# CSE 120: Principles of Operating Systems
# Lecture 15: Networks

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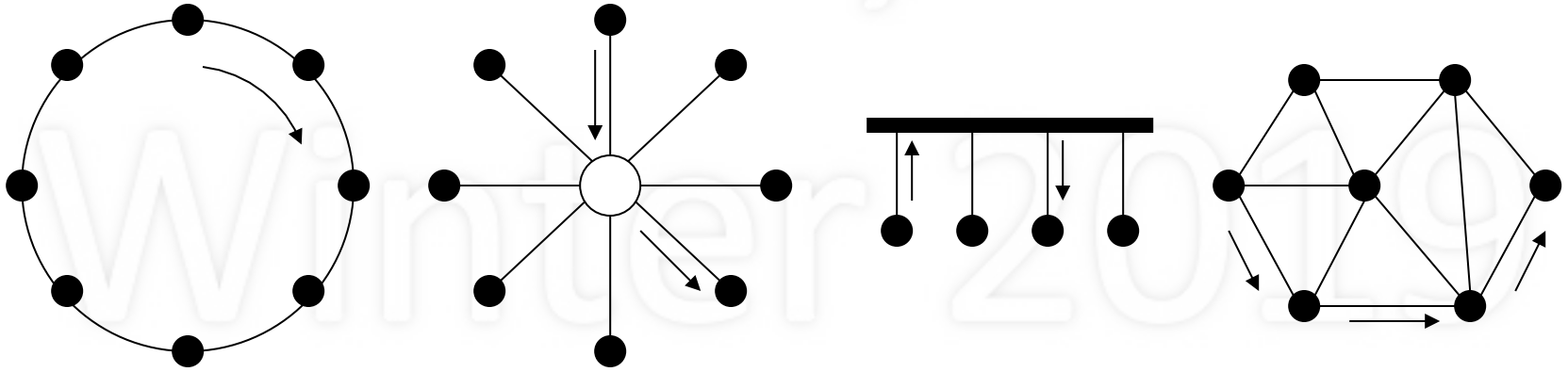
# What is a Network?

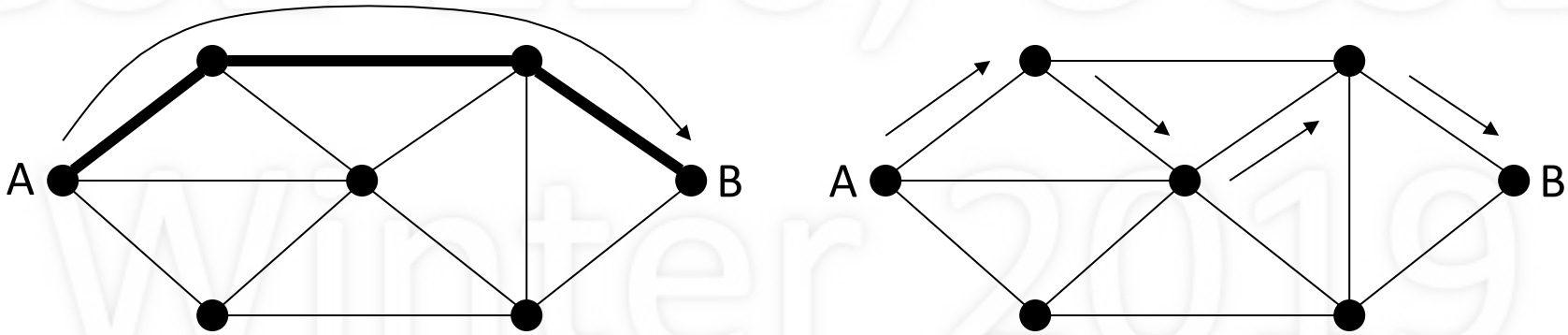
- Network
  - Set of computing nodes
  - Connected by communication links
  - Allows data transfer by a sender to a receiver
- Internetwork: a network of networks
  - The "Internet" is a global internetwork
  - Nodes communicate using IP (Internet Protocol)

# Types of Networks




- By topology: ring, star, bus, graph
- By geographic coverage
  - LAN: local area network (spanning floor, building)
  - WAN: wide area network (spanning state, country)

# Circuit-switching vs. Packet switching




- Circuit switching: establish path, send data
  - Reserve resources provide performance control
  - Example: telephone system
- Packet switching: forward packets hop to hop
  - Fair sharing despite bursts, statistical multiplexing
  - Example: postal system

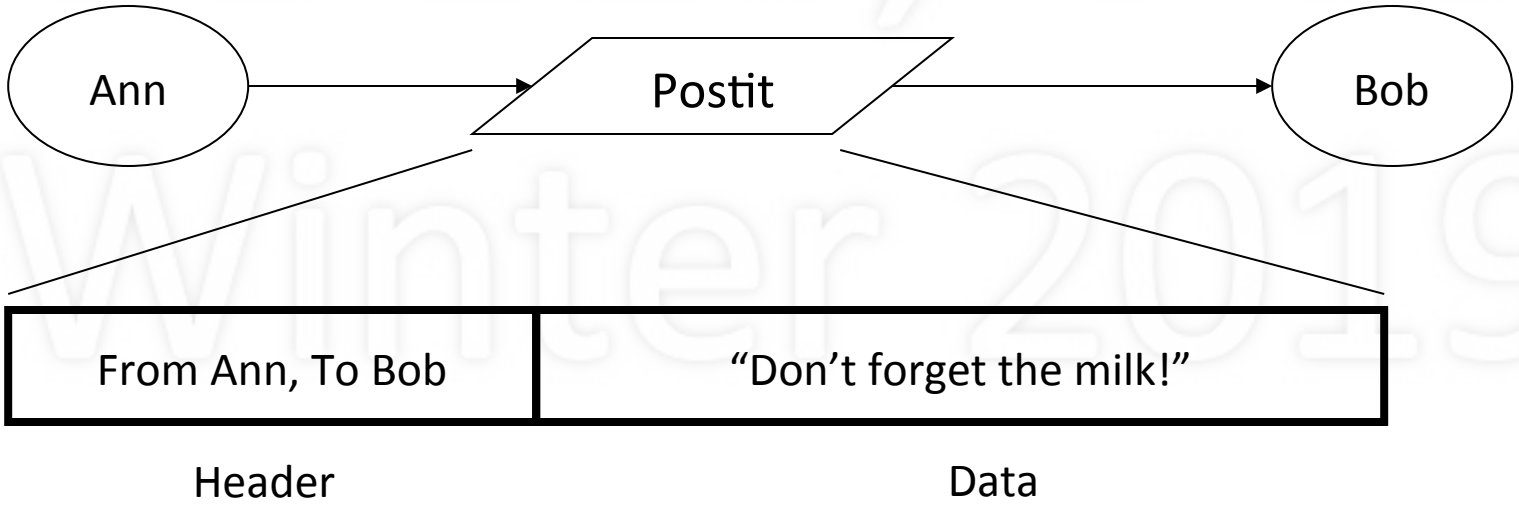
# What is a Protocol?

- Goal: get message from sender to receiver
- Protocol
  - agreed message format and transfer procedure
- Multiparty, so no central thread of control
  - sender and receiver are separate processes
- Expectations of operation
  - first you do x, then I do y, then you do z, ...
  - if you do q, I'll do p

# Message

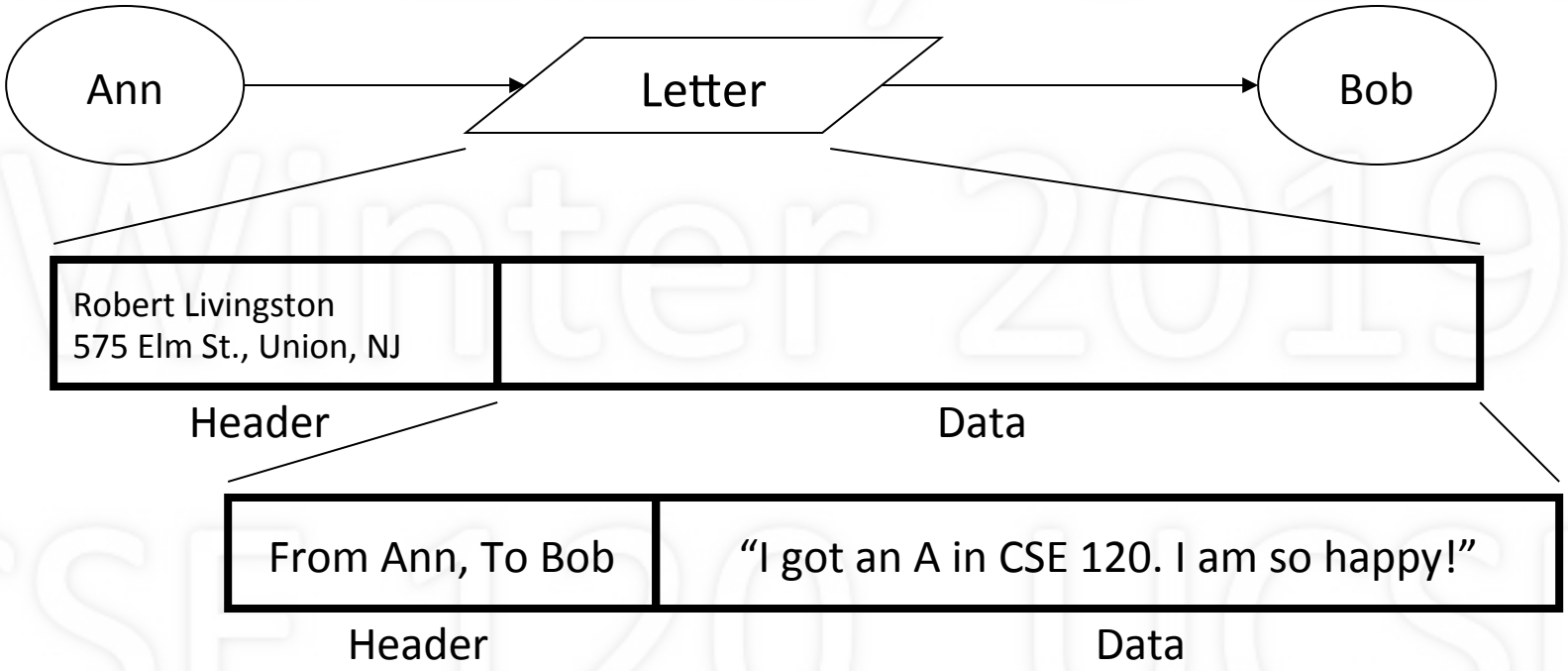

- Message: contains header and data
  - Similar terms: packet, datagram, frame, …
- Data: what sender wants to receiver to know
- Header: information to support protocol
  - Source and destination addresses
  - State of protocol operation
  - Error control (to check integrity of received data)

# Example: Ann Sends Message to Bob




- Protocol
  - Message format: (from, to), message contents
  - Transfer procedure: post on refrigerator

# Example: Ann Sends Message to Bob




- Protocol
  - Message format: address(es) on envelope, letter
  - Transfer procedure: postal system

# Layering: Separation of Functions

| Letter: written/sent by Ann, received/read by Bob |
| --- |
| Postal System: Mail delivery of letter in envelope |

- Ann and Bob
  - Don't have to know about delivery
  - However, aid postal system by providing addresses
- Postal System
  - Only has to know addresses and how to deliver
  - Doesn't care about "data": Ann, Bob, letter

# 7 Layers of OSI Reference Model

7 Application: application protocol, e.g., HTTP

6 Presentation: syntax, network format

5 Session: start/stop/manage connections

4 Transport: segment, reliability, flow control

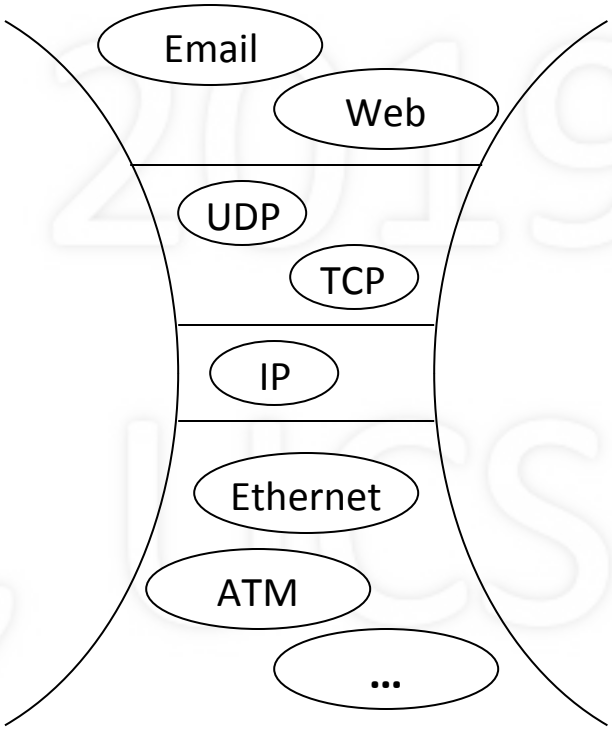
3 Network: logical addressing, routing

2 Link: physical addressing, framing

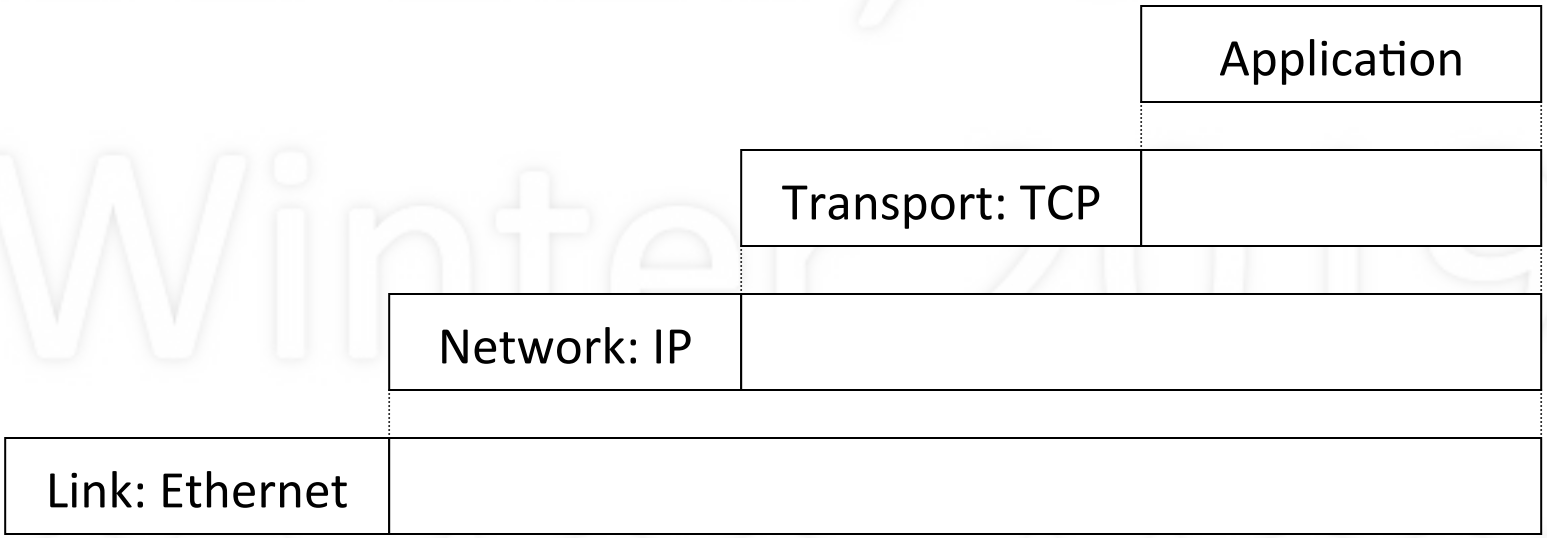
1 Physical: 0's and 1's over a wire

# Internet Protocol Stack

- "Hourglass" design
- Application: Email, Web
- Session: sockets
- Transport: TCP, UDP
- Network: IP
- Link: Ethernet
- Physical



# Encapsulation




- Higher level *n* within lower level *n*-1
- Can also have level within a level: tunneling
- Multiplexing and de-multiplexing

# Addresses

- Generally, three levels of addresses
  - Domain names: cs.ucsd.edu
  - Logical addresses (IP): 128.53.27.92
  - Physical addresses (Ethernet): 0x27A5BB17019D
- Address resolution
  - Mapping higher level name to lower level name
  - Techniques: table lookup, formula, protocol

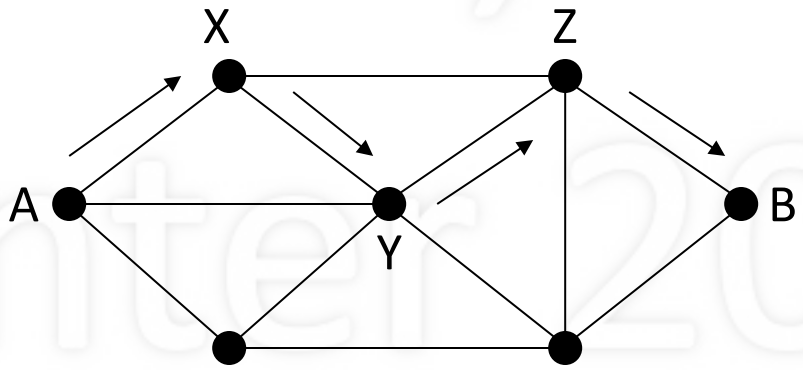
# Sizes of Address Spaces

- IPv4 (version 4, current/past)
  - 32 bit addresses
  - $2^{32}$ = 4 billion addresses
- IPv6 (version 6, future/current)
  - 128 bit addresses
  - $2^{128} = 2^8 \times (2^{10})^{12} = 256 \times (10^3)^{12} = 2.56 \times 10^{38}$

# How Many Addresses is $10^{38}$?

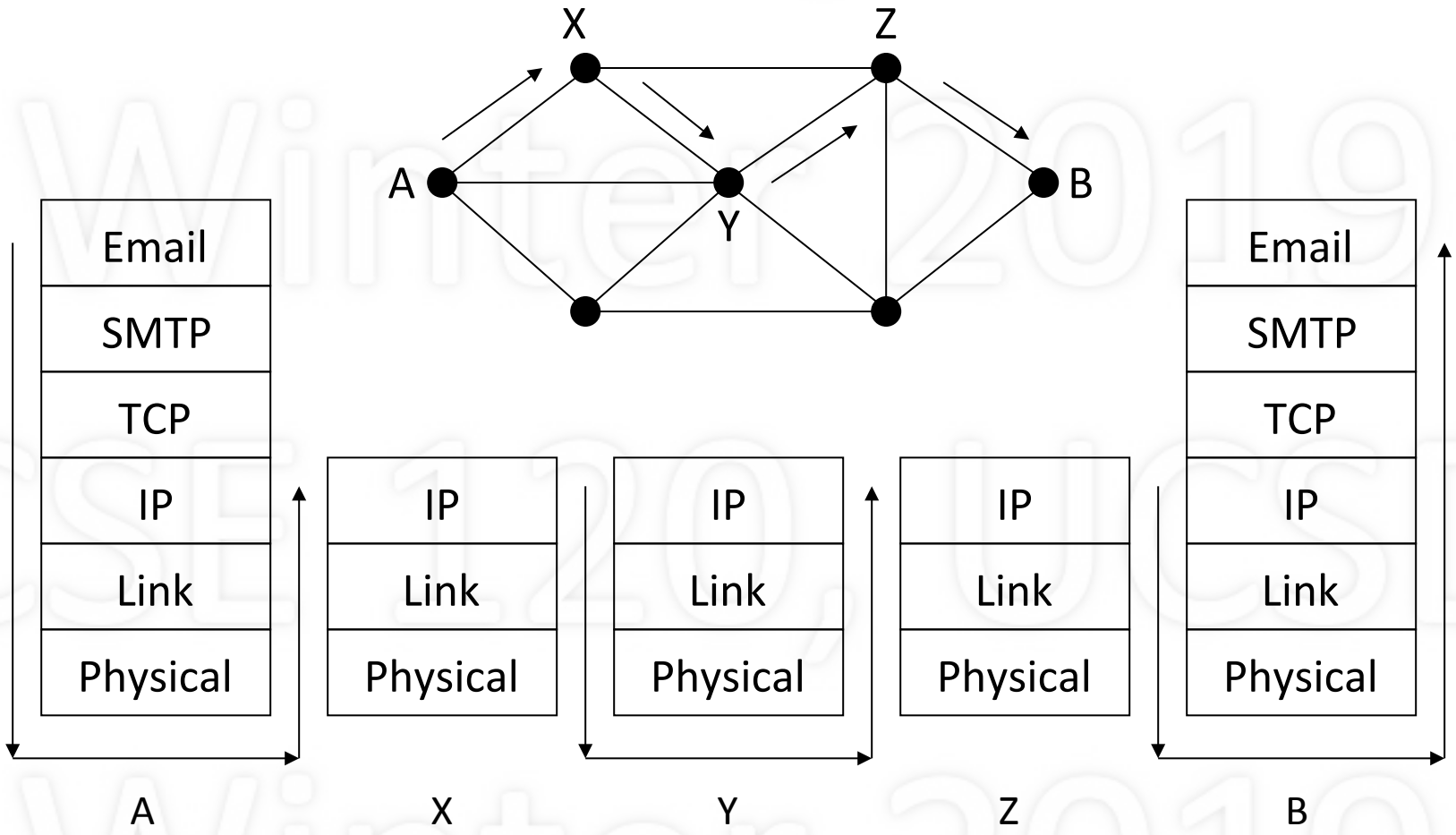
- How many addresses to cover the Earth?
- Earth surface area = $4\pi$ (6371 km)$^2$
- So, number of addresses per nm$^2$ ~ 500 000
  - Consider that cross-section of hair is 5 billion nm$^2$
  - Number of addresses: 2-3 million million!
- Had they picked 256 bits: $2^{256} = 10^{77}$
  - Number of atoms in the universe: $10^{80}$

# Routing




- Routing: how to get packet from A to B
  - A forwards to X; X to Y; Y to Z; Z to B
- Each intermediate node can be a decision point
  - Static: always make the same decision
  - Dynamic: decision can change (e.g., based on state)

# Example of Internet Routing



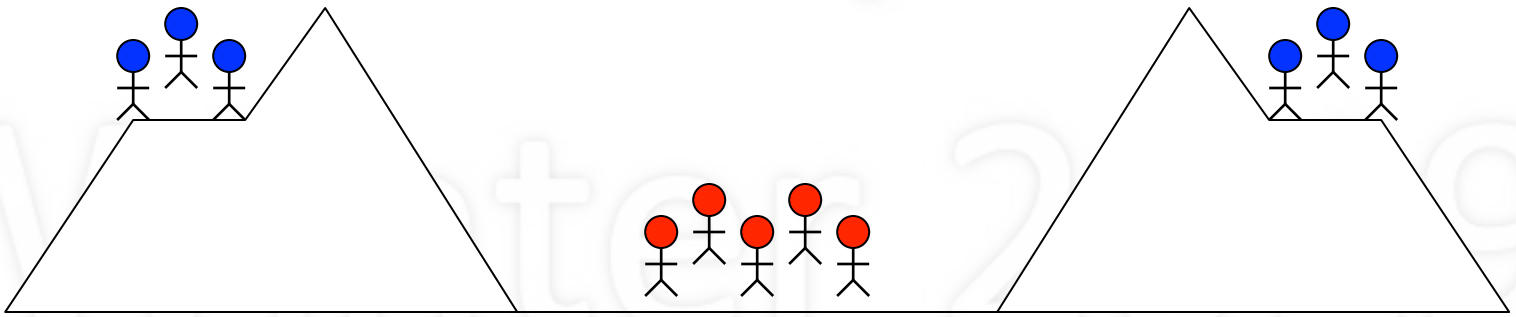
# Scalability

- How well does system grow
  - in terms of performance, reliability, etc.
- Ramifications of adding node or link
  - Local effects vs. global effects
- Information growth: important to reduce
  - Amount stored at nodes
  - Amount exchanged between nodes

# Error Control

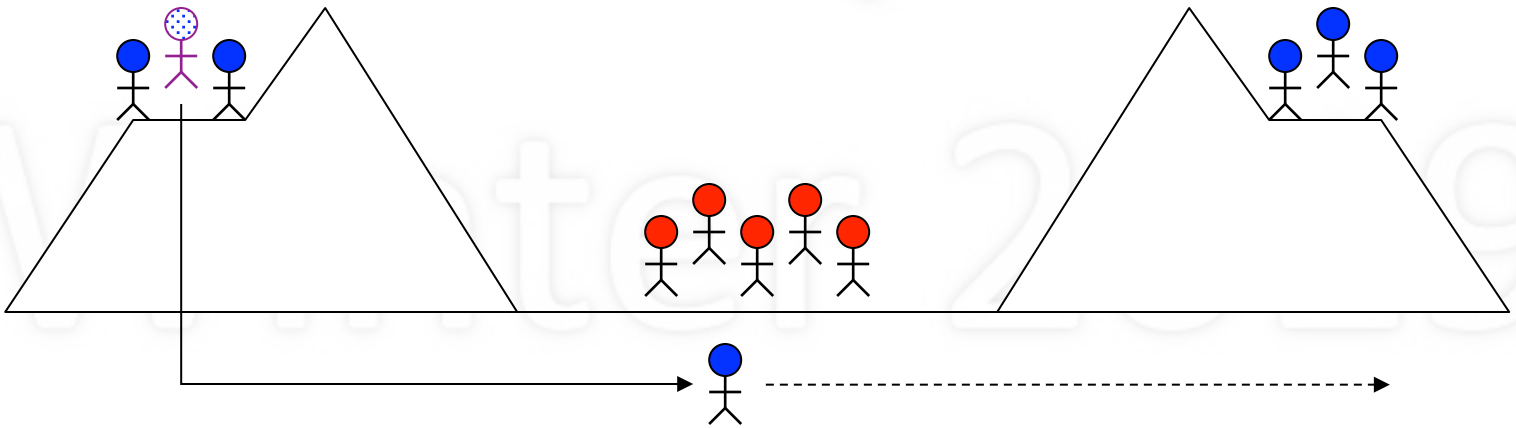
- Parity: even, odd, two-dimensional
- CRC (cyclic redundancy code)
- Checksum
- Automatic repeat request (ARQ)

# The Two General's Problem



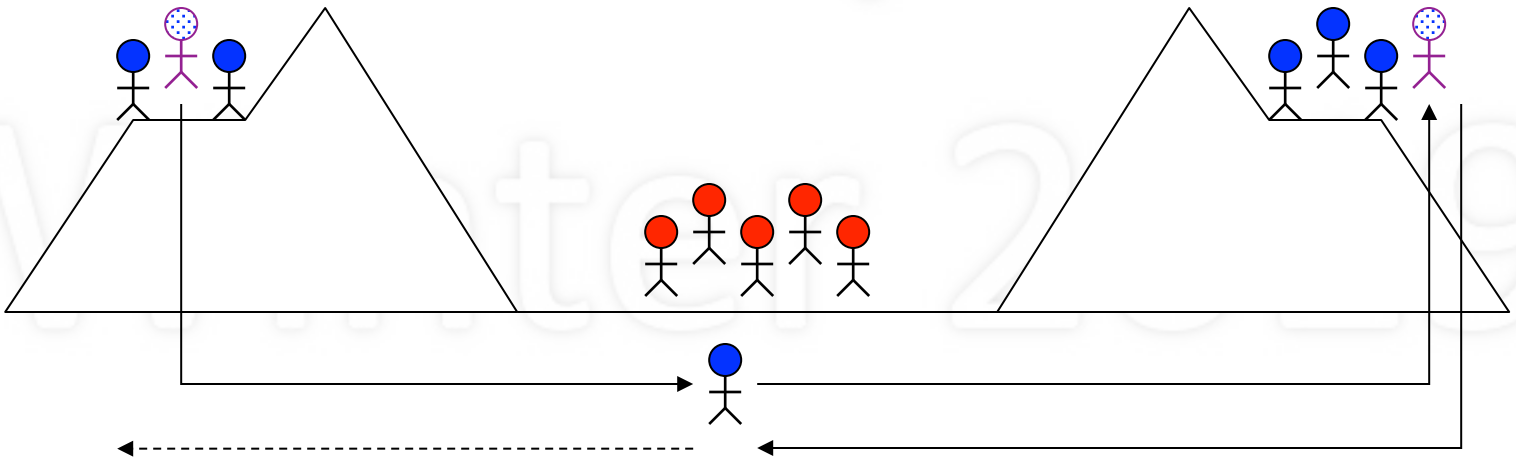
- Two army divisions (blue) surround enemy (red)
  - Each division led by a general
  - Both must agree when to simultaneously attack
  - If either side attacks alone, defeat
- Generals can only communicate via messengers
  - Messengers may get captured (unreliable channel)

# The Two Generals' Problem



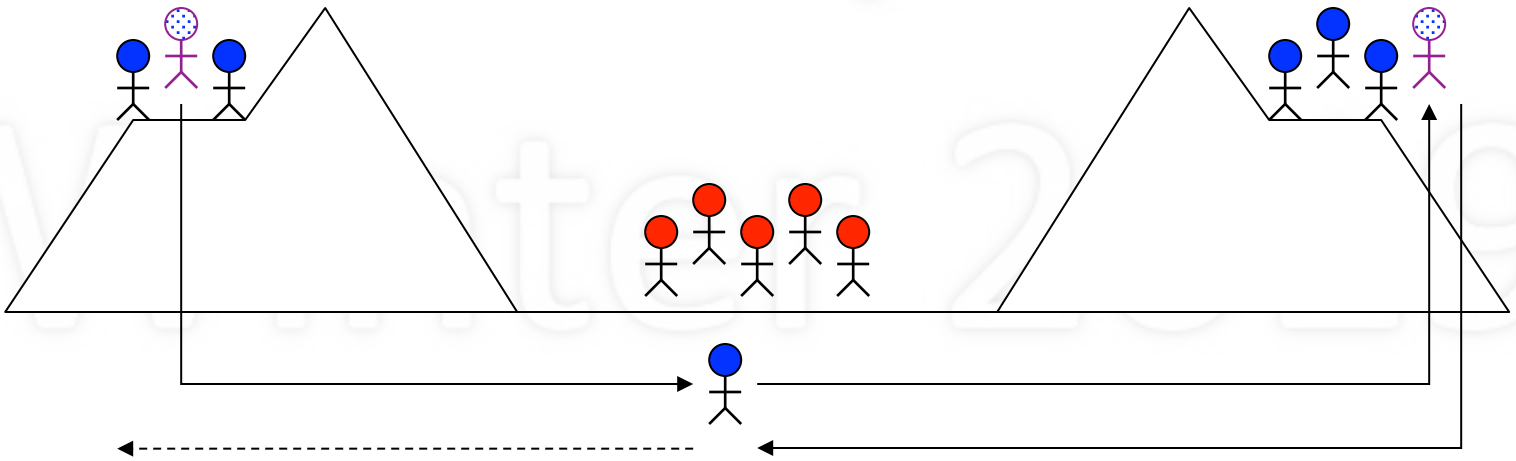
- How to coordinate?
  - Send messenger: "Attack at 6AM"
  - What if messenger doesn't make it?

# The Two Generals' Problem



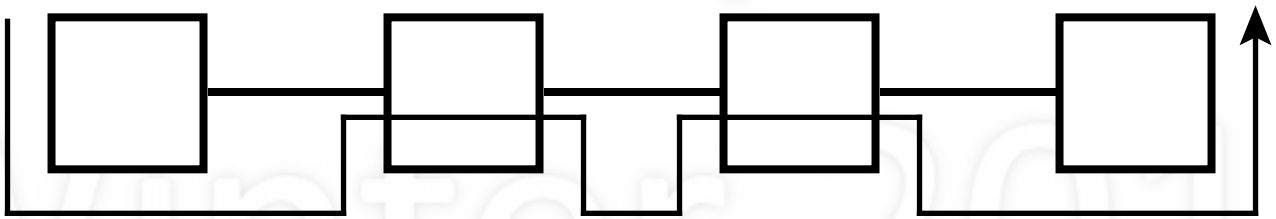
- How to be sure messenger made it?
  - Send acknowledgment: "I delivered message"
  - What if messenger doesn't make it?

# The Two Generals' Problem



- Main results
  - Can't create perfect channel out of faulty one
  - Technology doesn't help
  - Can only increase probability of success

# The "End-to-End" Argument



- Don't provide a function at lower layer if you have to do it at higher layer anyway - *unless there is a very good performance reason to do so*
- Examples: error control, quality of service
- Reference: Saltzer, Reed, Clark, "End-To-End Arguments in System Design," ACM Transactions on Computer Systems, Vol. 2 (4), pp. 277-288, 1984.

# Textbook

- Chap. 19
  - Lecture-related: 19.1-19.3


CSE 120, UCSD Winter 2019

# Review & Research

- What is a network? What is a node? What is a link?
- What is an internetwork?
- What distinguished "The Internet" from any other internetwork?**
- How do each of the following networks work: ring; star, bus, graph?* What are the pros/ cons of each?**

# R&R

- What is the difference between circuit-switching and packet-switching?* What are the pros/cons of each?**
- What is meant by "resource reservation", and why is it valuable?***
- What is meant by "statistical multiplexing", and why is it valuable?***

# R&R

- What is a protocol?
- In what way is a protocol different from a program that defines a single thread?**
- What is a message?
- What kinds of information comprise the header?**
- Why is the “state of protocol operation” part of the header?***

# R&R

- Why is it important to separate the header and the data?***
- On slide 8, why is the header and data of the inner (lower-positioned) message part of the data of the out (higher-positioned) message? ***
- What is meant by layering, i.e., separation of functions?***

# R&R

- What are the 7 layers of the OSI Reference Model, and what functionality lies at each layer?*
- What is the difference between logical addressing and physical addressing?**
- What is the purpose of framing?***

# R&R

- What are the layers of the Internet Protocol Stack?*
- Which layer is the most important layer, and why?**
- What is the meaning of encapsulation?*

# R&R

- What types of addresses are typical of the Internet?*
- Why are they called “levels” of addresses, and why are there (at least) 3 levels?***
- How is one level of address converted to another level?***

# R&R

- What is the difference between an IPv4 address and an IPv6 address, and what motivated this change?**
- What is routing?*
- What is meant by “each intermediate node can be a decision point”?**
- What is the difference between static and dynamic routing?**

# R&R

- On slide 17, can you explain the path through the various protocol layers of each node along the route?***
- Why do the intermediate nodes just show the lowest 3 layers while the source and destination nodes show all the layers?***
- What is meant by a system being “scalable”? **

# R&R

- What is error control?*
- What is a checksum, and how is it used?**
- What is the Two Generals' Problem?**
- What lesson do we learn from the Two Generals' Problem?**
- How does the Two Generals' Problem relate to networks?***
- What is the "End-to-End" problem?***