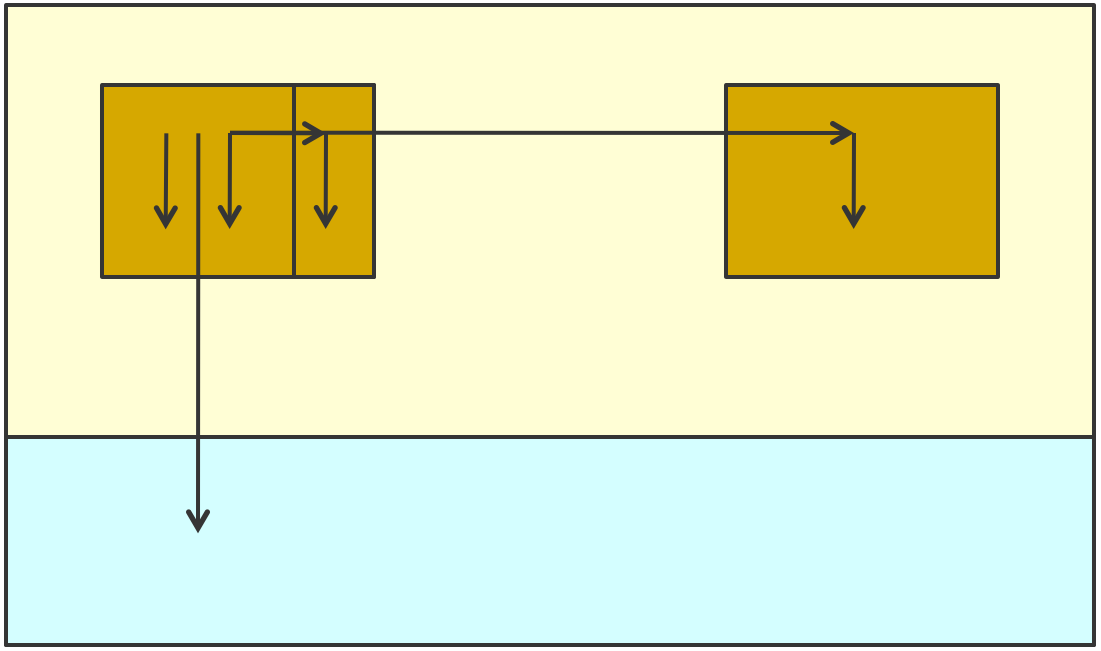
Introduction to Networking and the Internet

Announcements

- Brighten's office hours cancelled for today
  - extra hours next week
- Wade Fagen lecturing on Friday

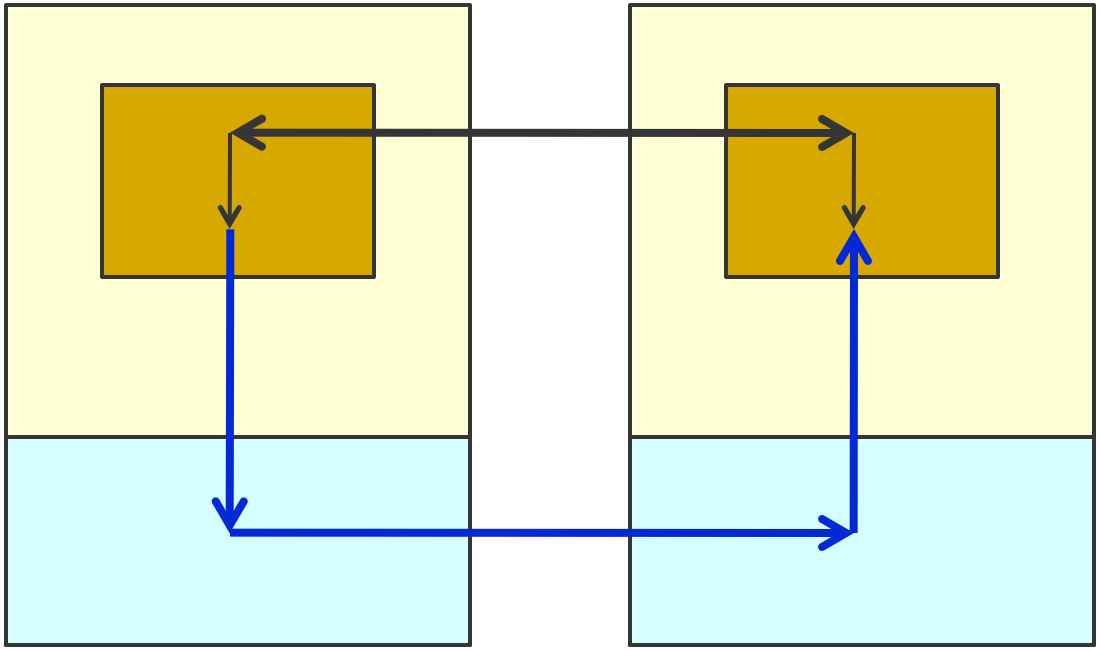
Where are we?

- Function calls, system calls, threads and processes



What's next?

- Networked communication and distributed applications

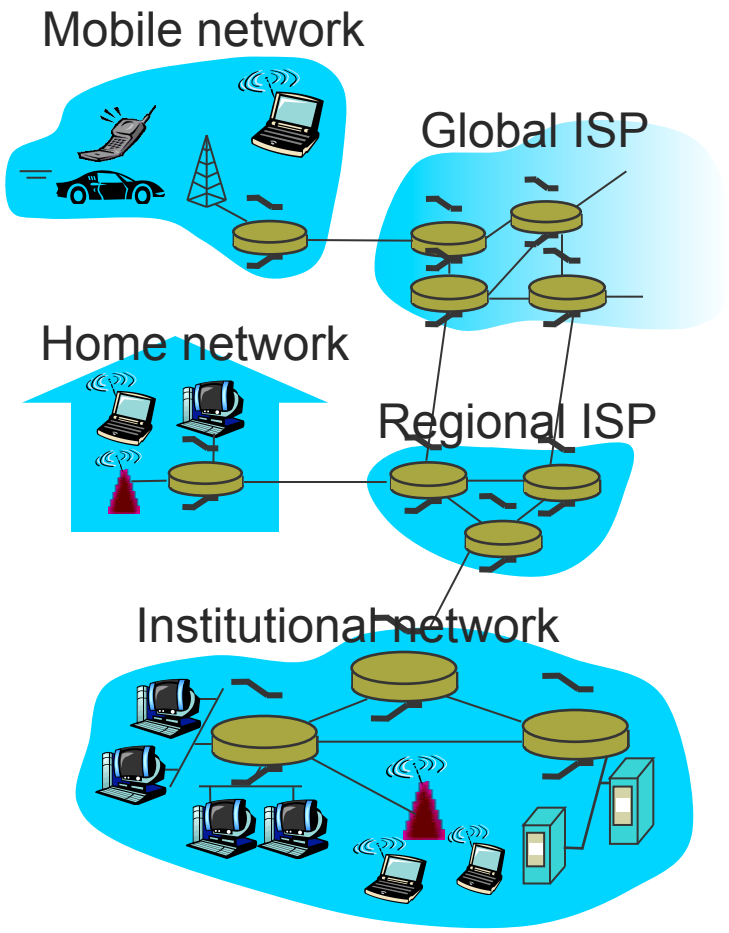


Introduction

- What is the Internet?
- Network edge
- What is a protocol?
- Protocol layers, service models

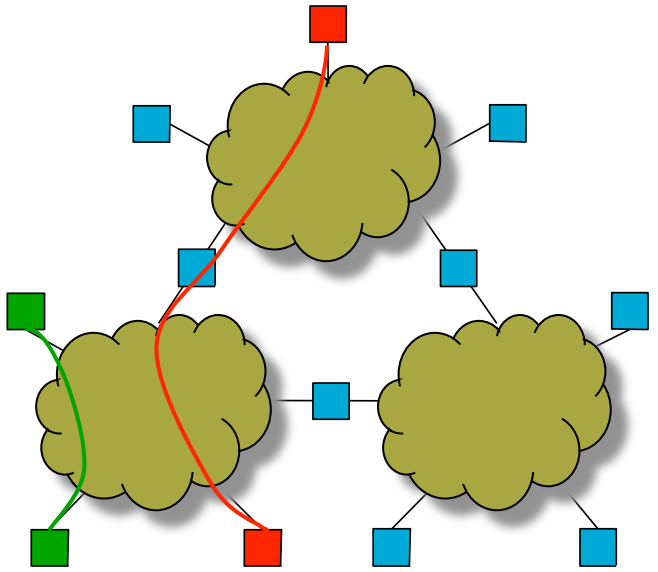
What is the Internet?

- Communication infrastructure
  - Enables distributed applications
  - Web, VoIP, email, games, e-commerce, file sharing
- Communication services
  - Provided to applications
  - Reliable data delivery from source to destination
  - “best effort” (unreliable) data delivery

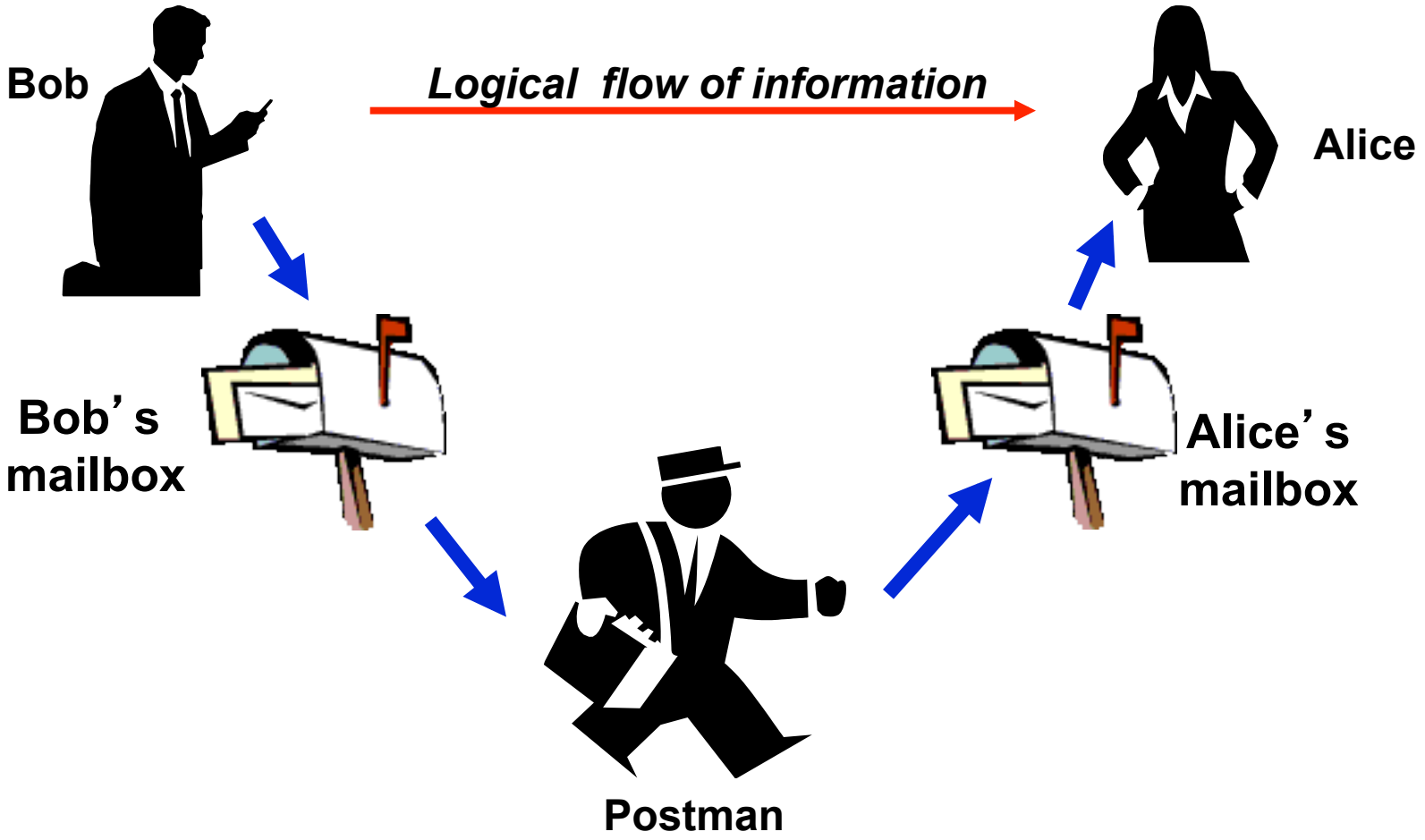


Network Service

- Goal
  - Transfer data between end systems
- Support For Common Services
  - Simplify the role of applications
  - Hide the complexity of the network
  - Semantics and interface depend on applications



Example: Sending a Letter



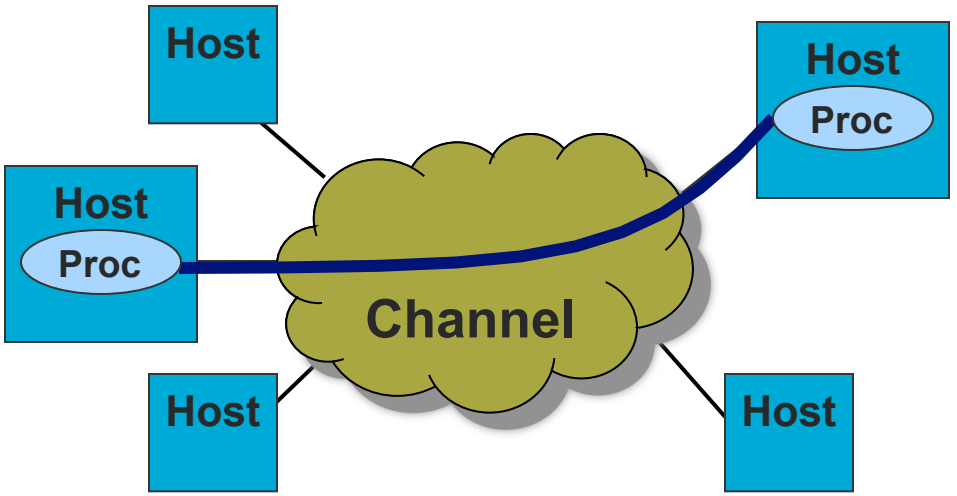
Services

- Unconfirmed service

- Acknowledged service

Channels

- Channel
  - The abstraction for application-level communication
- Idea
  - Turn host-to-host connectivity into process-to-process communication



Looks like IPC!

Networked Communication Challenges

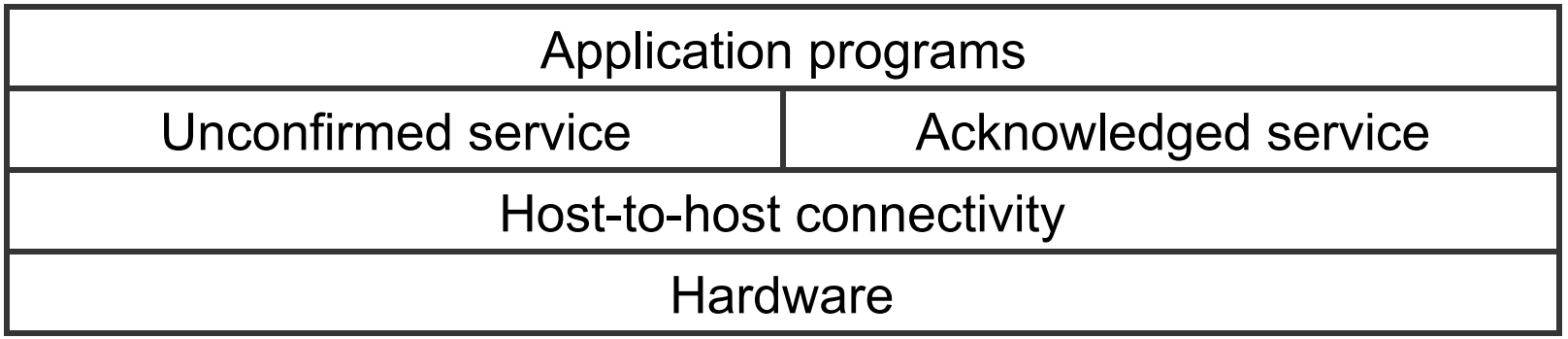
- Networked communication ≠ IPC
- Problems typically masked by communication channel abstractions
  - Bit errors (electrical interference)
  - Packet errors (congestion)
  - Link/node failures
  - Message delays
  - Out-of-order delivery
  - Eavesdropping
- Goal
  - Fill the gap between what applications expect and what the underlying technology provides

Network Architecture

- Networks are complex!
- Many "pieces"
  - Hosts
  - Routers
  - Links of various media
  - Applications
  - Protocols
  - Hardware, software
- Question
  - Is there any hope of organizing structure of network?

Abstraction through Layering

- Abstract system into layers:
  - Decompose the problem of building a network into manageable components
    - Each layer provides some functionality
  - Modular design provides flexibility
    - Modify layer independently
    - Allows alternative abstractions



Layering Example: Air Travel

- Layers
  - Each layer implements a service
  - Via its own internal-layer actions
  - Relying on services provided by layer below

Why layering?

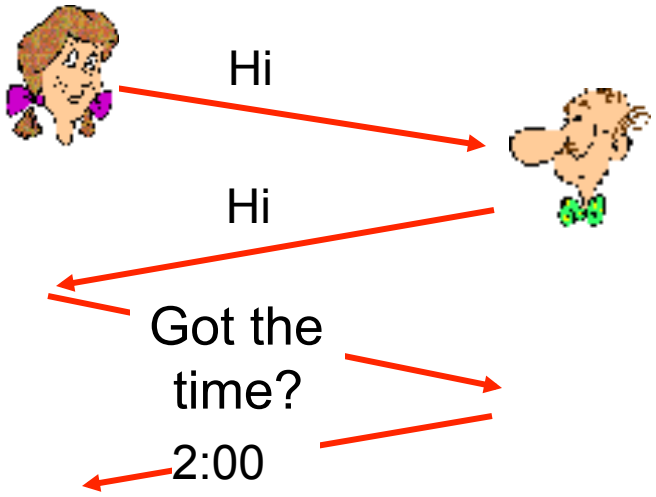
- Complexity
  - Explicit structure allows identification, relationship of complex system's pieces
- Modularity
  - Eases maintenance, updating of system
    - Change of implementation of layer's service transparent to rest of system
    - e.g., change in gate procedure doesn't affect rest of system

Protocol: Language of communication across hosts

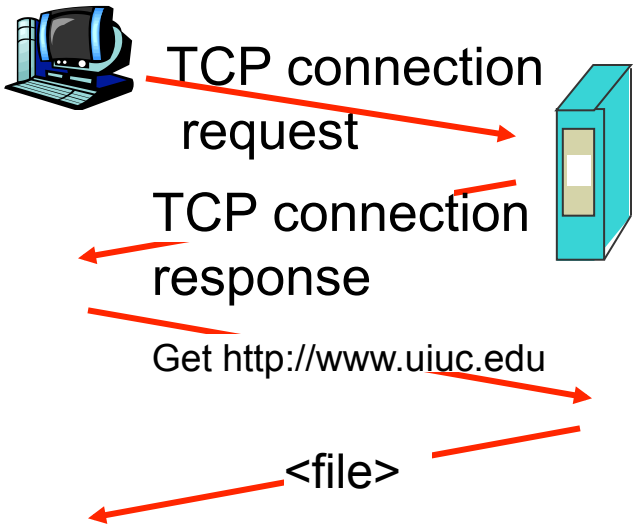
- Defines structure of communication between two instances of a layer (on two hosts)
- Protocols are defined by
  - Specific msgs sent
  - Specific actions taken when msgs received, or other events
- Protocols define
  - Format
  - Order of msgs sent and received among network entities
  - Actions taken on msg transmission, receipt

What is a Protocol?

- Human protocols
  - "what's the time?"
  - "I have a question"
  - Introductions



- Network protocols
  - Machines rather than humans
  - All internet communication is governed by protocols

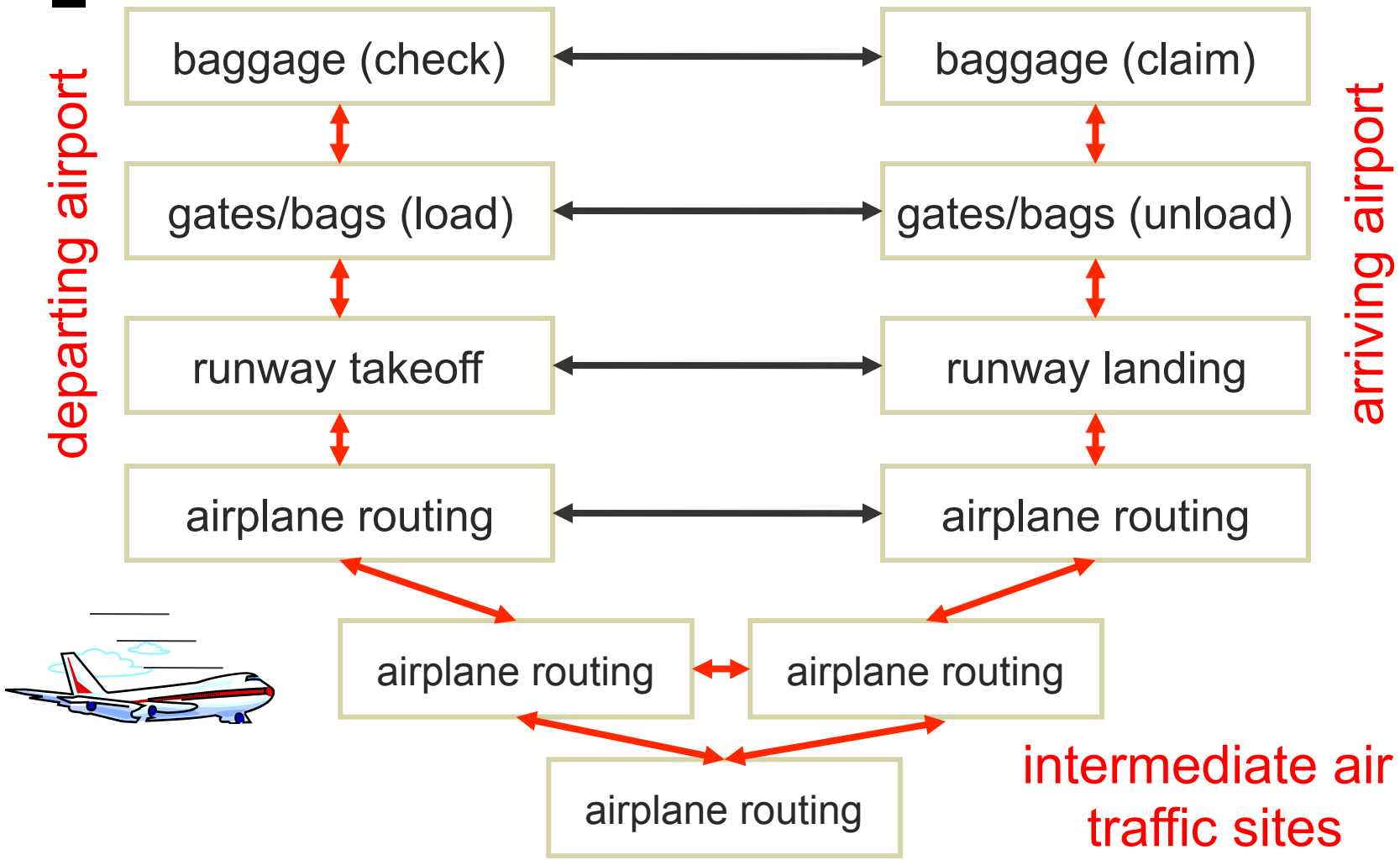


time

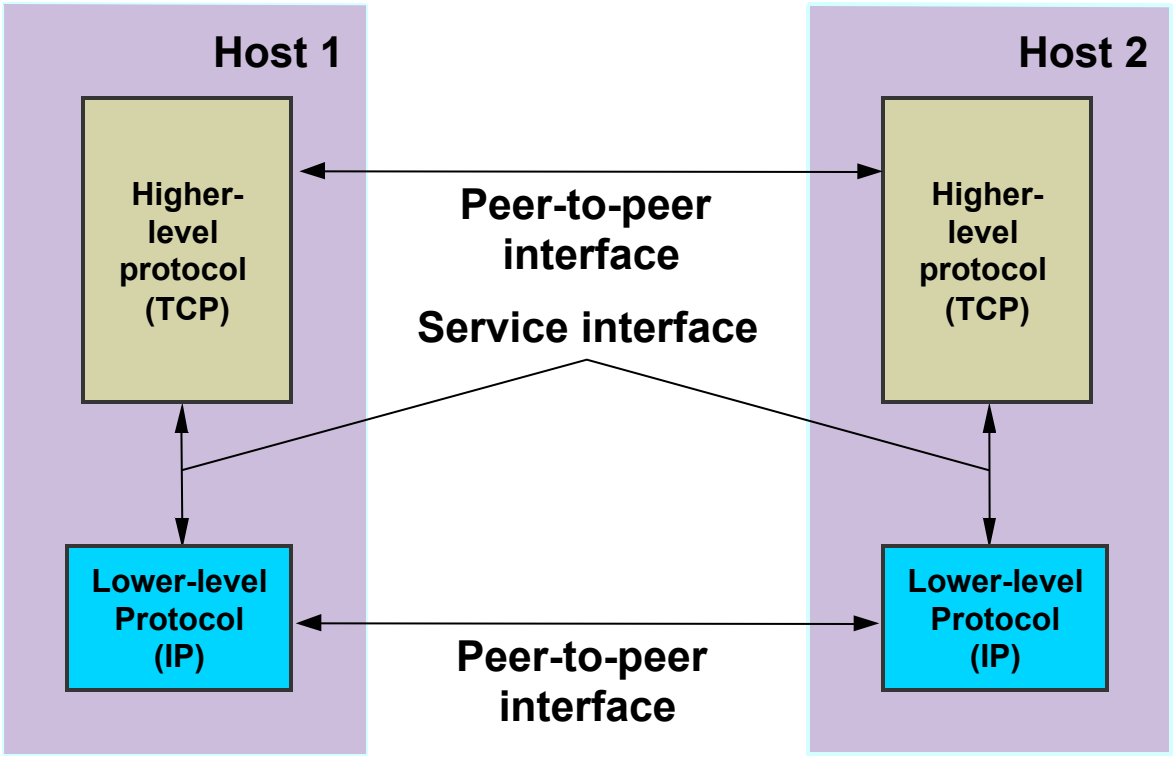
Network Protocols

- A protocol implements a communication service that higher-layer objects use to exchange messages
  - Service interface
    - To objects on the same computer that want to use its communication services
  - Peer interface
    - To its counterpart on a different machine
    - Peers communicate using the services of lower-level protocols

Interfaces



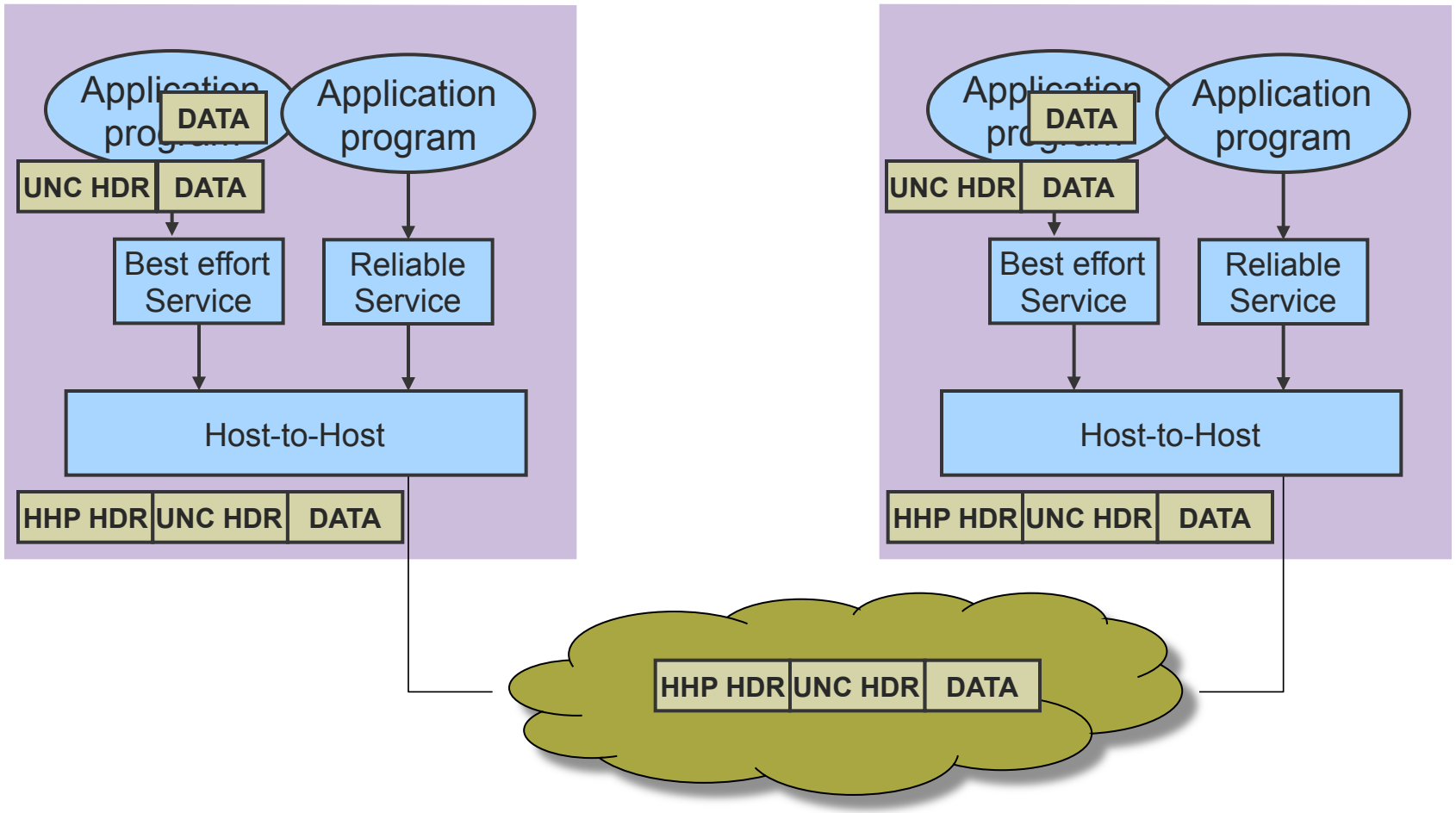
Interfaces



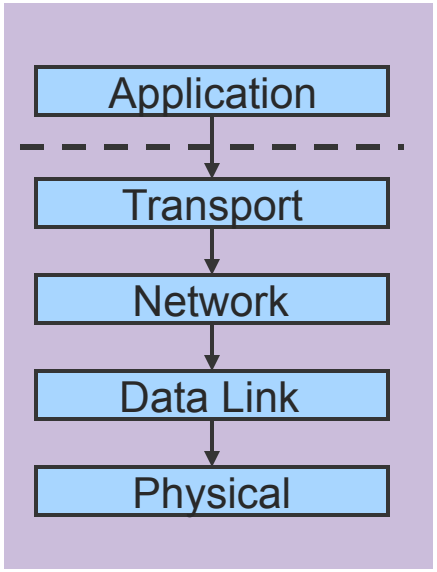
Layering Concepts

- Encapsulation
  - Higher layer protocols create messages and send them via the lower layer protocols
  - These messages are treated as data by the lower-level protocol
  - Higher-layer protocol adds its own control information in the form of headers or trailers
- Multiplexing and Demultiplexing
  - Use protocol keys in the header to determine correct upper-layer protocol

Encapsulation



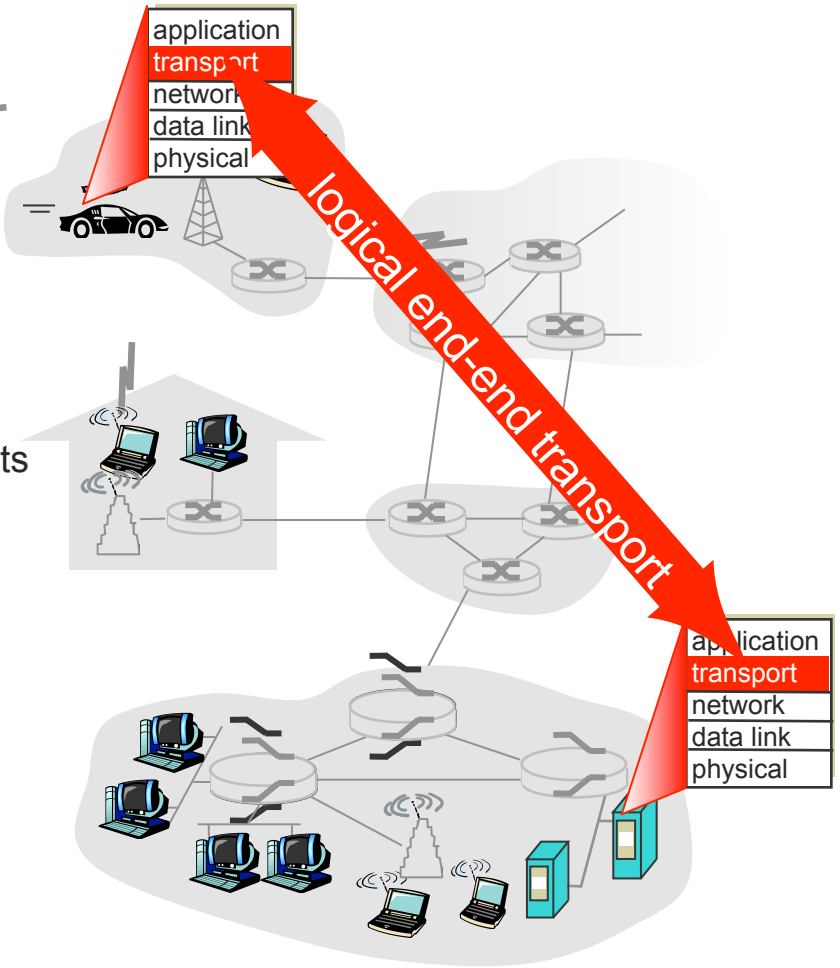
Internet Protocol Stack



- Application: Application specific protocols
- Transport: Process-to-process channel
- Network: Host-to-host packet delivery
- Data Link: Framing of data bits
- Physical: Transmission of raw bits

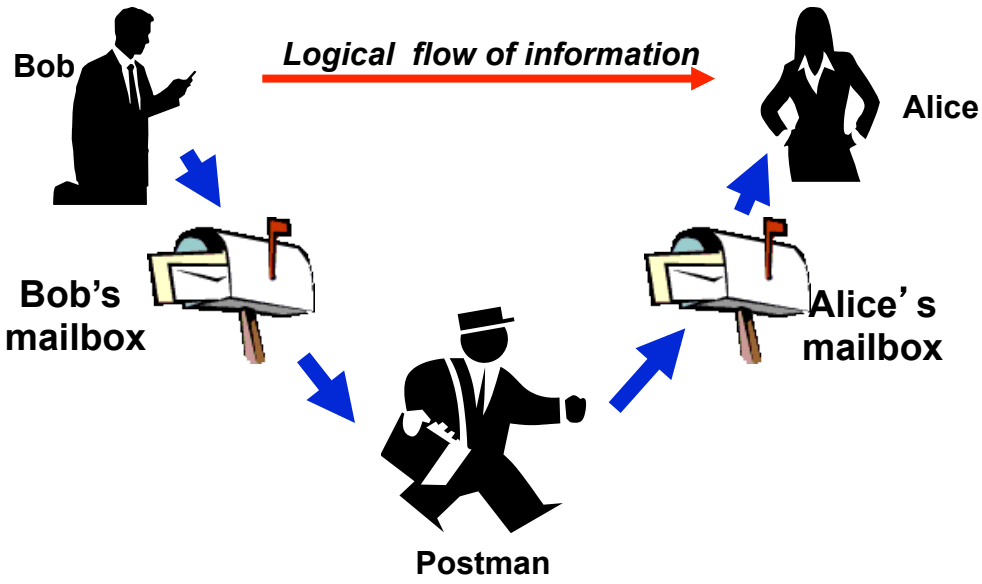
Transport Layer

- Provide logical communication between application processes running on different hosts
- Transport protocols run in end systems
  - Send side
    - Break application messages into segments
    - Pass to network layer
  - Receive side
    - Reassemble segments into messages
    - Pass to application layer
- More than one transport protocol available to applications
  - Internet: TCP and UDP



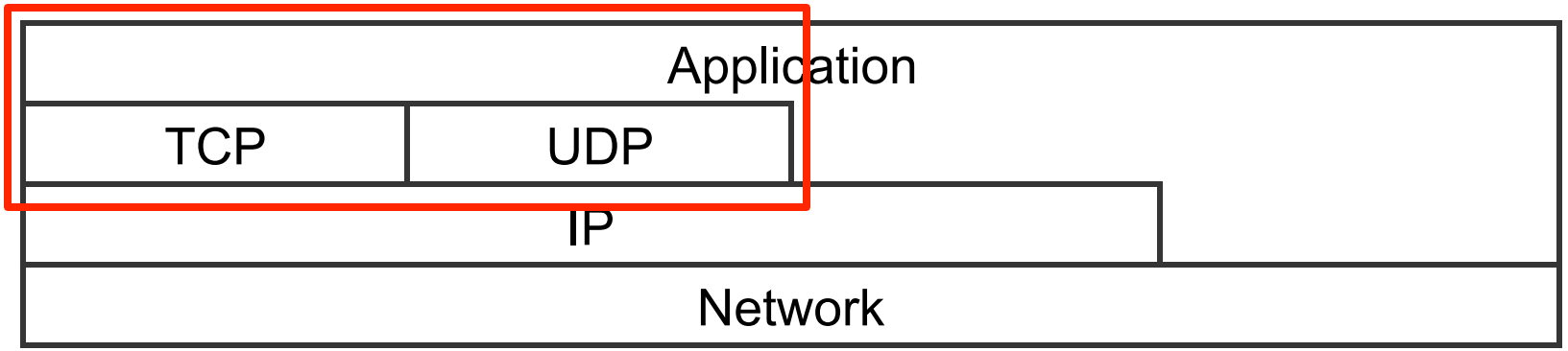
Transport vs. Network Layer

- Transport layer
  - Logical communication between processes
  - Relies on, enhances, network layer services
- Network layer
  - Logical communication between hosts



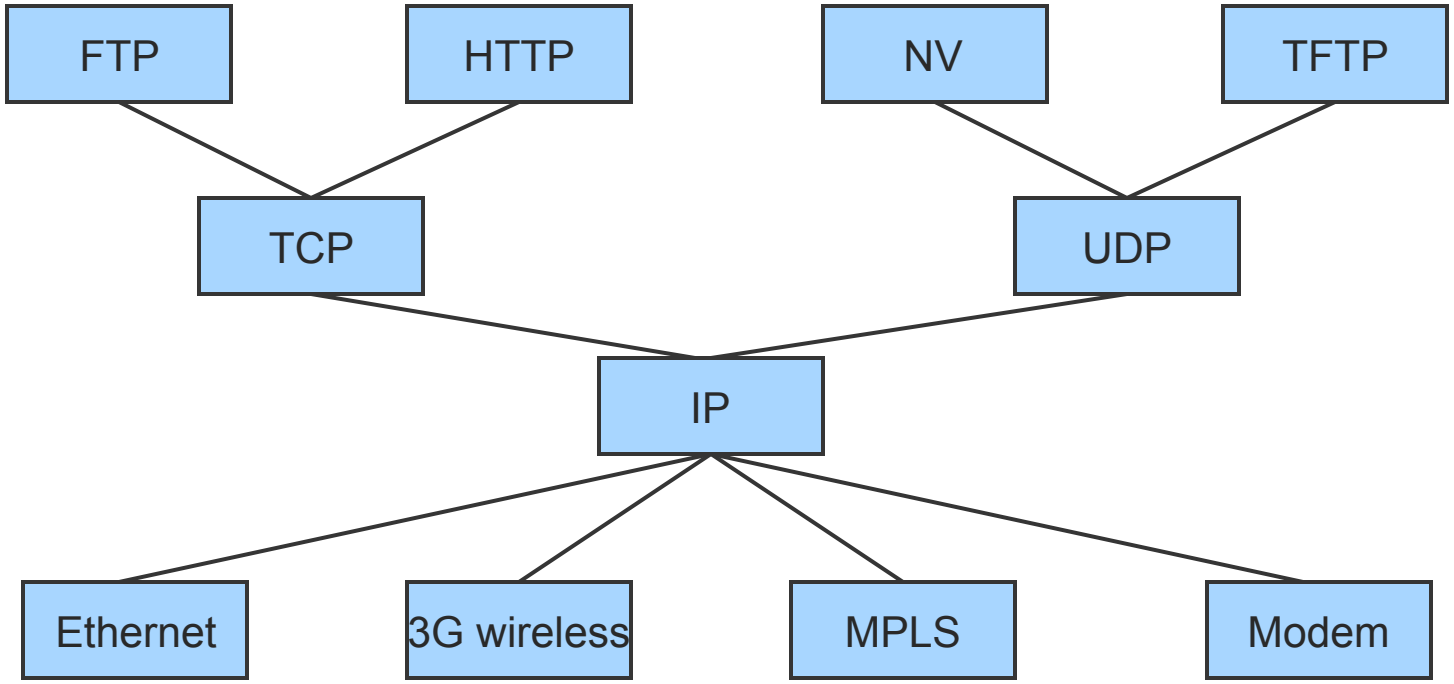
Internet Architecture

- Features
  - No strict layering



Internet Architecture – Hourglass Design

- Features
  - Hourglass shape – IP is the focal point



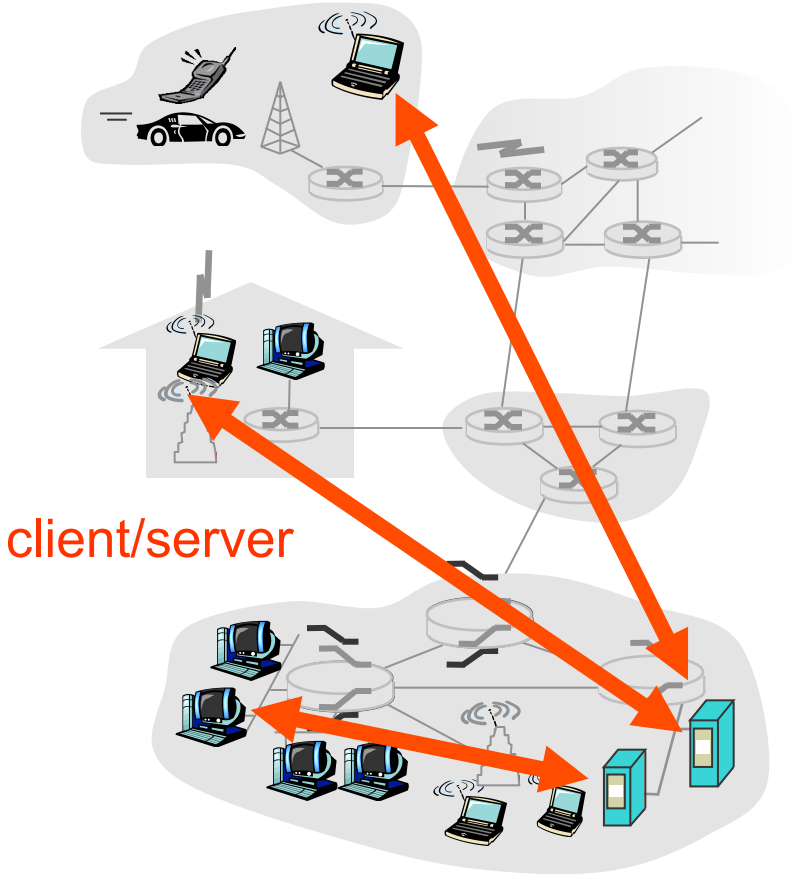
Network Applications

Creating a Network Application

- Write programs that
  - Run on (different) end systems
  - Communicate over network
    - e.g., web server software communicates with browser software
- No need to write software for network-core devices
  - Network-core devices do not run user applications

Client-server Architecture

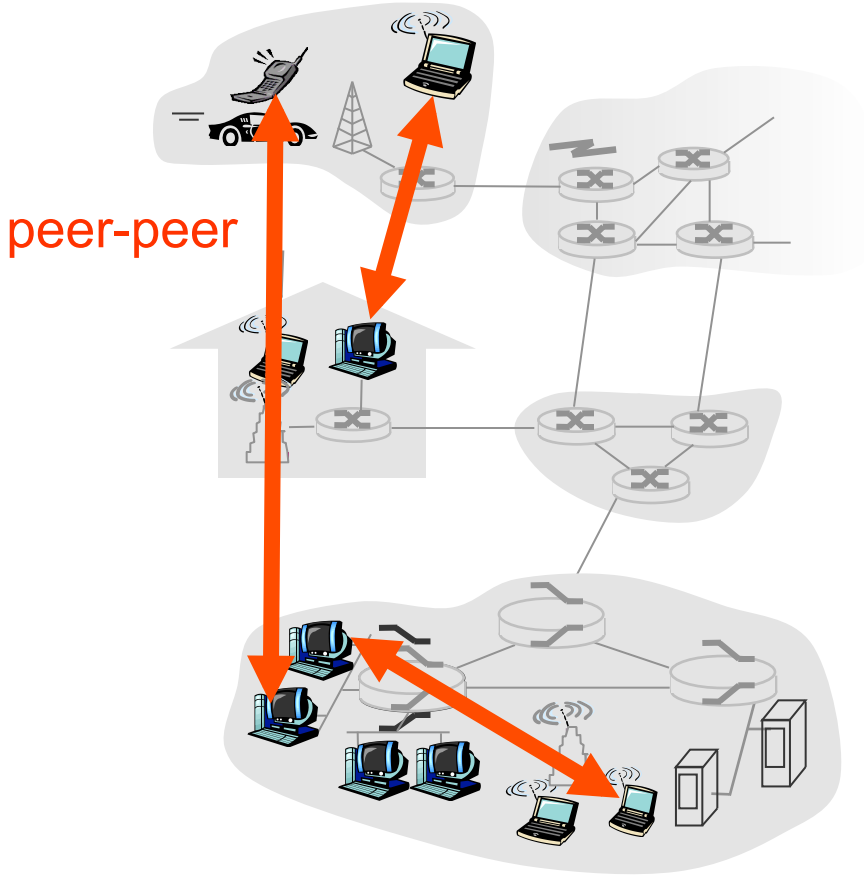
- Server
  - Always-on host
  - Well-known IP address
- Clients
  - Communicate with server
  - May be intermittently connected
  - May have dynamic IP addresses
  - Do not communicate directly with each other



P2P Architecture

- No always-on server
- Arbitrary end systems directly communicate
- Peers are intermittently connected and change IP addresses

- Highly scalable but difficult to manage



Hybrid Client-server and P2P

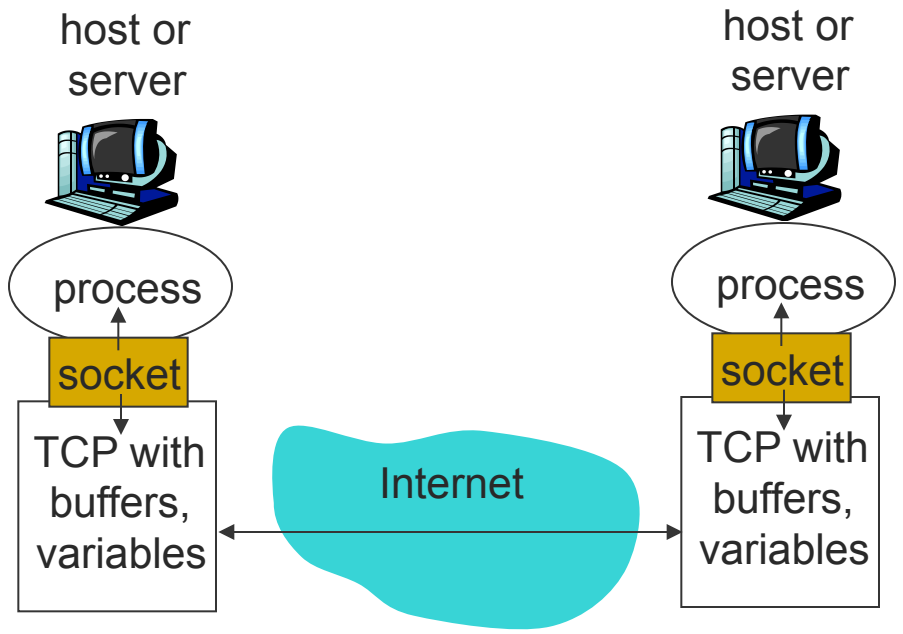
- Skype
  - Voice-over-IP P2P application
  - Centralized server: finding address of remote party
  - Client-client connection: direct (not through server)
- Instant messaging
  - Chatting between two users is P2P
  - Centralized service: client presence detection/location
  - User registers its IP address with central server when it comes online
  - User contacts central server to find IP addresses of buddies

Addressing Processes

- Receiving messages
  - Process must have identifier
  - Host device has unique 32-bit IP address
- Question
  - Does the IP address of host suffice for identifying the process?
  - Answer: No, many processes can be running on same host
- Process Identifier
  - Include both IP address and port number associated with process on host
- Example port numbers
  - HTTP server: 80
  - Mail server: 25

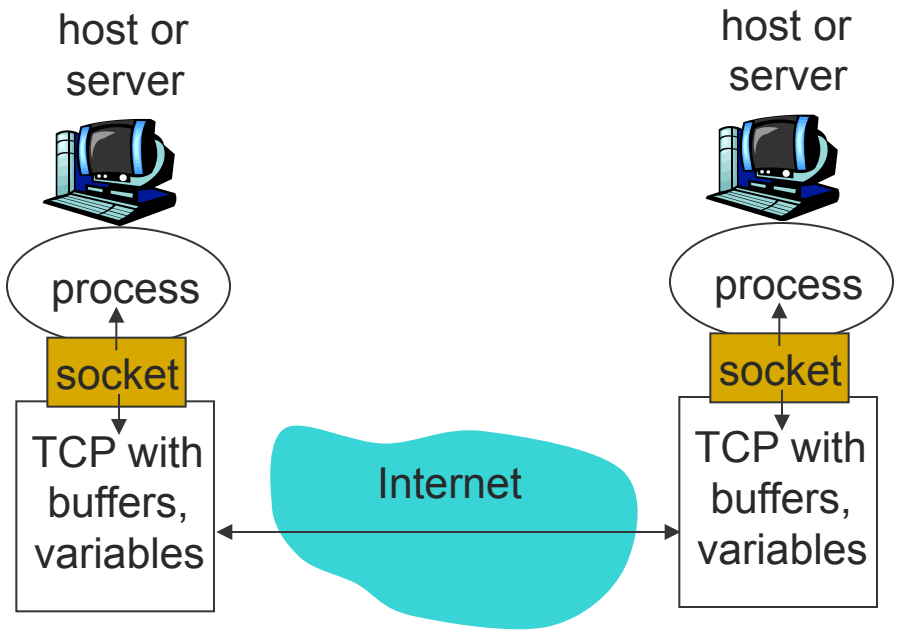
Sockets

- Process sends/receives messages to/from its socket
  - Analogous to a door
  - Sending process shoves messages out the door
  - Transport infrastructure on other side of door brings message to socket at receiving process



Sockets

- API
  - Choice of transport protocol
  - Ability to set a few parameters



Transport Services

- Data loss
  - Some applications (e.g., audio) can tolerate some loss
  - Other apps (e.g., file transfer, telnet) require 100% reliability
- Timing
  - Some applications (e.g., IP phones, interactive games) require low delay to be "effective"
- Throughput
  - Some applications (e.g., multimedia) have a minimum throughput to be "effective"
  - other applications ("elastic apps") make use of whatever throughput they get
- Security
  - Encryption, data integrity, …

Internet Transport Protocols

TCP

- Connection-oriented
  - setup required between client and server
- Reliable transport
- Flow control
  - Won't overwhelm receiver
- Congestion control
  - Won't overwhelm network
- Does not provide
  - Timing, throughput guarantees, security

UDP

- Unreliable data transfer
- Does not provide
  - Connection setup, reliability, flow control, congestion control, timing, throughput guarantee, or security

- Question
  - Why bother? Why is there a UDP?