

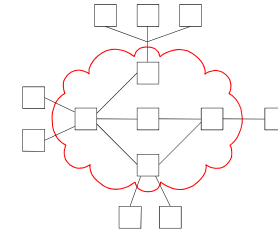
Internet

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Basic Building Blocks for Computer Networks

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



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

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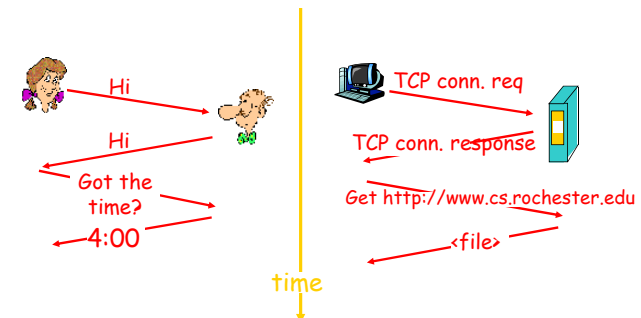
Routing and Addressing

- 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

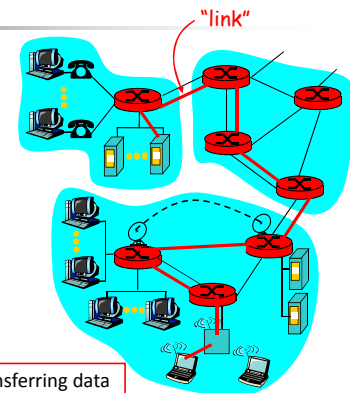
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Link Layer

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 Protocol: Ethernet

- Developed at Xerox PARC in 1970s
- First widely used technology for local-area networks (now dominant)
- Standardized as IEEE 802.3
- Original protocol envisions a single shared link connecting all nodes
 - A key part of the protocol resolves interfering uses of the shared link by multiple nodes
- Today, though, switched Ethernet gives each node a dedicated link so there is no multi-node interference on a link

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Link Layer Protocol: WiFi

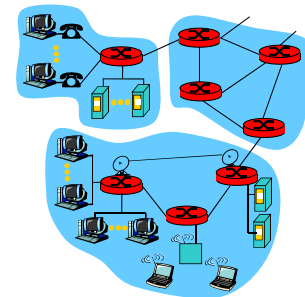
- Intend to function as Ethernet without wires
- Interference is a real issue, so much of the protocol deals with coordination to minimize interference
- Range up to 100 meters; speed up to 300Mbps
- Longer range (tens of kilometers) in point-to-point mode



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Network Layer Functions

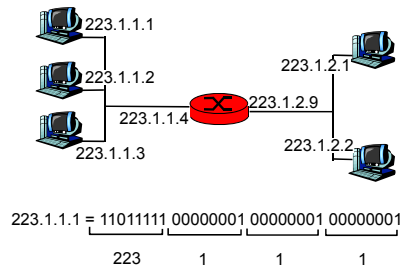
- Transport packet from sending to receiving hosts
 - **addressing**: uniquely identify each node in the network
 - **routing**: determine a path from source to dest and route packets along the path
- Network connecting devices
 - called "**routers**"
 - participate in network protocols
- Links
 - connect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



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IP Addressing

- **IP address:**
 - 32-bit identifier for each host, router interface
- Multiple networks are connected by routers



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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.
- Hierarchical management and routing are the key foundation for scalability

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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)

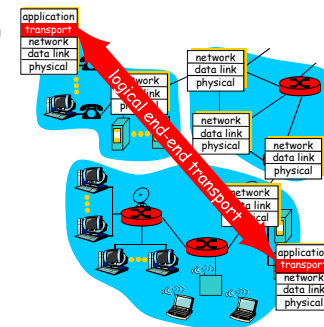
Network address translation

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

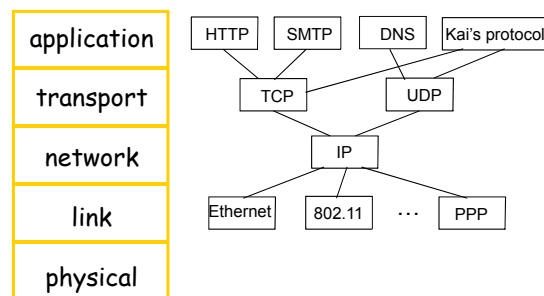
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UDP In Practice

- 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 only in customized ways
- Used for:
 - 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



- Hourglass structure.

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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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