Introduction to Networking and the Internet

Introduction

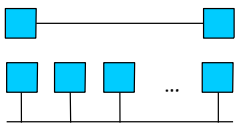
- What is the Internet?
- Network edge
- What is a protocol?
- Protocol layers, service models

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

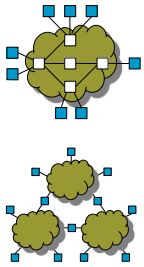
Connectivity

- Building Block
  - Links: coax cable, optical fiber, …
  - Nodes: workstations, routers, …
- Links:
  - Point-to-point
  - Multiple access



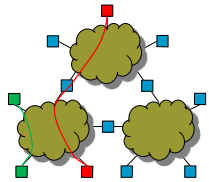
Indirect Connectivity

- Switched Networks
- Internetworks
- Recursive definition of a network
  - Two or more nodes connected by a physical link
  - Two or more networks connected by one or more nodes



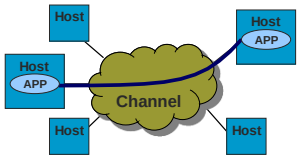
Network Service

- Goal
  - Transfer data between end systems
- Support For Common Services
  - Idea
    - Common services simplify the role of applications
    - Hide the complexity of the network without overly constraining the application designer
  - Semantics and interface depend on applications
    - Request/reply: FTP, HTTP, Digital Library
    - Message stream: audio, video



Channels

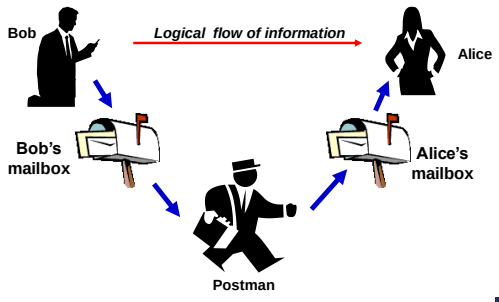
- Channel
  - The abstraction for application-level communication
- Idea
  - Turn host-to-host connectivity into process-to-process communication



Inter-process Communication

- 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

Example: Sending a Letter



Services

- Unconfirmed service

- Acknowledged service

Network Architecture

- Challenge
  - Fill the gap between hardware capabilities and application expectations, and to do so while delivering "good" performance
- How do network designers cope with complexity?
  - Layering
  - Protocols
  - Standards

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

<table>
<tr><td colspan="2">Application programs</td></tr>
<tr><td>Message stream channel</td><td>Request/reply channel</td></tr>
<tr><td colspan="2">Host-to-host connectivity</td></tr>
<tr><td colspan="2">Hardware</td></tr>
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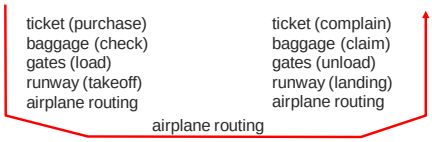
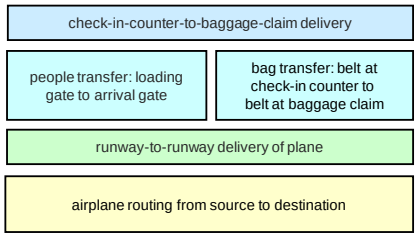
Example: Air Travel

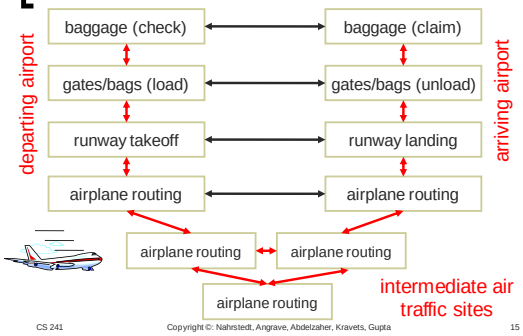
- Layers
  - Each layer implements a service
  - Via its own internal-layer actions
  - Relying on services provided by layer below



Air Travel: Services



Distributed Layering

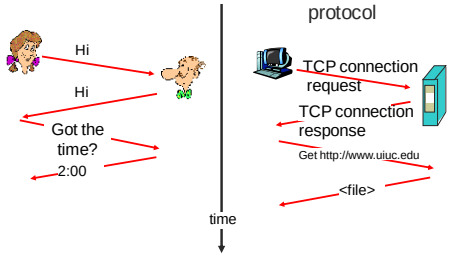


What is a Protocol?

- 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
- Human protocols
  - "what's the time?"
  - "I have a question"
  - Introductions
- Network protocols
  - Machines rather than humans
  - All communication activity in Internet is governed by protocols

What is a Protocol?

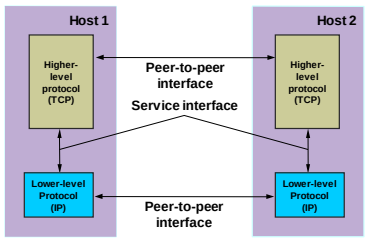
- A human protocol
- A computer network protocol



Network Protocols

- Definition
  - A protocol is an abstract object that makes up the layers of a network system
  - A protocol provides 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

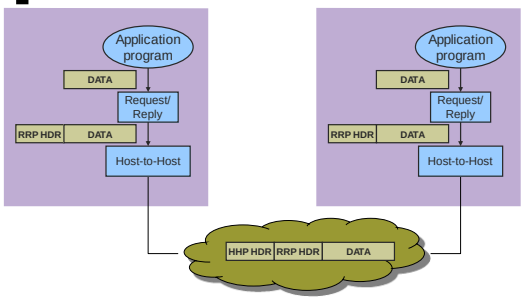
Interfaces



Layering Concepts

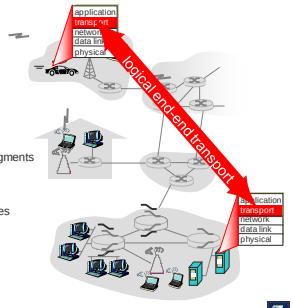
- Encapsulation
  - Higher layer protocols create messages and send them via the lower layer protocols
  - These messages are treated as data by the lower-level protocol
  - Higher-layer protocol adds its own control information in the form of headers or trailers
- Multiplexing and Demultiplexing
  -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

Encapsulation

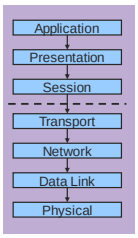


Example: Transport Layer

- 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

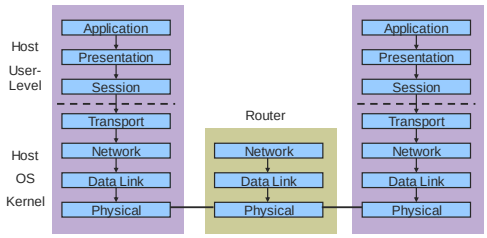


OSI Protocol Stack



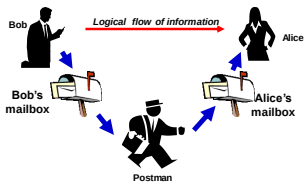
- Application: Application specific protocols
- Presentation: Format of exchanged data
- Session: Name space for connection mgmt
- Transport: Process-to-process channel
- Network: Host-to-host packet delivery
- Data Link: Framing of data bits
- Physical: Transmission of raw bits

OSI Protocol Stack



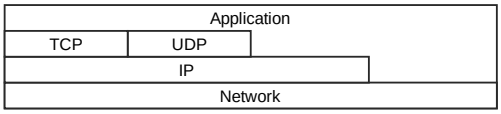
Transport vs. Network Layer

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

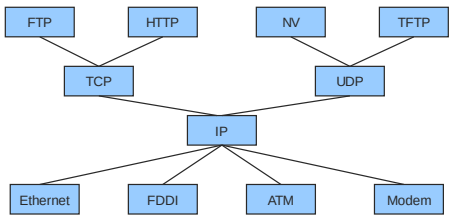


Internet Architecture

- Features:
  - No strict layering
  - Hourglass shape – IP is the focal point



Internet Architecture – Hourglass Design



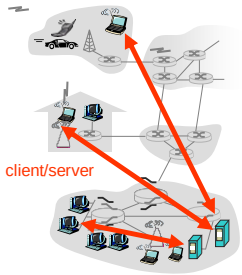
Network Applications

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

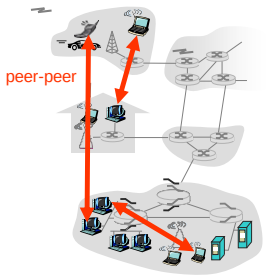
Client-server Architecture

- 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

Communicating Processes

- Process
  - Program running within a host
- Inter-process communication
  - Two processes communicating within same host
- Message Passing
  - Two processes communicating between different hosts
- Client process
  - Initiates communication
- Server process
  - Waits to be contacted

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?

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
  - A socket is 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
- 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?