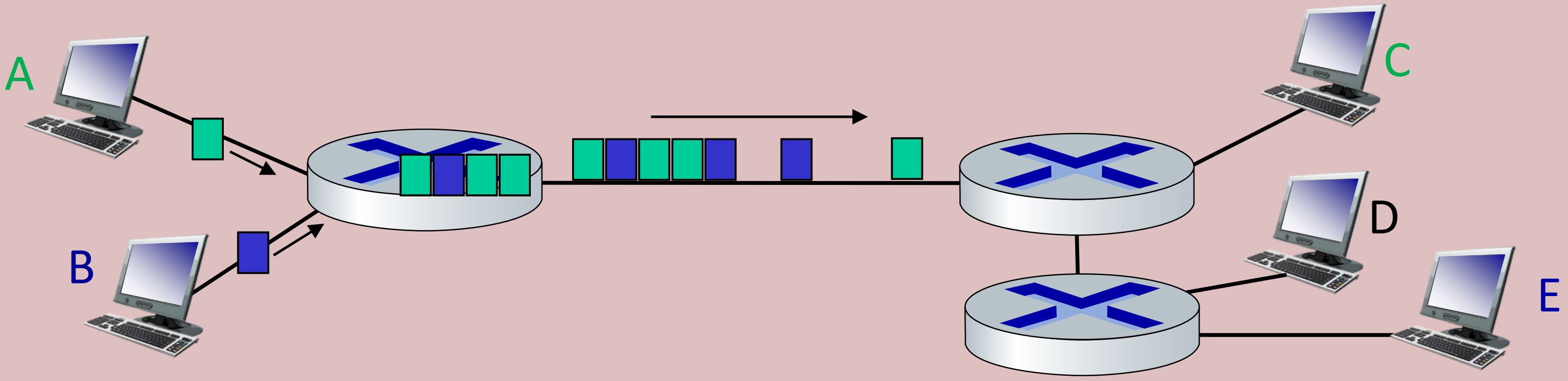
Circuit Switching

- Used by PSTN
- Resources reserved in advance along path via complex signaling to set up call
- Messages all take the same path
- Cut-through switching
- Less efficient, but has guarantees



Packet Switching

- Used by Internet
- Breaks messages into smaller packets
- Store-and-forward
- Possible for different packets to take different paths for same message
- Possible for multiple messages to use the same path
- More efficient, but no guarantees



Thank You!

Networks

Packet-Switched Network Performance

Adopted from material in “Computer Networking: A Top Down Approach” by Kurose and Ross and slides developed by William Conner

Packet-Switched Network Performance

Section 1.4

Network Performance Metrics

- Packet delay (sum of following)
  - Processing
  - Queueing
  - Transmission
  - Propagation
- Packet loss
- Throughput

Packet Delay – Processing

- Check header of whole message for bit errors (discuss error detection later)

- Determine output link for next hop

- Typically on the order of microseconds

Packet Delay – Queueing

- Wait behind other packets for transmission at output link on router
- Depends on congestion at router (more traffic increases length of queue)
- Could lead to packet loss if queue fills up

Packet Delay - Transmission

- Time it takes to put bits on the wire, not the time it takes bits to travel to the other end of the wire
- L/R where L is packet length (in bits) and R is link bandwidth (in bits/sec or bps)

Packet Delay – Propagation

- Time it takes a single bit to travel across the physical link from one end to the other

- D/V where D is the length of the physical link in meters and V is the propagation speed in meters/sec

Packet Loss

- Router buffers (i.e. queues) have finite capacity
- If queue is full, newly arriving packets are dropped
- Dropped packets must be retransmitted from upstream

Throughput

- Measure of how much data is transferred per unit time for a given sender/receiver
- Bandwidth is an upper bound for throughput
- Instantaneous vs. average

Thank You!

Networks

Protocols

Adopted from material in “Computer Networking: A Top Down Approach” by Kurose and Ross and slides developed by William Conner

Protocols

Section 1.5

What is the Internet?

- Inter-connected networks
  - Internetwork
  - “Network of networks”
- Global scale wide area network
- Not the same as the WWW
  - WWW was the “killer application” for the Internet
  - Covered next week

Protocols

- Protocol (personal): proper etiquette
- Protocol (diplomacy): formal rules and conventions observed by diplomats
- Protocol (networking): format and order of messages exchanged between two or more entities; also actions taken

Protocol Suite

- Collection of related protocols
- Much of this course will focus on the TCP/IP protocol suite used to implement the Internet

Monday Morning Protocol

Alice: Morning, Bob. How was your weekend?

Bob: Not bad, Alice. How was your weekend?

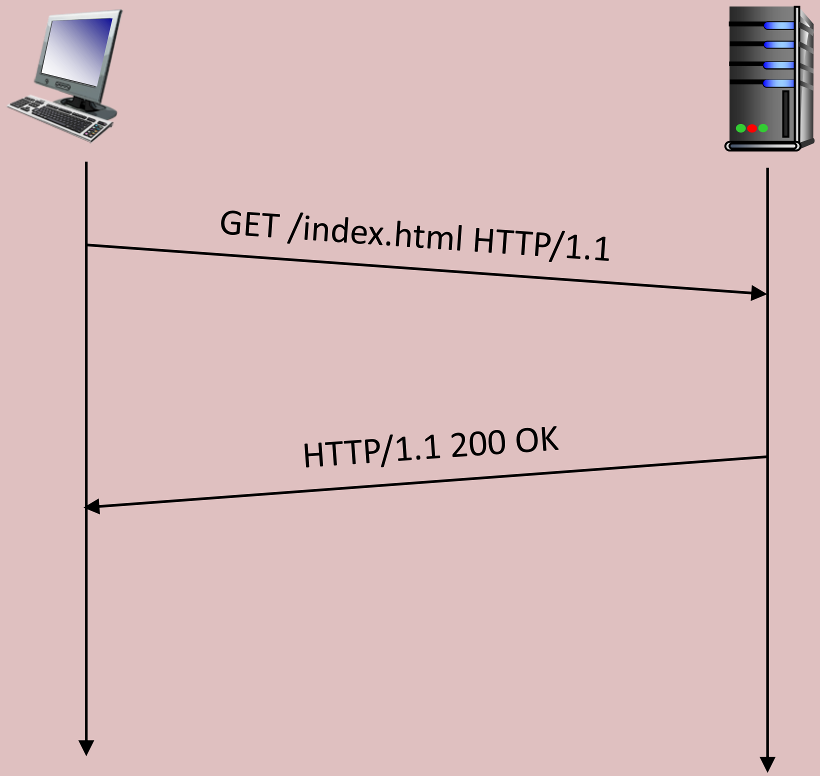
Alice: Not bad.

CTA Passenger Protocol Suite

- Allow passengers to exit the train before boarding
- After boarding the train, move to the middle of the car
- Do not place bags on empty seats

Source: https://www.transitchicago.com/courtesy/

Hypertext Transfer Protocol



Network Reference Models

- Categorize protocols into layers
  - Layer N provides services to layer N+1
  - Layer N depends on services from layer N-1

- Influenced by modular OS design
  - Hide internal implementation details
  - Provide well-defined interface
  - Easy to swap implementations as long as interfaces do not change

Network Reference Models

- Two major network reference models, but only one currently used in practice
- Open Systems Interconnection (OSI) reference model
- ARPANET reference model

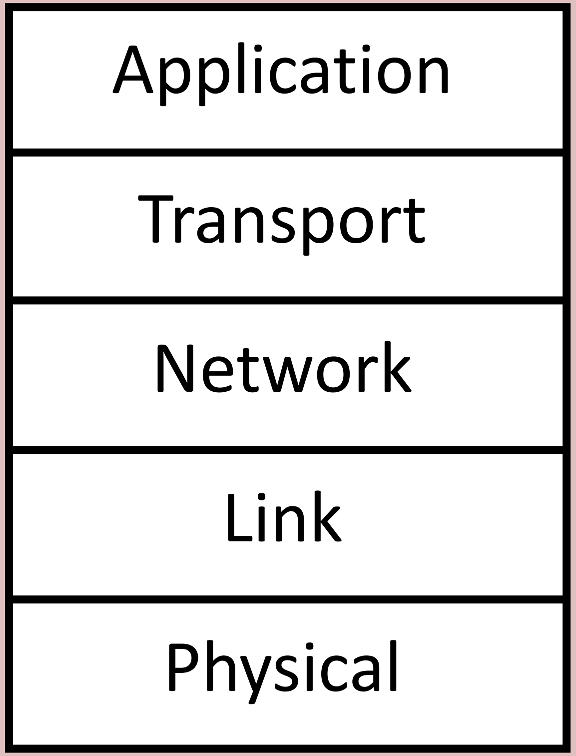
OSI Reference Model

- Specified by International Organization for Standards (ISO)
- Early 1980s

Application
Presentation
Session
Transport
Network
Link
Physical

APRANET Reference Model

- Used by TCP/IP protocol suite (Internet)
- Presentation and session layer rolled into application
- Used in this course

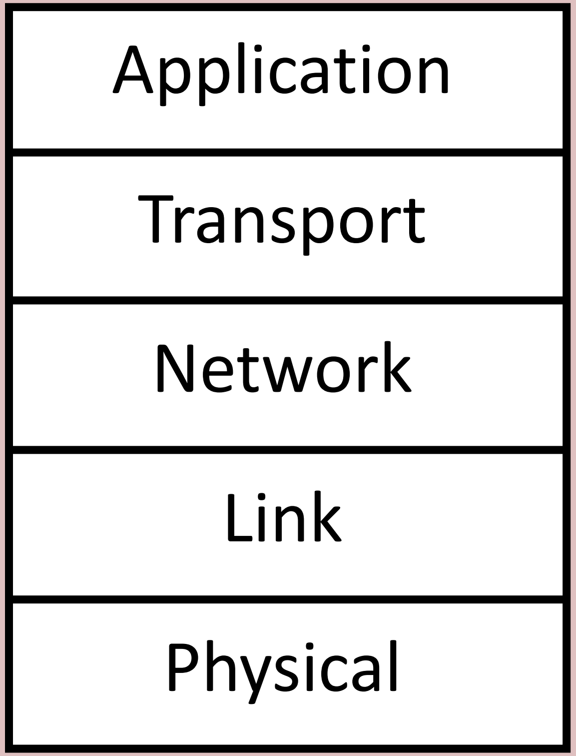


APRANET Reference Model

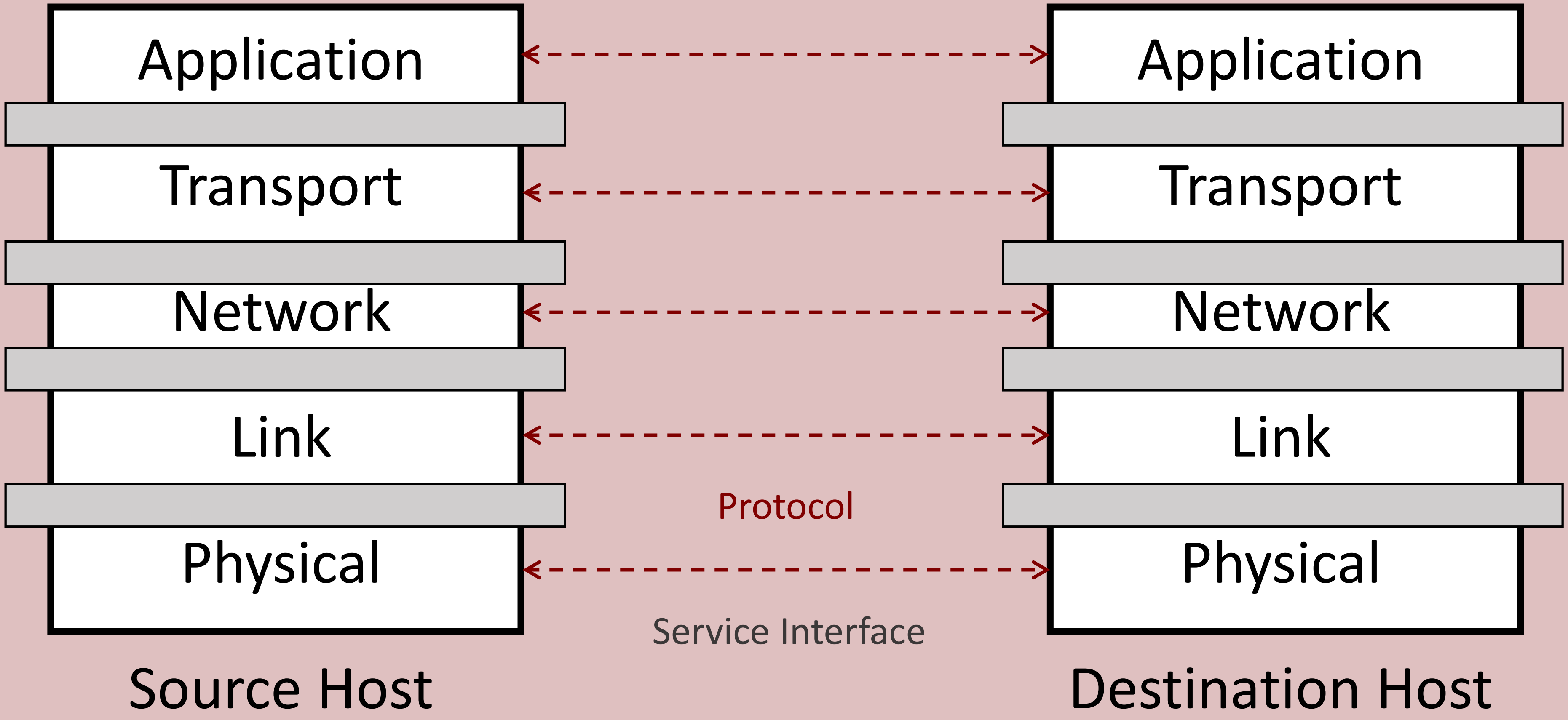
- Transport layer provides process-to-process data transfer to application

- Network layer provides machine-to-machine data transfer to transport

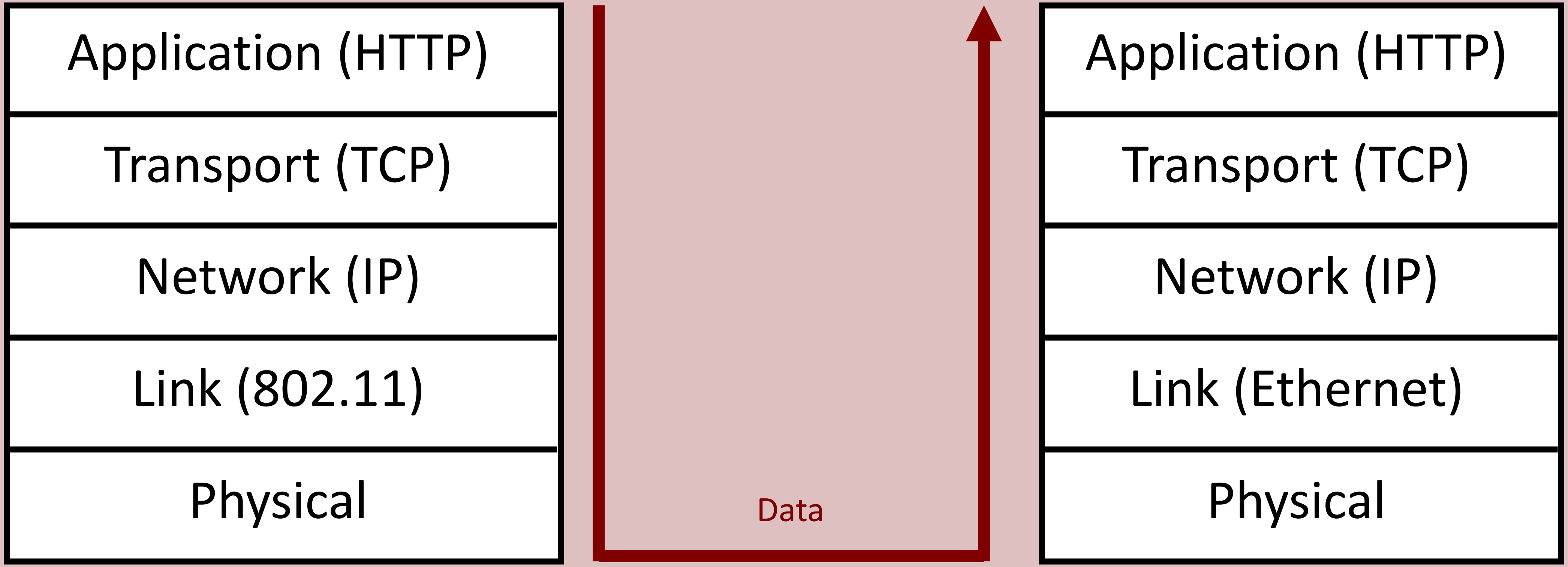
- Link layer provides single hop data transfer to network



Protocol Stack



Example: Protocol Stack

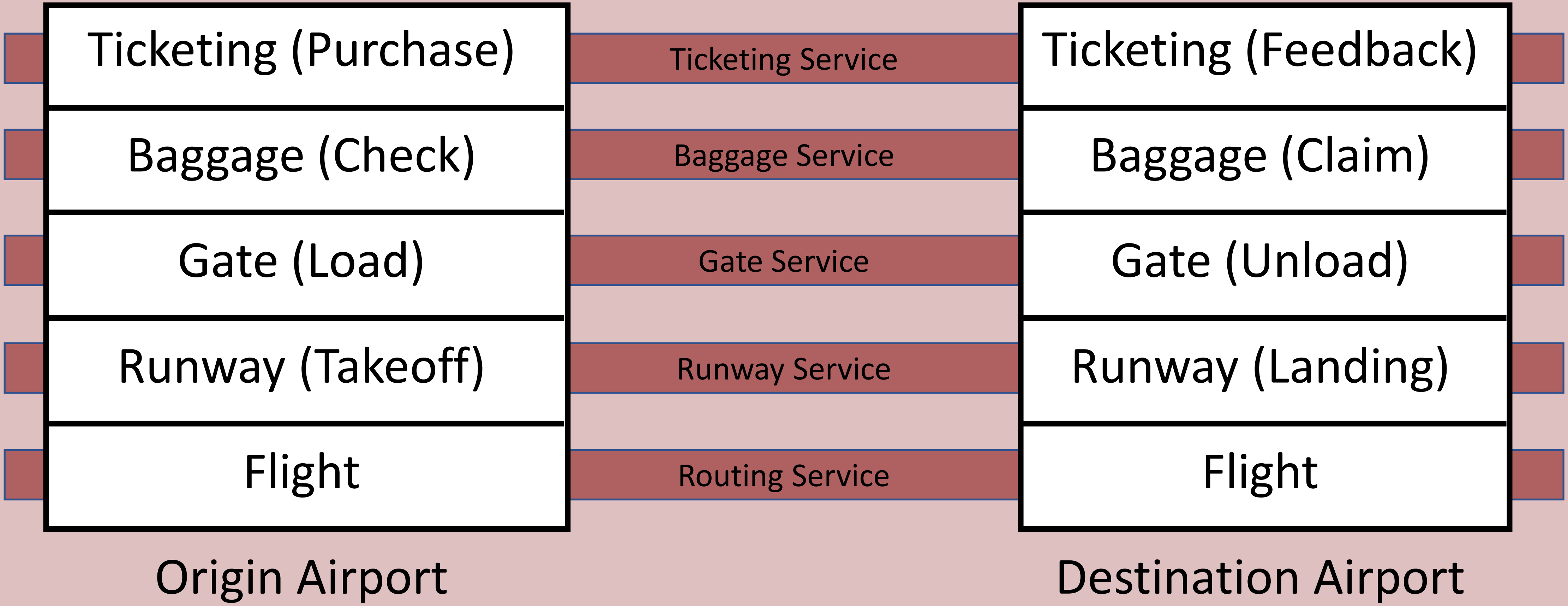


Source Host

Destination Host

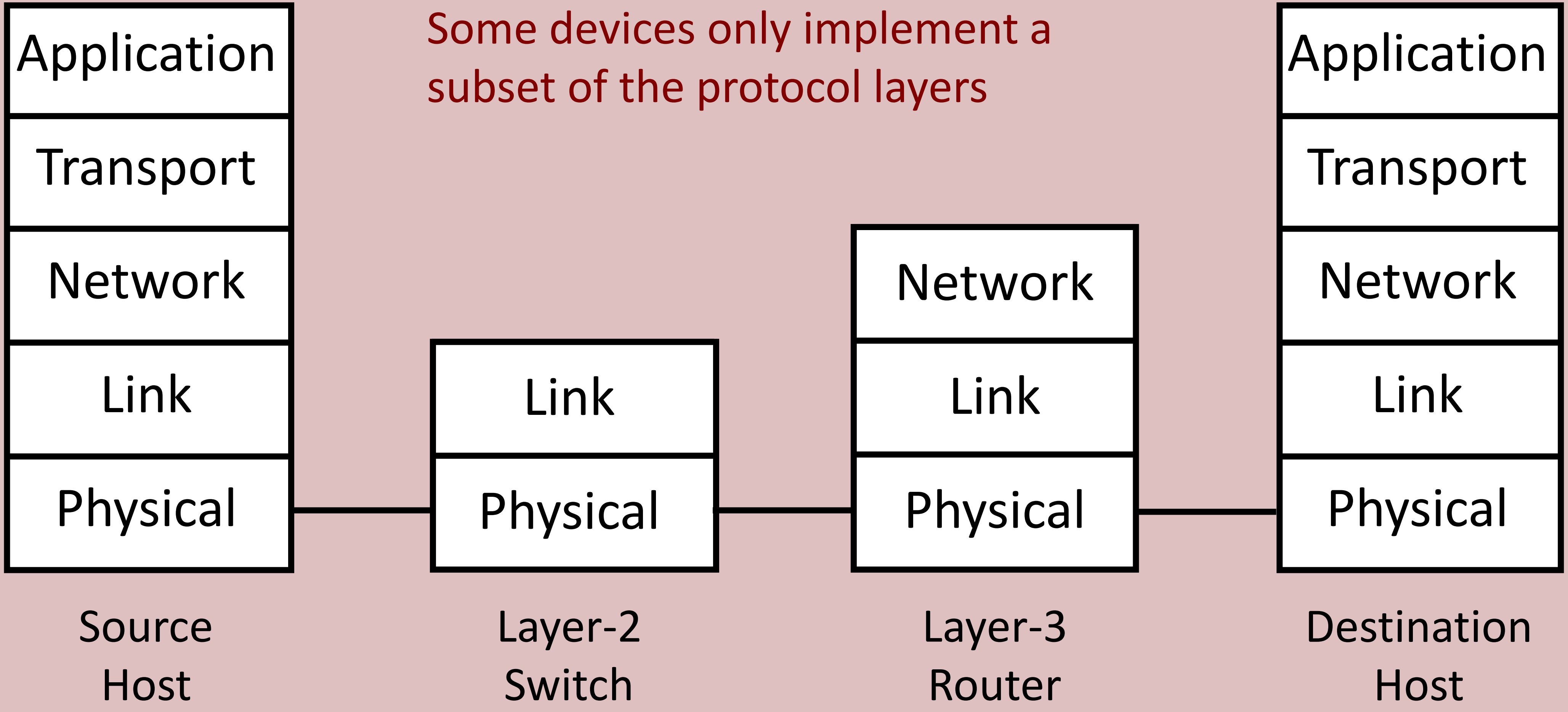
Airplane Analogy (Textbook)

Airplane Analogy (Textbook)



Each layer implements a service, via its own internal-layer actions, relying on services provided by the layer below

Device Layers



Some devices only implement a subset of the protocol layers

Protocol Data Unit (PDU)

- Formal term used for layer-specific protocol message

- PDU at layer N is protocol message sent between protocols at layer N

*In practice, "datagram" is often used for both UDP and IP

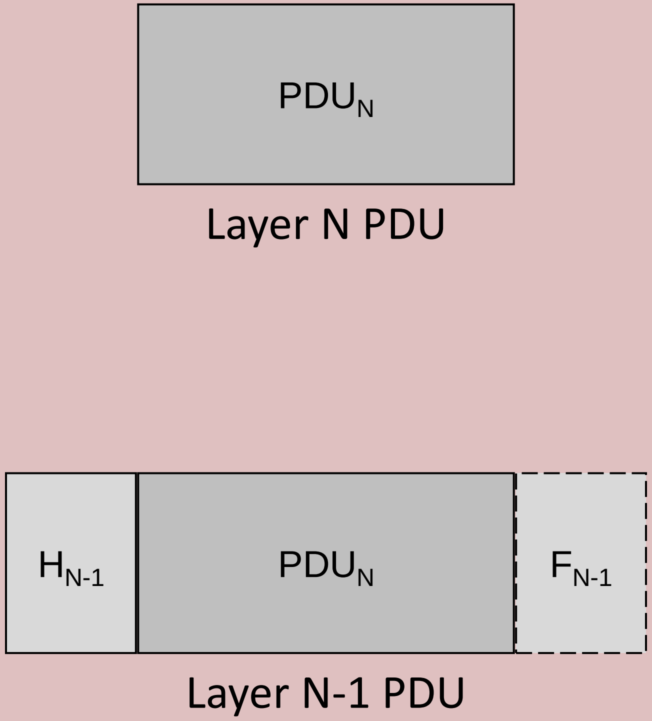
Message (Application)
Segment (Transport)
Datagram (Network)
Frame (Link)
Bit (Physical)

Encapsulation

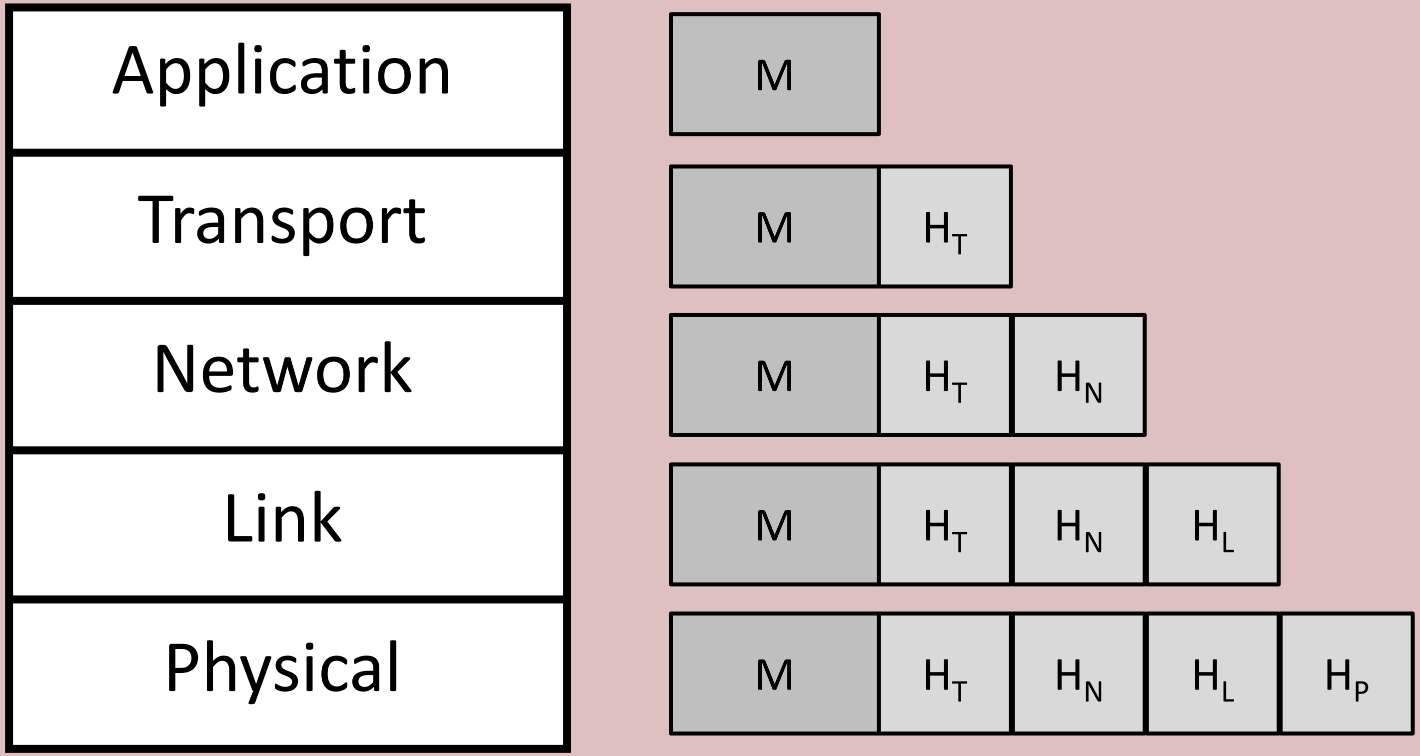
- Layer N data typically encapsulated as opaque bytes by layer N-1
  - Header
  - Footer (optional)

- Multiplex: encapsulate N-PDU into (N-1)-PDU

- Demultiplex: decapsulate N-PDU from (N-1)-PDU



Encapsulation



End-to-End Argument

- System design principle
- Important functionality should usually be implemented in higher layers at the end systems
- Examples of important functionality
  - Reliable message delivery
  - Encryption and authentication

End-to-End Argument

- Heavily influenced TCP/IP design
- Internet: dumb network, smart hosts (supports end-to-end argument)
- Telephone: dumb hosts, smart network (contradicts end-to-end argument)

Network Security

- Security considerations
  - Applies to each layer of protocol stack
  - Required section for RFCs (RFC 3552)

- Original Internet designs often did not prioritize security
  - Initial threat model: mutually trusted hosts and routers at research institutions
  - Challenge: retrofit security

Internet Standardization

- Protocols must be standardized for interoperability
  - Browsers talk to Web servers
  - Gateway routers talk to core routers
- Internet Engineering Task Force (IETF)
  - Meets three times per year
  - Standardize core Internet protocols
- Request for Comments (RFC)
  - Published standards for Internet protocols
  - Some drafts never become RFCs

Other Standardization

- IEEE (low layers)
  - Wi-Fi
  - Ethernet
- W3C (Web)
  - HTML and CSS
  - Browsers
- ITU-T (telephony)
  - Telephone system
  - Cellular networks

Registration Authorities

- Allocate IP address blocks
- Assign domain names

- IANA
  - Internet Assigned Numbers Authority
  - Global registration authority
  - Used to be run by one person until 1998

- ICANN
  - Internet Corporation for Assigned Names and Numbers
  - Now in charge of IANA

Regional Internet Registries (RIR)

- Assigned large address blocks by IANA
- APNIC: Asia/Pacific
- ARIN: North America, Africa (south of equator), and part of Caribbean
- LACNIC: Latin America and part of Caribbean
- RIPE NCC: Europe, Middle East, Central Asia, and Africa (north of equator)

Thank You!

Networks

Internet History

Adopted from material in “Computer Networking: A Top Down Approach” by Kurose and Ross and slides developed by William Conner

Internet History

Section 1.7

Internet History (1960s)

1962: Kleinrock (MIT) PhD thesis on the mathematical theory of packet switching

1966: Advanced Research Projects Agency (ARPA) funds ARPANET packet-switched networking project

1969: First successful message sent on ARPANET by a UCLA student to Stanford

Internet History (1970s)

1971: ALOHAnet wireless network (University of Hawaii)

1972: First email program

1972: ARPAnet reaches 15 nodes

1974: Cerf and Kahn seminal paper that defined today's Internet architecture

1976: Ethernet invented (Xerox PARC)

1979: ARPAnet reaches 200 nodes

Internet History (1980s)

1982: SMTP defined in RFC 821

1983: TCP/IP deployed

1983: DNS defined in RFCs 882 and 883

1985: FTP defined in RFC 959

1988: TCP congestion control published

1989: Berners-Lee invents WWW

Internet History (1990s)

1990: ARPAnet decommissioned

1993: Mosaic browser released (UIUC), predecessor to Netscape Navigator

1995: AOL reaches 1M members

1996: AOL reaches 5M members

1999: Napster p2p file sharing launched

Present

2016: ~5B devices attached to Internet

2017: ~1.86B Facebook users

2017: ~1.5B YouTube users

2017: ~328M Twitter users

2017: ~166M Snapchat users

How many of these “users” are actually bots?

Thank You!

Networks

Socket Programming

Adopted from material in “Computer Networking: A Top Down Approach” by Kurose and Ross and slides developed by William Conner

Socket API

- Socket API: application programming interface to network operations

- C POSIX library, Java, and Python all support socket APIs

- Programming assignments will involve socket programming

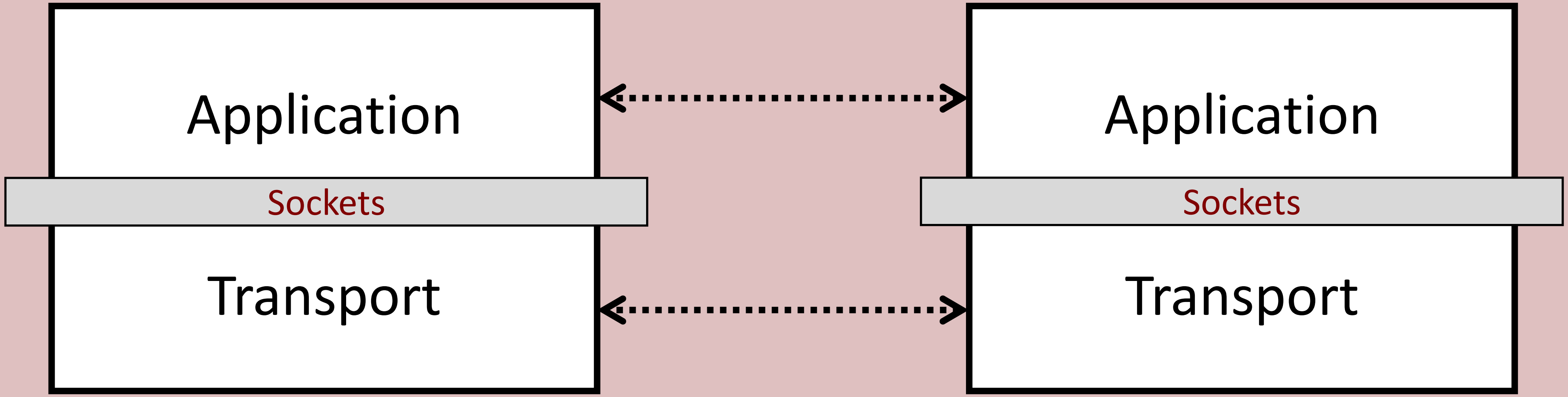
Sockets

- Communication endpoint
  - Door to a process
  - Socket address is host IP address and port number

- UNIX file descriptors used for file handles, pipes, and network sockets

- Associated with particular transport (typically TCP or UDP)

Sockets


Application
Sockets
Transport
Application
Sockets
Transport

Socket Programming - Client

1. Create new client socket
2. Open connection to server
3. Write request to server
4. Read response from server
5. Close socket

Socket Programming - Server

1. Create new server socket
2. Listen for connections from clients
3. Accept incoming connection
4. Spawn new thread to handle client request on accept socket
5. Close accept socket
6. Repeat

Programming Tutorials

Socket Programming:

https://docs.python.org/3/howto/sockets.html

Threading:

https://docs.python.org/3/library/threading.html

Thank You!