

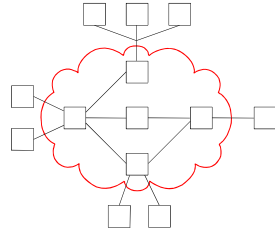
# Internet

Kai Shen

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## Basic Building Blocks for Computer Networks

- Network: two or most hosts connected by links/switches



- Host nodes:
  - PCs, servers, hand-held devices, sensors ...
- Links:
  - Twisted pair, coaxial cable, phone line, optical fiber, wireless radio channels ...

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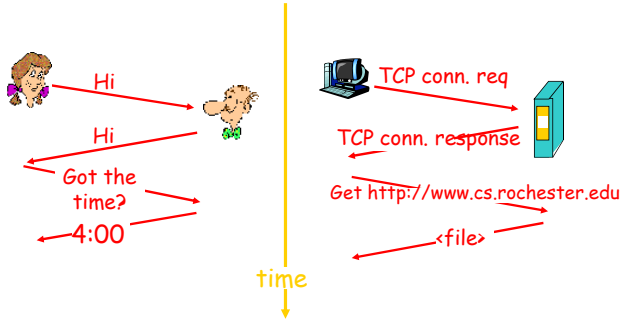
## Routing and Addressing

- Routing: finding a route (path) to the destination.
- Address: identifier of network end points.
- Types of traffic/addressing
  - unicast: to a single destination node;
  - broadcast: to all nodes on the network;
  - multicast: to some subset of nodes on the network;
  - anycast: to any one in a set of nodes.

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## Network Protocol: An Example

- A human protocol and a computer network protocol:



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## Network Protocol

- A network protocol describes how communication entities (sender/receiver) should interact to accomplish a networking task.
  - format, order of messages sent and received between network entities
  - actions taken on message transmission, receipt
- Protocols define communication interface, not node-local implementations
  - allow two sides of a communication task to be independently implemented (Google Chrome browser interacts with Microsoft IIS server).

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## Network Architecture: Layers

- Separation of network functions/features allow independent design and implementation
  - **Distributing the complexity.**
- Layering is a vertical separation of network functions/features.
  - **Hiding the complexity:** each layer interface hides complexity in this layer and layers below.
- Disadvantage of layering?
  - Lack of full information sharing.

Application programs
Host-to-host data transport
Host-to-host connectivity
Communications over link hardware

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## Internet Architecture

Bottom-up:

- **physical:** electromagnetic signals "on the wire"
- **link:** digital signals (data) transfer on one link (between neighboring network elements)
  - encoding, framing, error correction, access control for shared links
- **network:** host-to-host multi-hop connectivity
  - routing, addressing
- **transport:** host-to-host data transport
  - reliable data transport, congestion control, flow control
- **application:** anything you want to do on computer networks

application
transport
network
link
physical

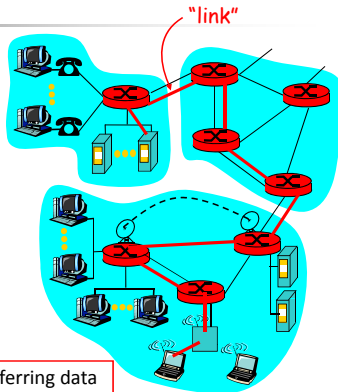
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## Link Layer

Some terminology:

- nodes in the network edge are **hosts**; nodes in the network core are **routers**
- communication channels that connect adjacent nodes along communication path are **links**
  - LANs, modem links, satellite links, wireless radio links

**data-link layer** has responsibility of transferring data from one node to adjacent node over a link.



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### Link Layer Functions

- **Encoding**
  - encode binary data to/from electromagnetic signals
- **Framing**
  - encapsulate data into frame, adding header, trailer
  - 'physical addresses' to identify source, dest (**different from IP address!**)
- **Link access control**
  - coordinate access for shared link
- **Flow control**
  - control the send rate such that the sender does not overwhelm the receiver
- **Error detection and/or correction**
  - errors caused by signal attenuation, electromagnetic noise.
  - receiver detects errors (drops frame or signals sender for retransmission)
- **Reliable delivery over the link**
  - typically mean no data loss and/or in-order delivery

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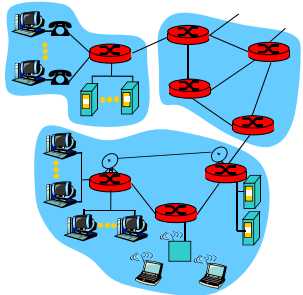
### Link Layer Protocols

- Ethernet
- WiFi
- PPP
- ... ..

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### Network Layer Functions

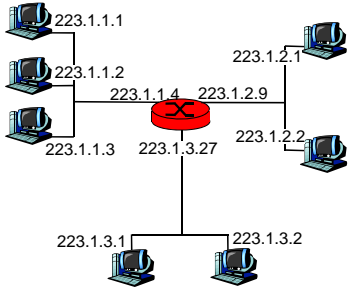
- Transport packet from sending to receiving hosts
  - **addressing**: uniquely identify each node in the network
  - **routing**: determine a path from source to dest and route packets along the path
- Network connecting devices
  - called "**routers**"
  - participate in network protocols
- Links
  - connect adjacent hosts, routers



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### IP Addressing

- **IP address**:
  - 32-bit identifier for each host, router interface
- **Interface**: connecting point into each data link
  - A router typically has multiple interfaces
  - A host often has single interface



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## IP Networks and Addressing

- Internet hosts are divided into networks for hierarchical
  - **Management:** URCS gets a chunk of IP addresses and manage them without bothering anyone else
  - **Routing:** First route between IP networks (fewer networks than hosts) and then route to destination host after reaching destination network.
- IP address is divided into network and host parts
  - address format: **a.b.c.d/x**, where x is # bits in network part of address

11001000 00010111 00010000 00000000  
200.23.16.0/23

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## IP Address Depletion

Address depletion  $\Rightarrow$  32-bit address space soon to be used up.

Observation: not every host is online at a given time.

**DHCP:** allow host to *dynamically* obtain its IP address from network server when it joins network

- can renew its lease on address in use
- allows reuse of addresses (only hold address while connected)

Network address translation

IPv6 (128-bit addresses)

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## Transport-layer Overview

- **Network layer:** host-to-host logical communication between *hosts*.
- **Transport layer:** logical communication between *applications*.
  - multiple comm. applications can reside in one host.
  - comm. applications can be a Web browser/server, an FTP client/server, etc.

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## TCP & UDP

TCP

- **Connection-oriented:**
  - handshaking (exchange of control msgs) to initialize sender, receiver state before data exchange
- **Reliable data transfer:**
  - guaranteed arrival, no error, in order
- **Flow controlled:**
  - sender does not overwhelm receiver
- **Congestion controlled:**
  - sender does not overwhelm the network

UDP

- None of the above

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### UDP In Practice

- When to use UDP?
  - TCP services are not useful, or even hurtful
  - TCP services are useful, but not worth the cost
  - TCP services are useful, but in customized ways
- Used for:
  - routing exchanges between routers
  - network performance measurements
  - streaming multimedia apps
    - loss tolerant, rate sensitive
    - flow control and loss recovery sometimes implemented at the application level

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### Protocols for the Internet Architecture

The diagram shows a stack of five layers on the left: application, transport, network, link, and physical. To the right, protocols are mapped to these layers: HTTP, SMTP, DNS, and Kai's protocol are in the application layer; TCP and UDP are in the transport layer; IP is in the network layer; Ethernet, 802.11, and PPP are in the link layer. Arrows indicate that TCP and UDP connect to IP, and IP connects to the link layer protocols.

- Hourglass design.
- Understand layers, protocols, protocol implementations.

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### History/Dominance of the Internet

- Internet (TCP/IP) evolved from a U.S. Defense Department-supported project called ARPANET.
- Internet/ARPANET wasn't the first/only electronic network:
  - Telephone network, X.25
- The Internet becomes dominant today because:
  - Simple network core (packet switching) with efficiency and extensibility.
  - A good TCP/IP implementation was bundled with a popular UNIX operating system (Berkeley UNIX).

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### Hardware and Software Organization of an Internet Application

The diagram compares the organization of an Internet client host and an Internet server host. Both have a 'Client' or 'Server' box at the top representing 'User code'. Below this is a 'Sockets interface (system calls)' box representing 'Kernel code'. At the bottom is a 'Network adapter' box representing 'Hardware and firmware'. A 'Hardware interface (interrupts)' box is shown between the kernel code and hardware. Both hosts connect to an 'Internet' box at the bottom.

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## IP Address vs. Machine Name

**People:** multiple identifiers

- SSN – good for machine bookkeeping, indexing
- name – human friendly, easy to remember

**Internet hosts:**

- IP address - used for addressing, routing on the Internet
- “name”, e.g., cycle1.csug.rochester.edu - human friendly

**Q:** map between IP addresses and names?

- **DNS query:** find the IP address for a given name
- not part of Internet as a network
- ease of use for Internet applications
  - “ssh cycle1.csug.rochester.edu” vs. “ssh 128.151.69.85”
  - <http://www.google.com> vs. <http://173.194.73.103>, or <http://173.194.73.104>, or <http://173.194.73.105>, or ...

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## Domain Name System (DNS)

- Try “nslookup www.google.com”
- Distributed database
  - implemented with collaboration of many name servers distributed all over the Internet
  - local name server, authoritative name server, root name server
  - extensive caching (local name server as well as local host)
- DNS queries
  - **name lookup:** find the IP address for a given name
  - others: find mail server for a domain, find a host’s IPv6 address using its IPv4 address ...

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