Introduction

Chapter 1

- Uses of Computer Networks
- Network Hardware
- Network Software
- Reference Models
- Example Networks
- Network Standardization
- Metric Units

Revised: August 2011

Uses of Computer Networks

Computer networks are collections of autonomous computers, e.g., the Internet

They have many uses:

- Business Applications »
- Home Applications »
- Mobile Users »

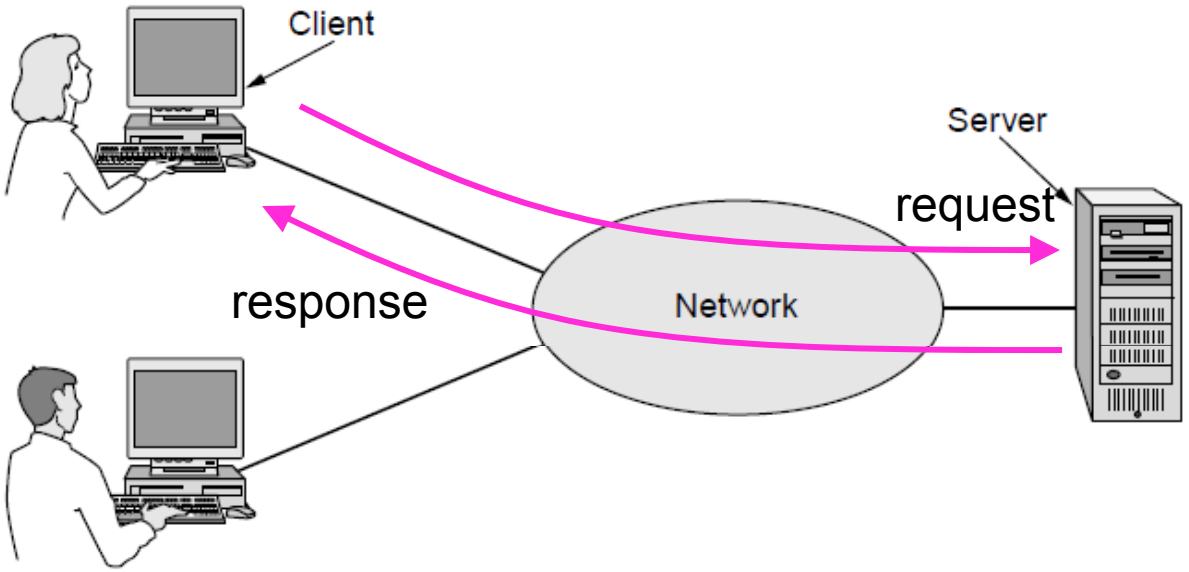
These uses raise:

- Social Issues »

This text covers networks for all of these uses

Business Applications

Companies use networks and computers for resource sharing with the client-server model:



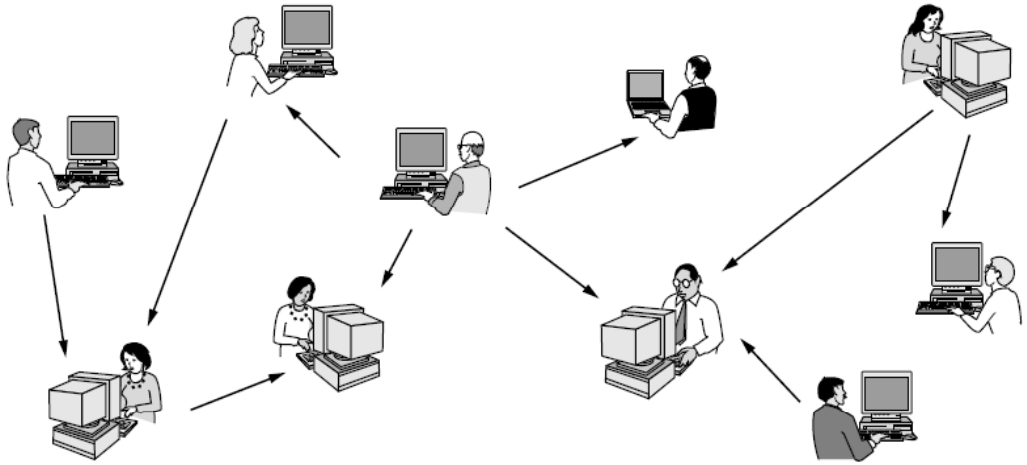
Other popular uses are communication, e.g., email, VoIP, and e-commerce

Home Applications

Homes contain many networked devices, e.g., computers, TVs, connected to the Internet by cable, DSL, wireless, etc.

Home users communicate, e.g., social networks, consume content, e.g., video, and transact, e.g., auctions

Some application use the peer-to-peer model in which there are no fixed clients and servers:



Mobile Users

Tablets, laptops, and smart phones are popular devices; WiFi hotspots and 3G cellular provide wireless connectivity.

Mobile users communicate, e.g., voice and texts, consume content, e.g., video and Web, and use sensors, e.g., GPS.

Wireless and mobile are related but different:

Wireless	Mobile	Typical applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in unwired buildings
Yes	Yes	Store inventory with a handheld computer

Social Issues

- Network neutrality – no network restrictions
- Content ownership, e.g., DMCA takedowns
- Anonymity and censorship
- Privacy, e.g., Web tracking and profiling
- Theft, e.g., botnets and phishing

Network Hardware

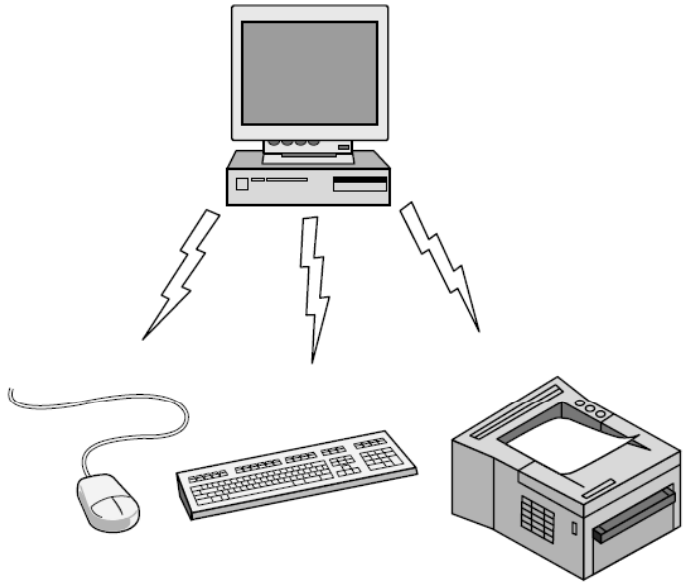
Networks can be classified by their scale:

Scale	Type
Vicinity	PAN (Personal Area Network) »
Building	LAN (Local Area Network) »
City	MAN (Metropolitan Area Network) »
Country	WAN (Wide Area Network) »
Planet	The Internet (network of all networks)

Personal Area Network

Connect devices over the range of a person

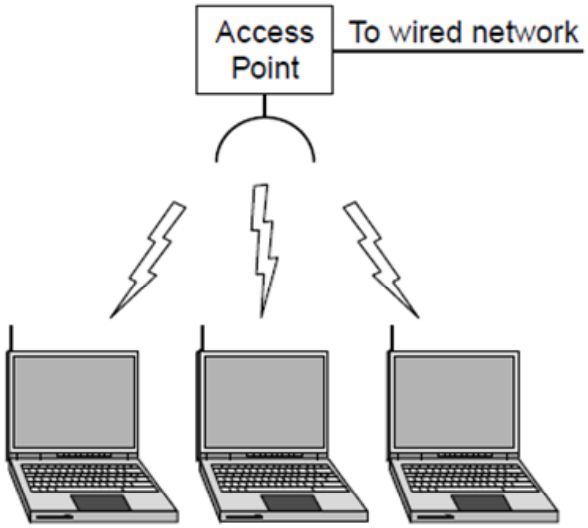
Example of a Bluetooth (wireless) PAN:



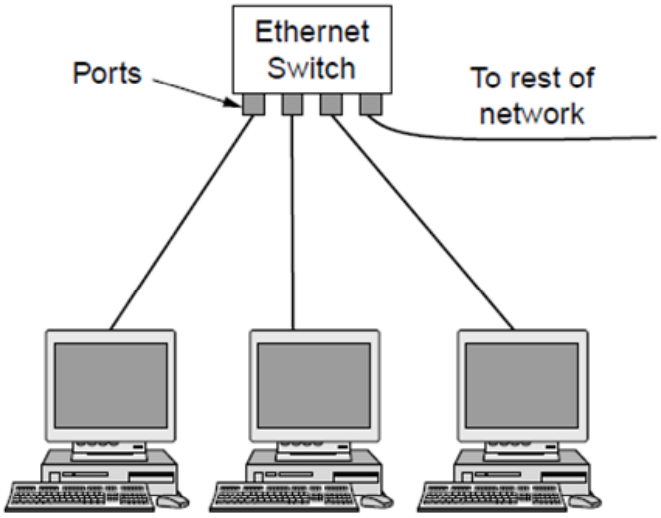
Local Area Networks

Connect devices in a home or office building

Called enterprise network in a company



Wireless LAN with 802.11

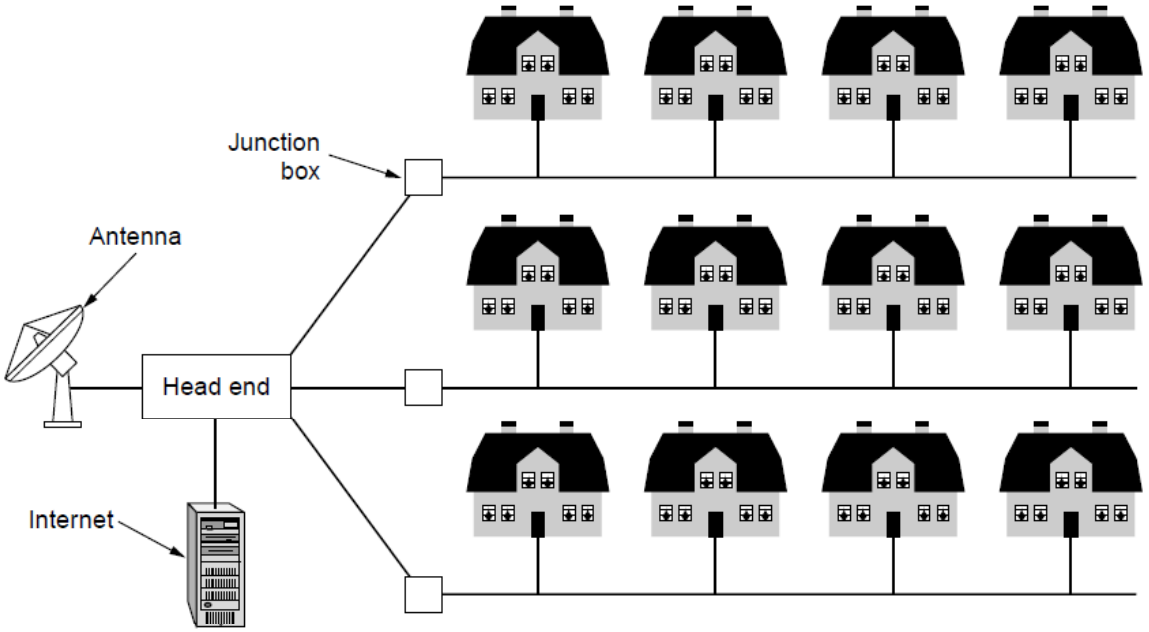


Wired LAN with switched Ethernet

Metropolitan Area Networks

Connect devices over a metropolitan area

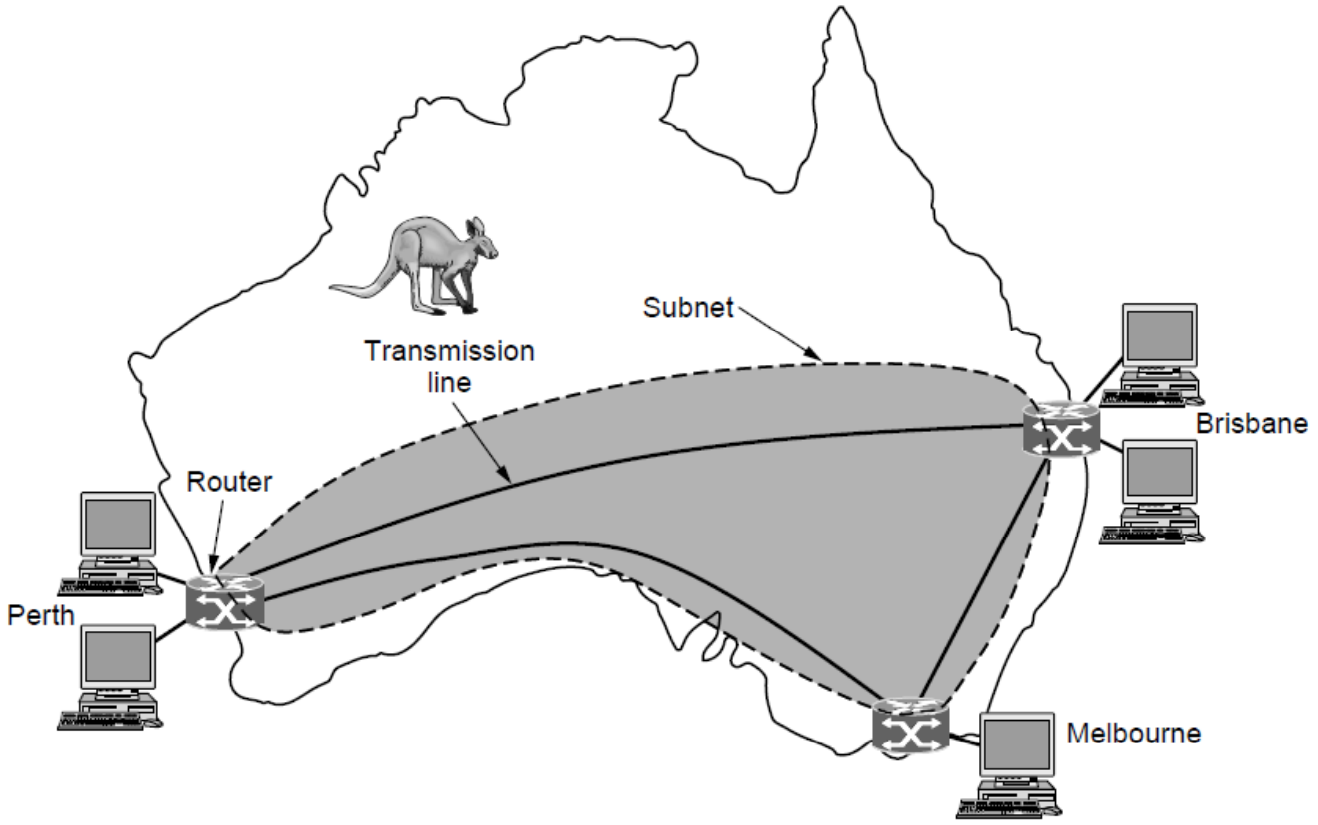
Example MAN based on cable TV:



Wide Area Networks (1)

Connect devices over a country

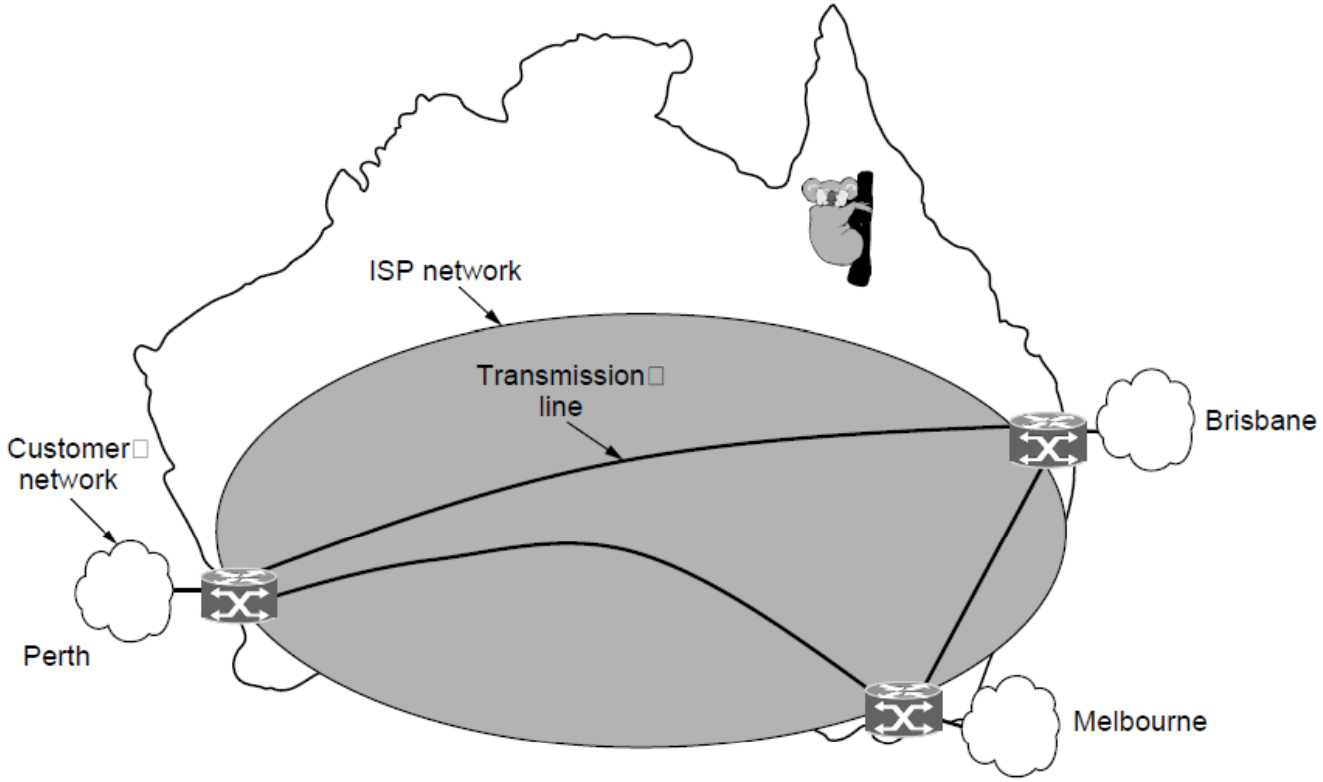
Example WAN connecting three branch offices:



Wide Area Networks (2)

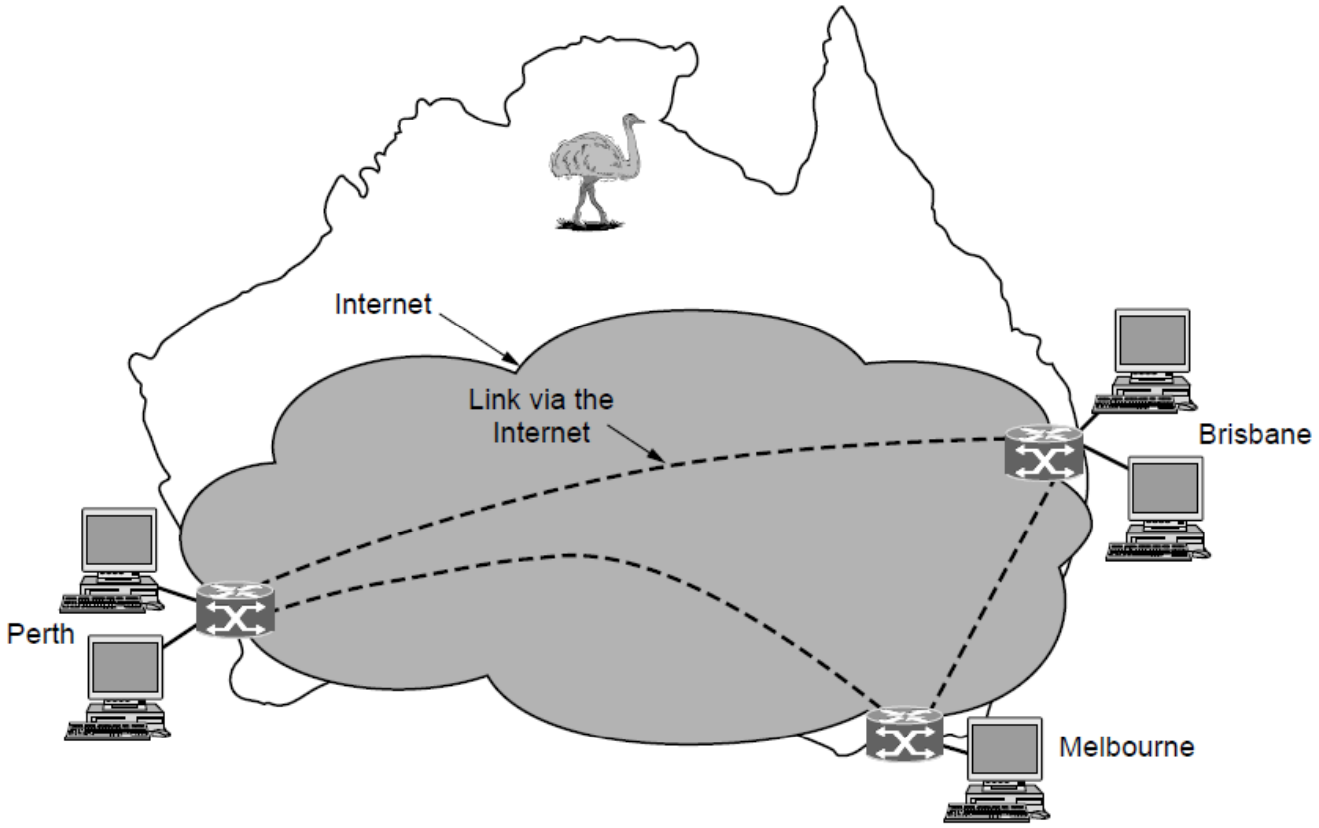
An ISP (Internet Service Provider) network is also a WAN.

Customers buy connectivity from the ISP to use it.



Wide Area Networks (3)

A VPN (Virtual Private Network) is a WAN built from virtual links that run on top of the Internet.



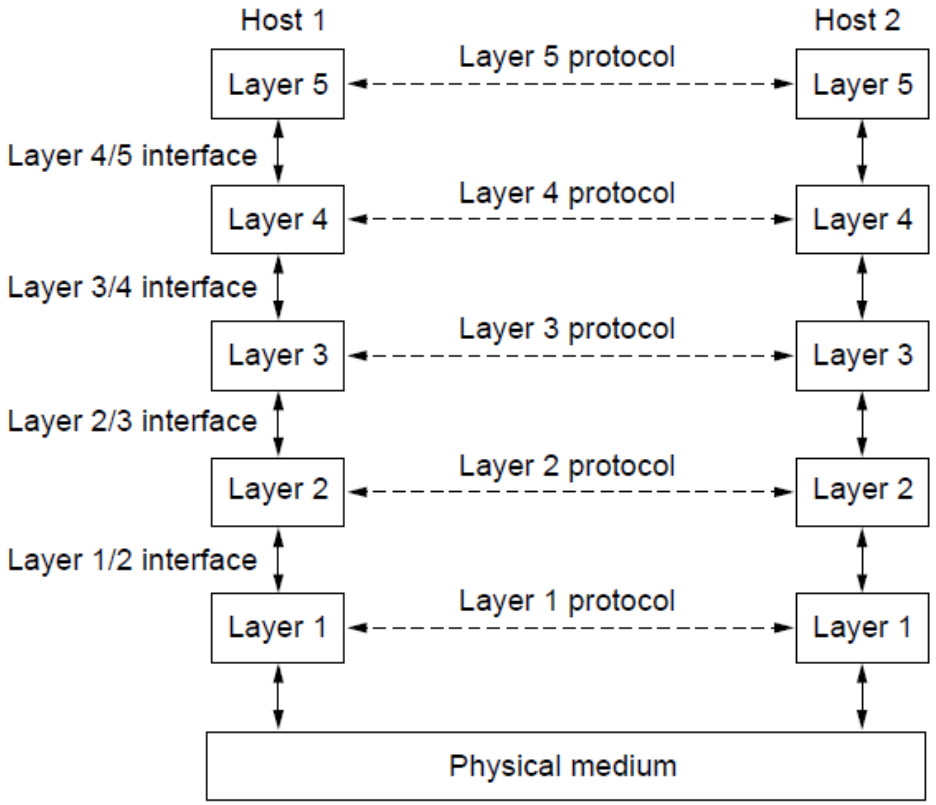
Network Software

- Protocol layers »
- Design issues for the layers »
- Connection-oriented vs. connectionless service »
- Service primitives »
- Relationship of services to protocols »

Protocol Layers (1)

Protocol layering is the main structuring method used to divide up network functionality.

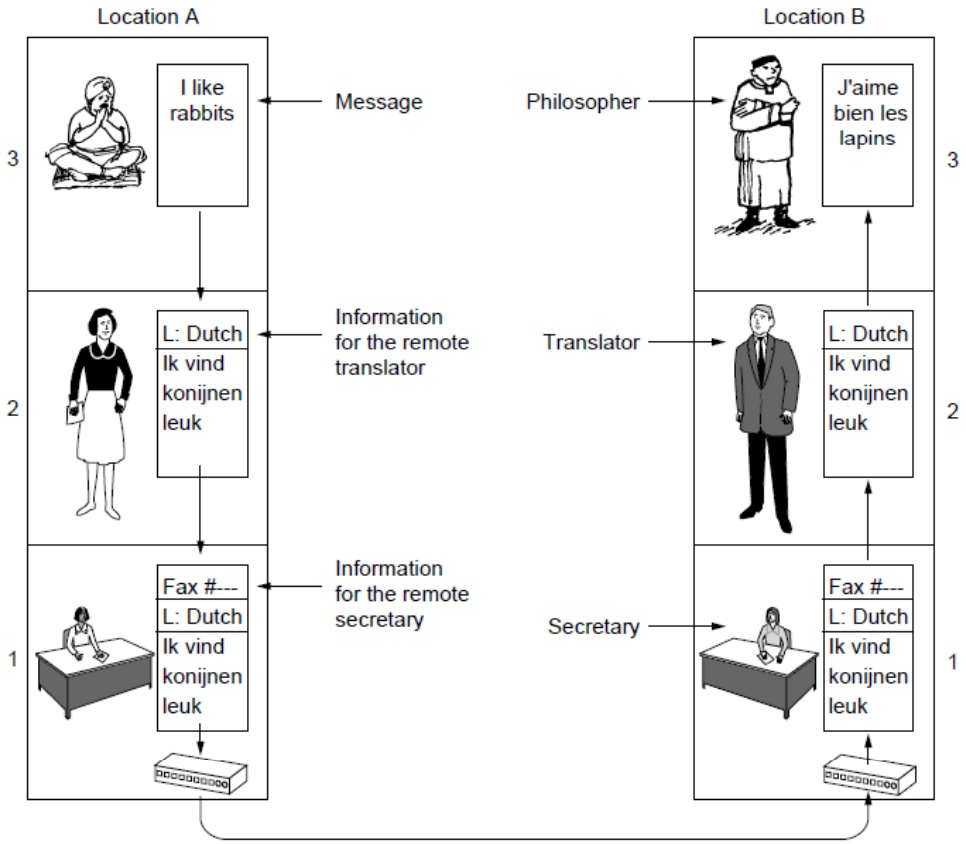
- Each protocol instance talks virtually to its peer
- Each layer communicates only by using the one below
- Lower layer services are accessed by an interface
- At bottom, messages are carried by the medium



Protocol Layers (2)

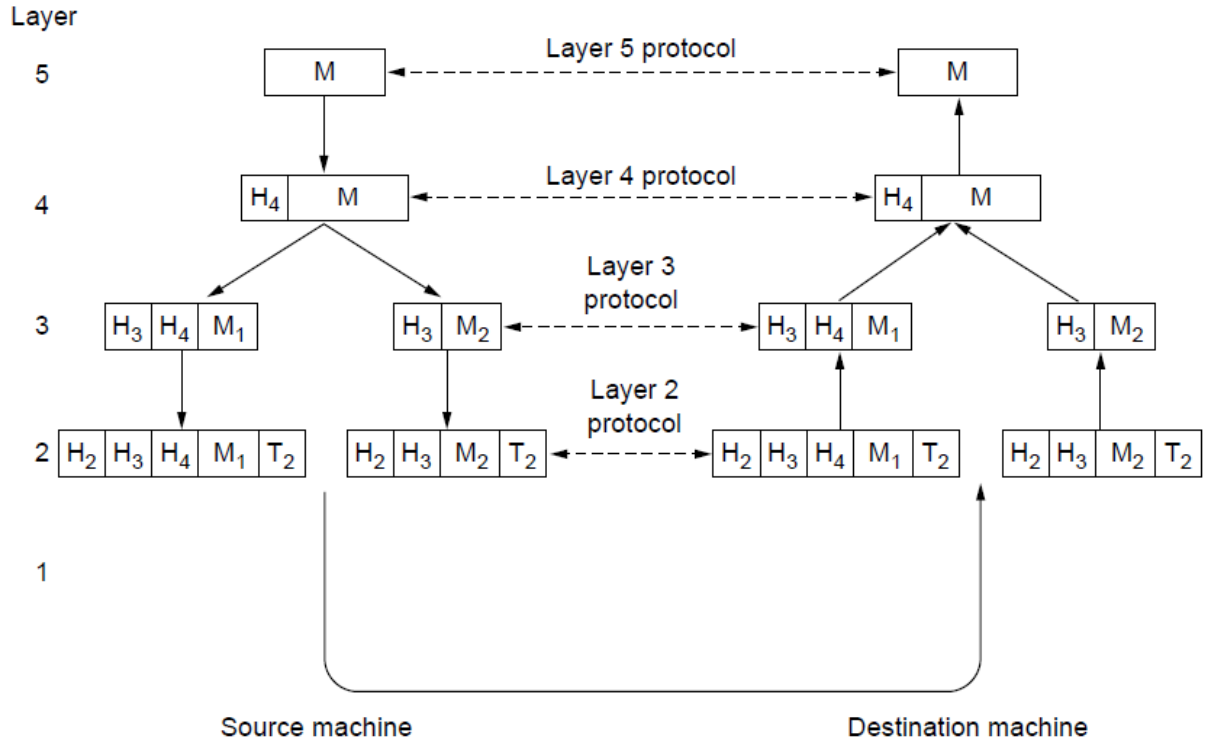
Example: the philosopher-translator-secretary architecture

Each protocol at different layers serves a different purpose



Protocol Layers (3)

Each lower layer adds its own header (with control information) to the message to transmit and removes it on receive



Layers may also split and join messages, etc.

Design Issues for the Layers

Each layer solves a particular problem but must include mechanisms to address a set of recurring design issues

Issue	**Example mechanisms at different layers**
Reliability despite failures	Codes for error detection/correction (§3.2, 3.3) Routing around failures (§5.2)
Network growth and evolution	Addressing (§5.6) and naming (§7.1) Protocol layering (§1.3)
Allocation of resources like bandwidth	Multiple access (§4.2) Congestion control (§5.3, 6.3)
Security against various threats	Confidentiality of messages (§8.2, 8.6) Authentication of communicating parties (§8.7)

Connection-Oriented vs. Connectionless

Service provided by a layer may be kinds of either:

- Connection-oriented, must be set up for ongoing use (and torn down after use), e.g., phone call
- Connectionless, messages are handled separately, e.g., postal delivery

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Movie download
	Unreliable connection	Voice over IP
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Text messaging
	Request-reply	Database query

Service Primitives (1)

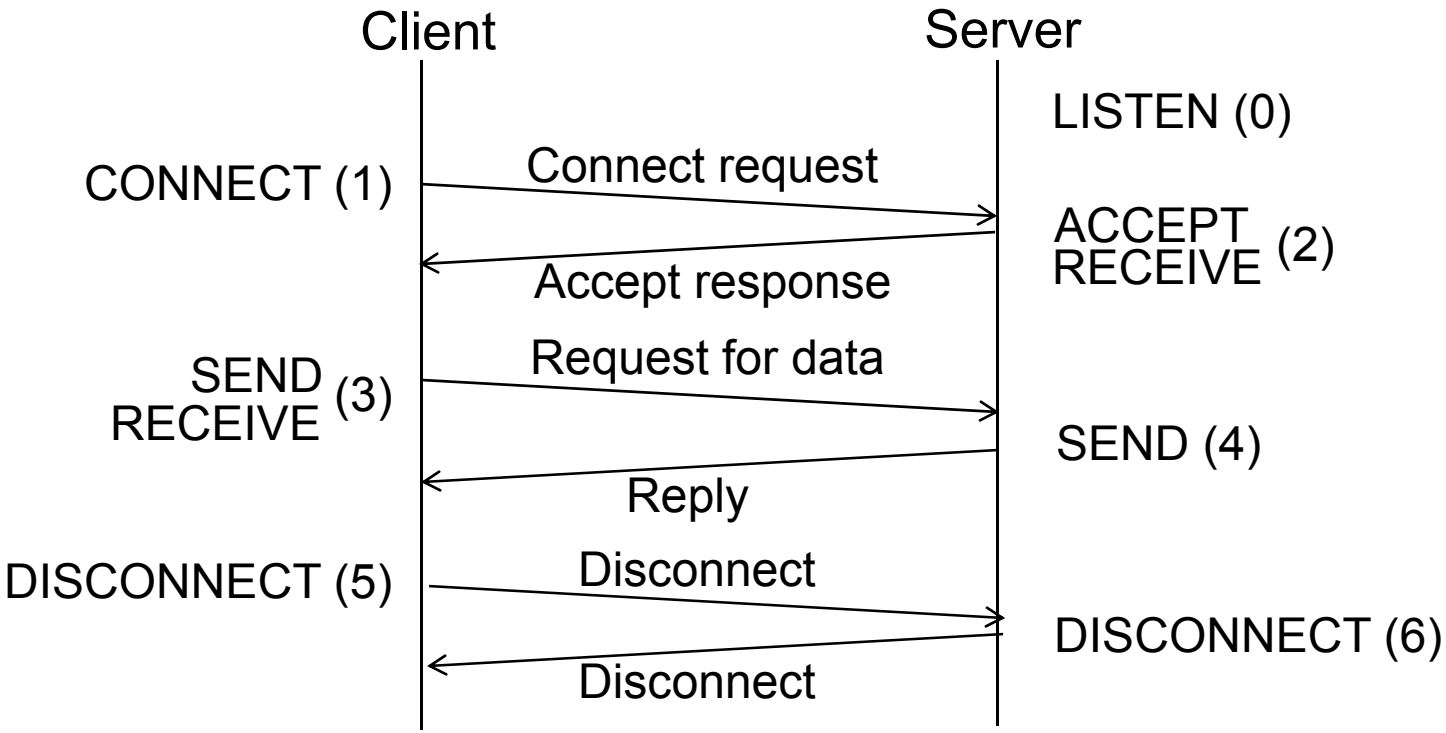
A service is provided to the layer above as primitives

Hypothetical example of service primitives that may provide a reliable byte stream (connection-oriented) service:

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
ACCEPT	Accept an incoming connection from a peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Service Primitives (2)

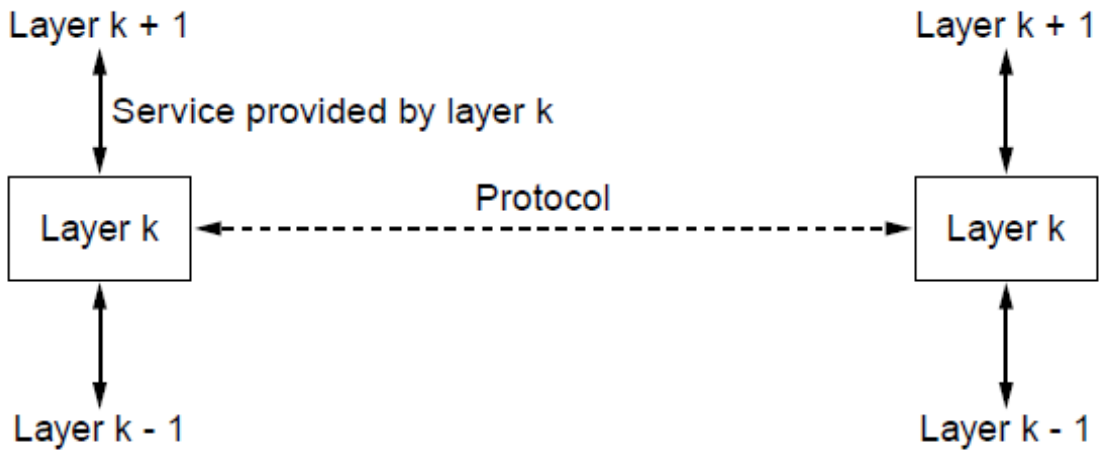
Hypothetical example of how these primitives may be used for a client-server interaction



Relationship of Services to Protocols

Recap:

- A layer provides a service to the one above [vertical]
- A layer talks to its peer using a protocol [horizontal]



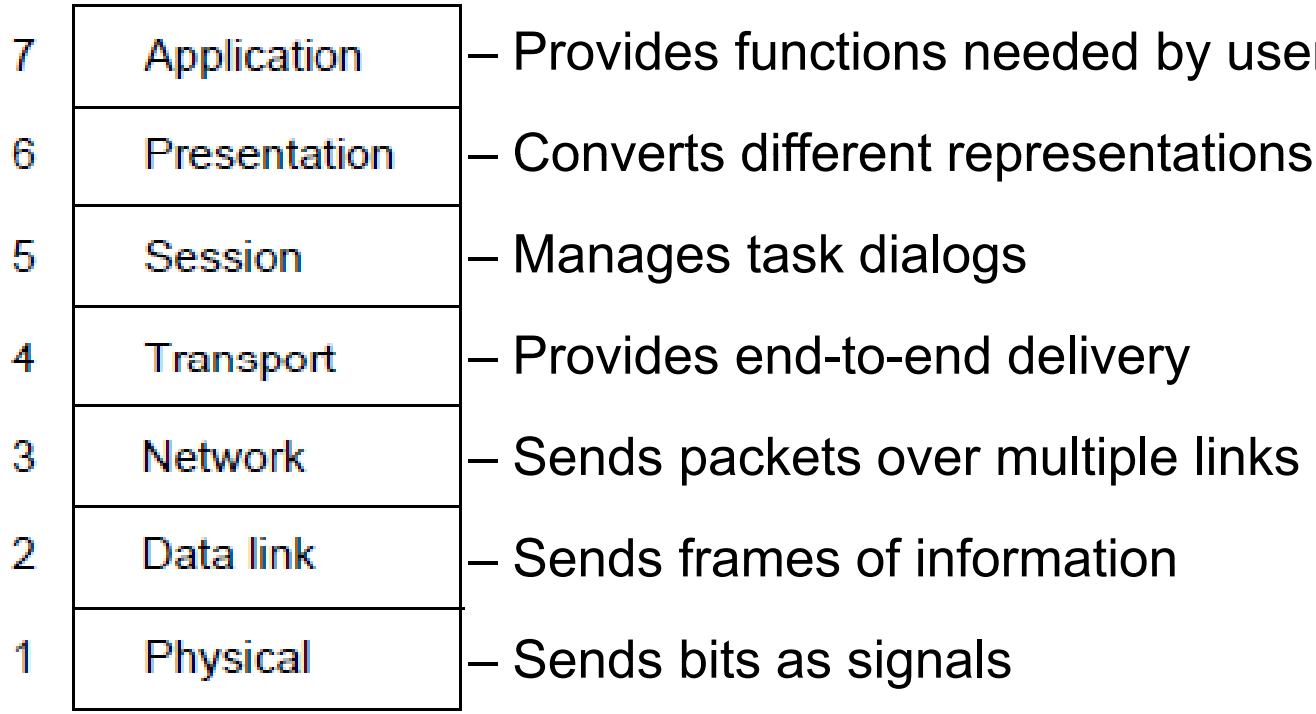
Reference Models

Reference models describe the layers in a network architecture

- OSI reference model »
- TCP/IP reference model »
- Model used for this text »
- Critique of OSI and TCP/IP »

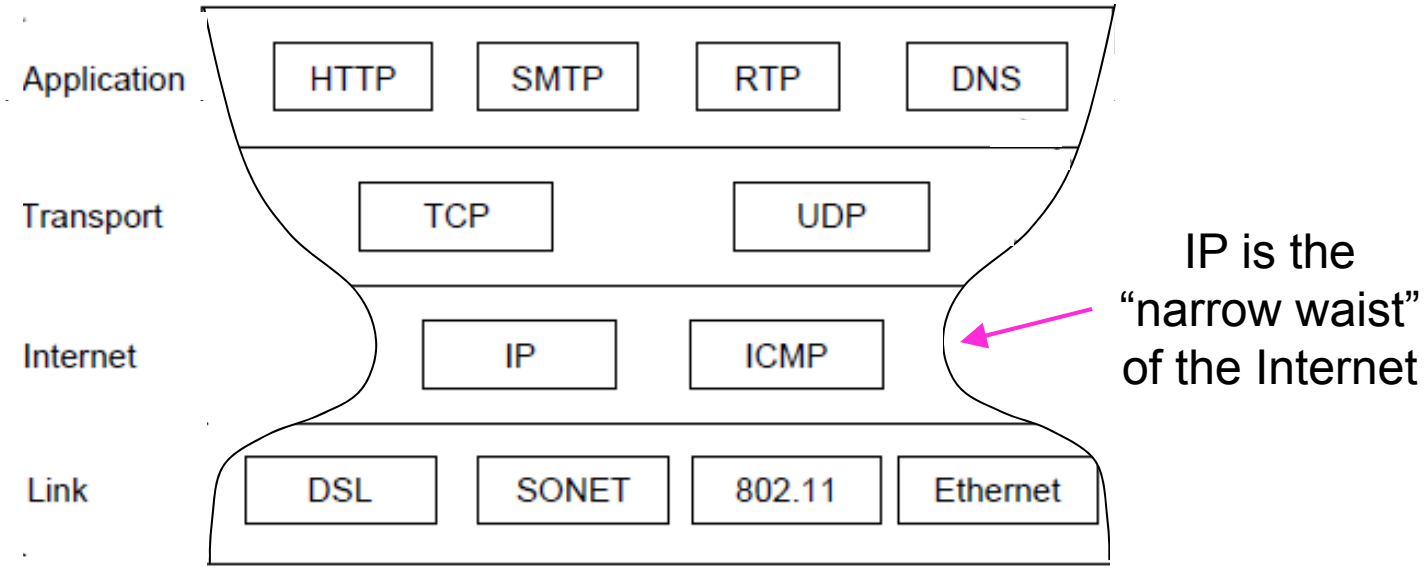
OSI Reference Model

A principled, international standard, seven layer model to connect different systems



TCP/IP Reference Model

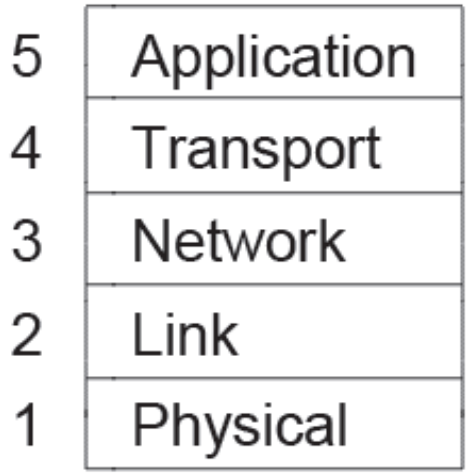
A four layer model derived from experimentation; omits some OSI layers and uses the IP as the network layer.



Protocols are shown in their respective layers

Model Used in this Book

It is based on the TCP/IP model but we call out the physical layer and look beyond Internet protocols.



Critique of OSI & TCP/IP

OSI:

- \+ Very influential model with clear concepts
- – Models, protocols and adoption all bogged down by politics and complexity

TCP/IP:

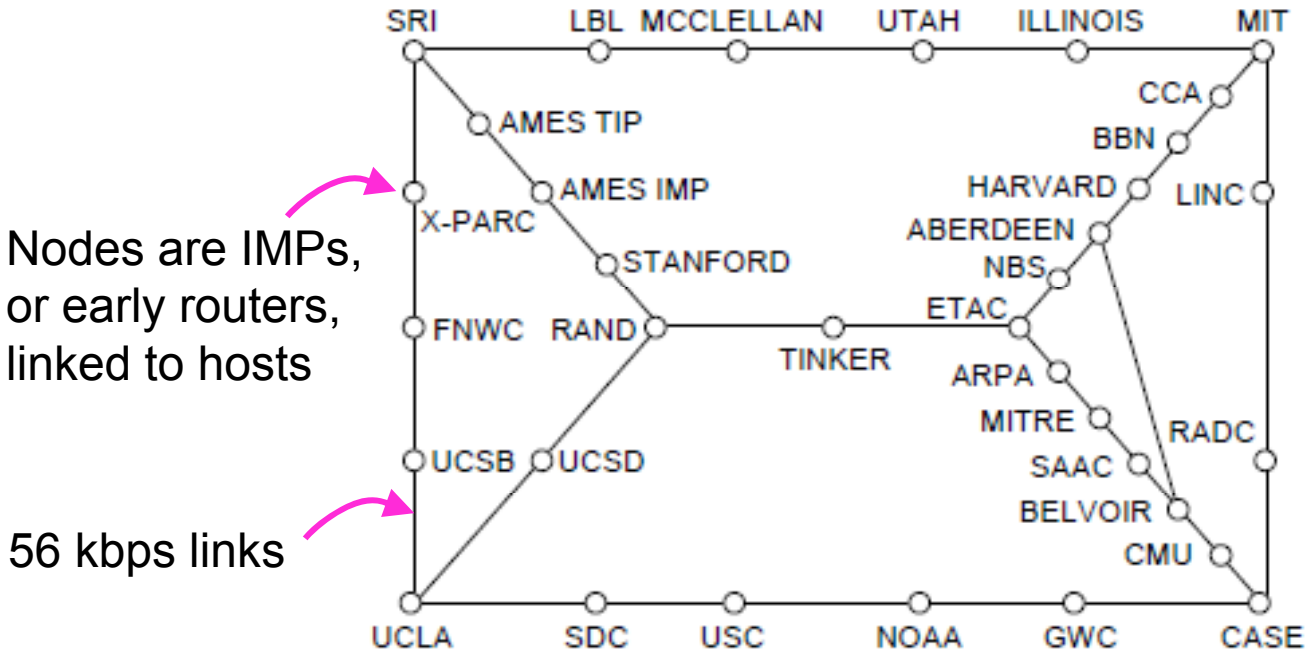
- \+ Very successful protocols that worked well and thrived
- – Weak model derived after the fact from protocols

Example Networks

- The Internet »
- 3G mobile phone networks »
- Wireless LANs »
- RFID and sensor networks »

Internet (1)

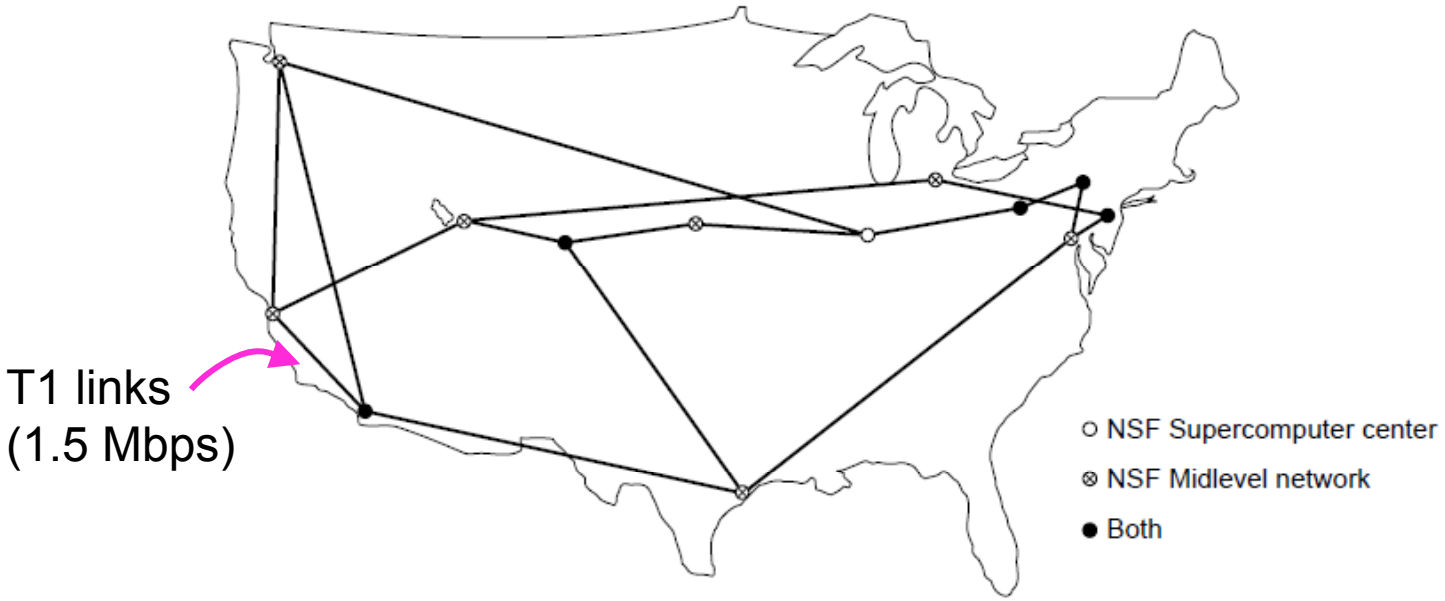
Before the Internet was the ARPANET, a decentralized, packet-switched network based on Baran's ideas.



ARPANET topology in Sept 1972.

Internet (2)

The early Internet used NSFNET (1985-1995) as its backbone; universities connected to get on the Internet



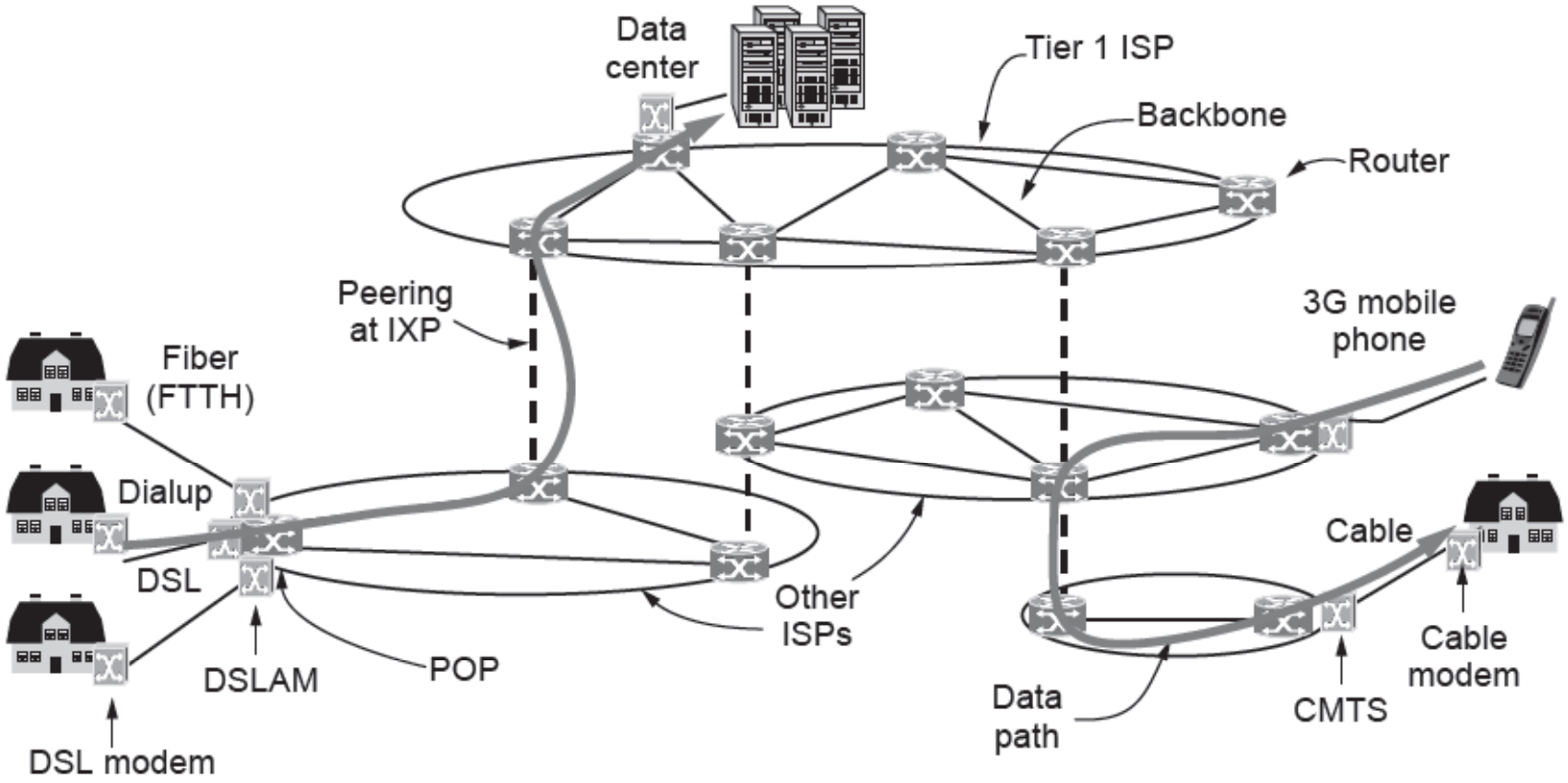
NSFNET topology in 1988

Internet (3)

The modern Internet is more complex:

- ISP networks serve as the Internet backbone
- ISPs connect or peer to exchange traffic at IXPs
- Within each network routers switch packets
- Between networks, traffic exchange is set by business agreements
- Customers connect at the edge by many means
  - Cable, DSL, Fiber-to-the-Home, 3G/4G wireless, dialup
- Data centers concentrate many servers (“the cloud”)
- Most traffic is content from data centers (esp. video)
- The architecture continues to evolve

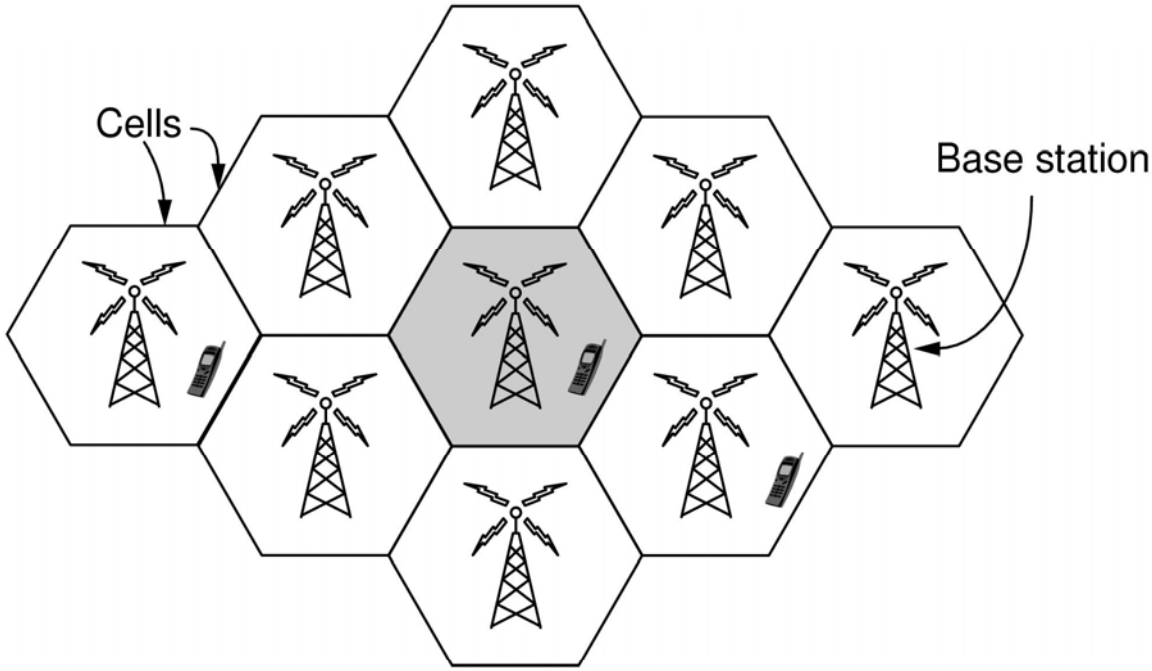
Internet (4)



Architecture of the Internet

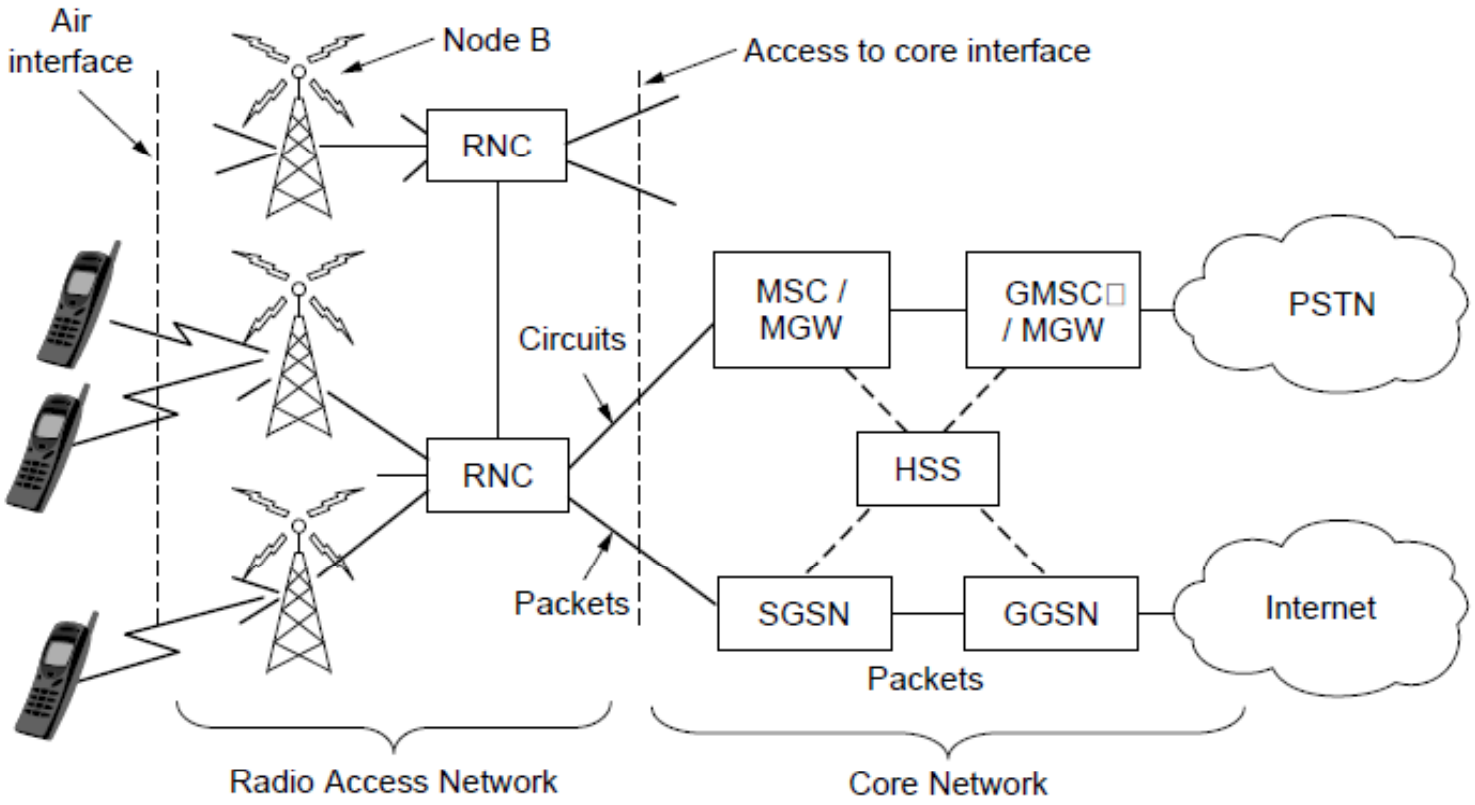
3G Mobile Phone Networks (1)

3G network is based on spatial cells; each cell provides wireless service to mobiles within it via a base station



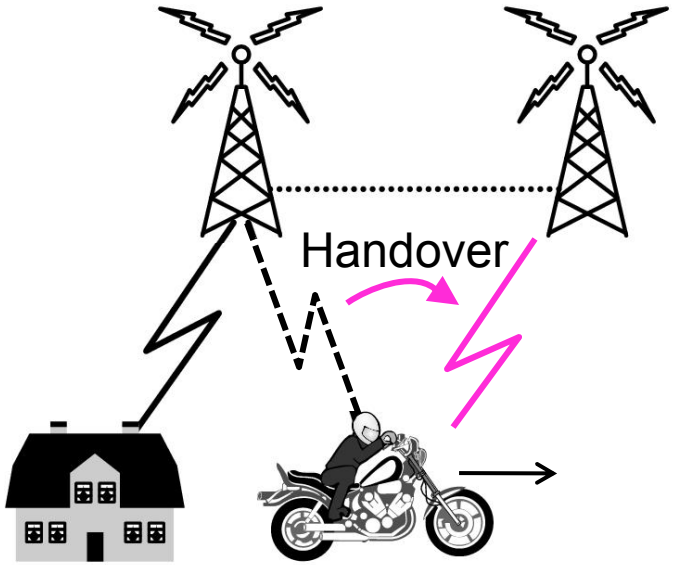
3G Mobile Phone Networks (2)

Base stations connect to the core network to find other mobiles and send data to the phone network and Internet



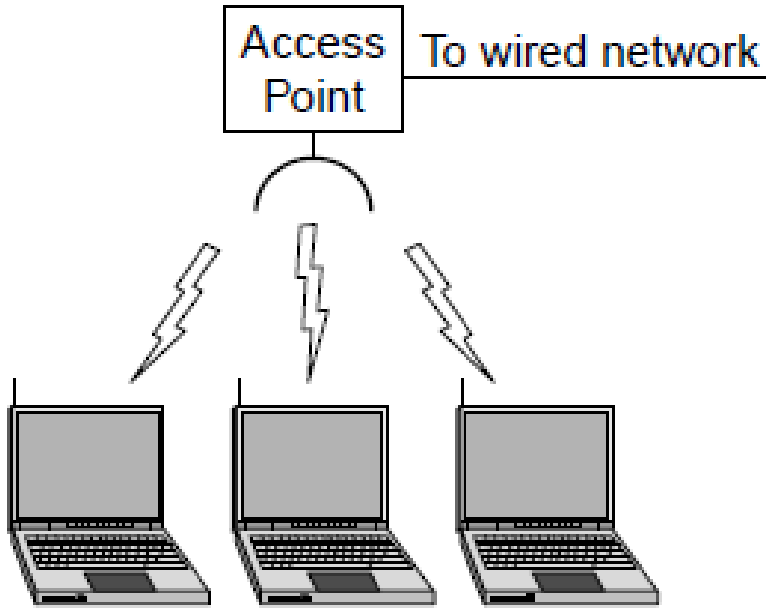
3G Mobile Phone Networks (3)

As mobiles move, base stations hand them off from one cell to the next, and the network tracks their location



Wireless LANs (1)

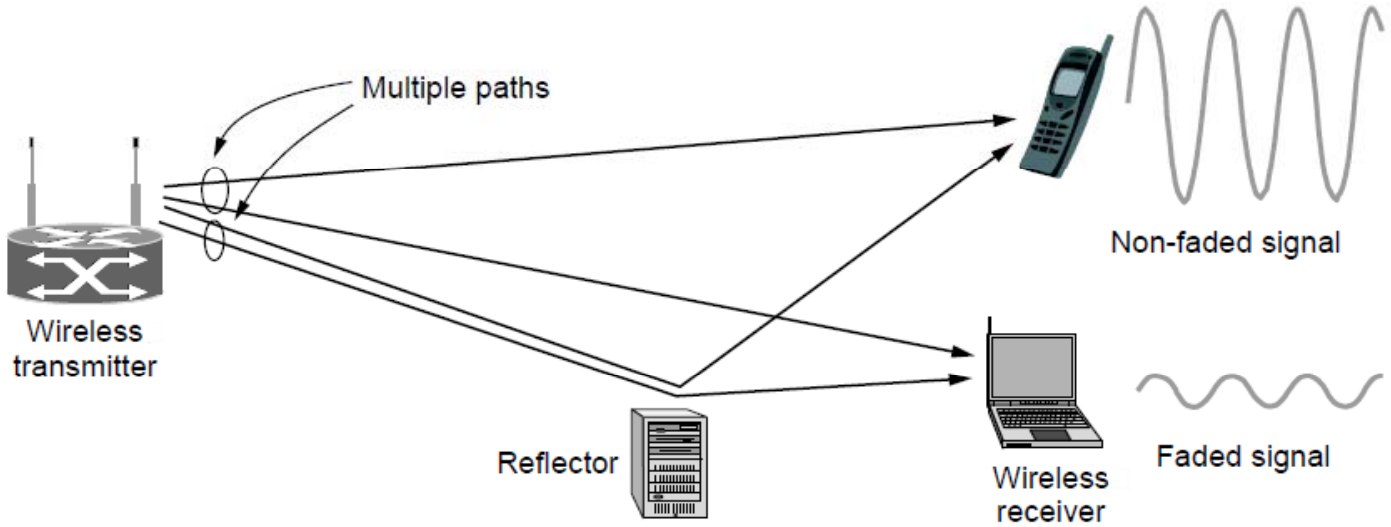
In 802.11, clients communicate via an AP (Access Point) that is wired to the rest of the network.



Wireless LANs (2)

Signals in the 2.4GHz ISM band vary in strength due to many effects, such as multipath fading due to reflections

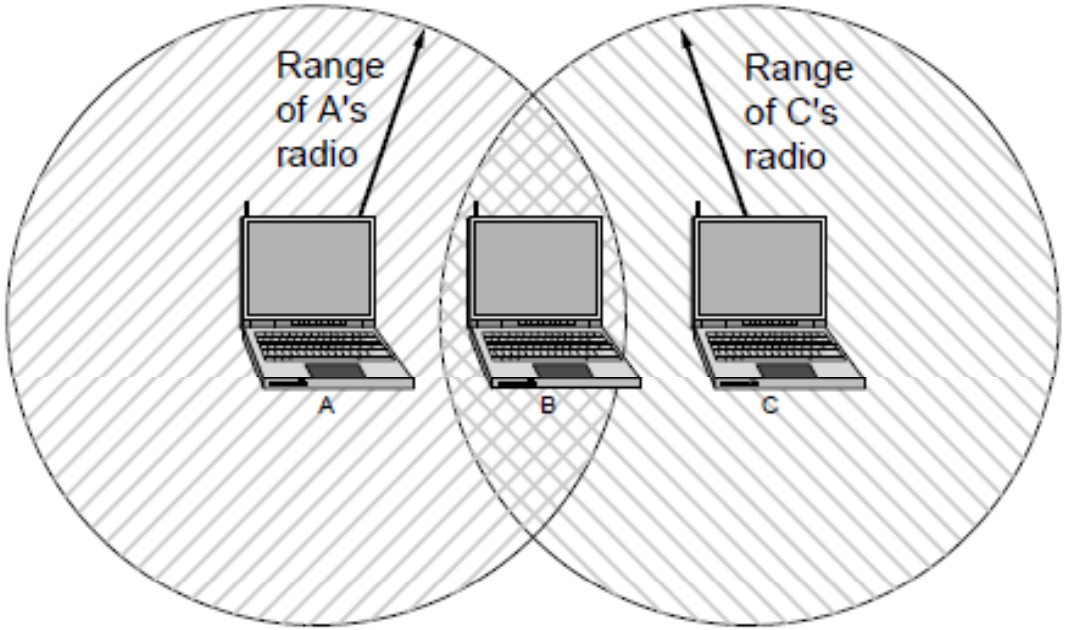
- requires complex transmission schemes, e.g., OFDM



Wireless LANs (3)

Radio broadcasts interfere with each other, and radio ranges may incompletely overlap

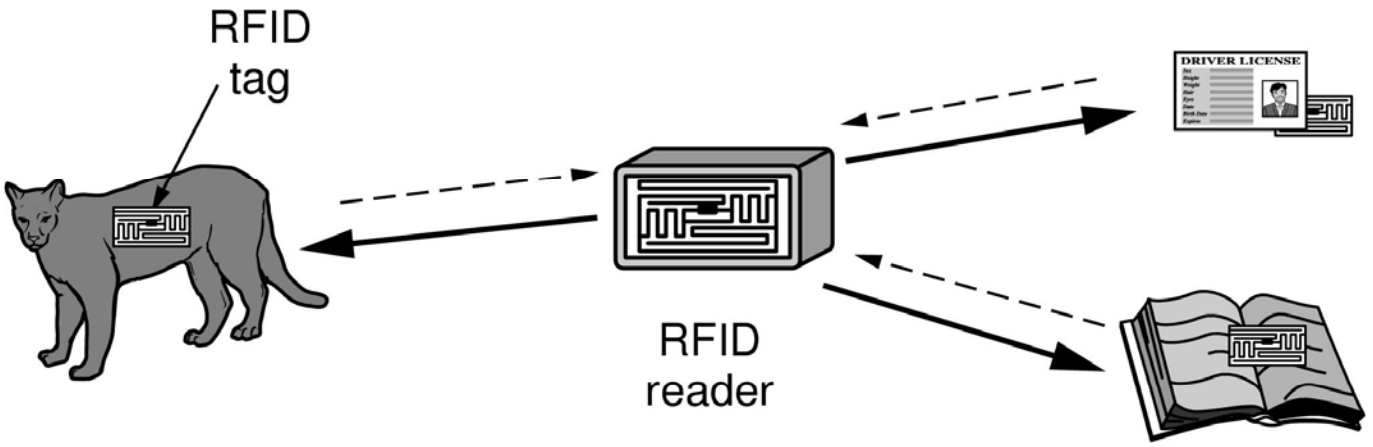
- CSMA (Carrier Sense Multiple Access) designs are used



RFID and Sensor Networks (1)

Passive UHF RFID networks everyday objects:

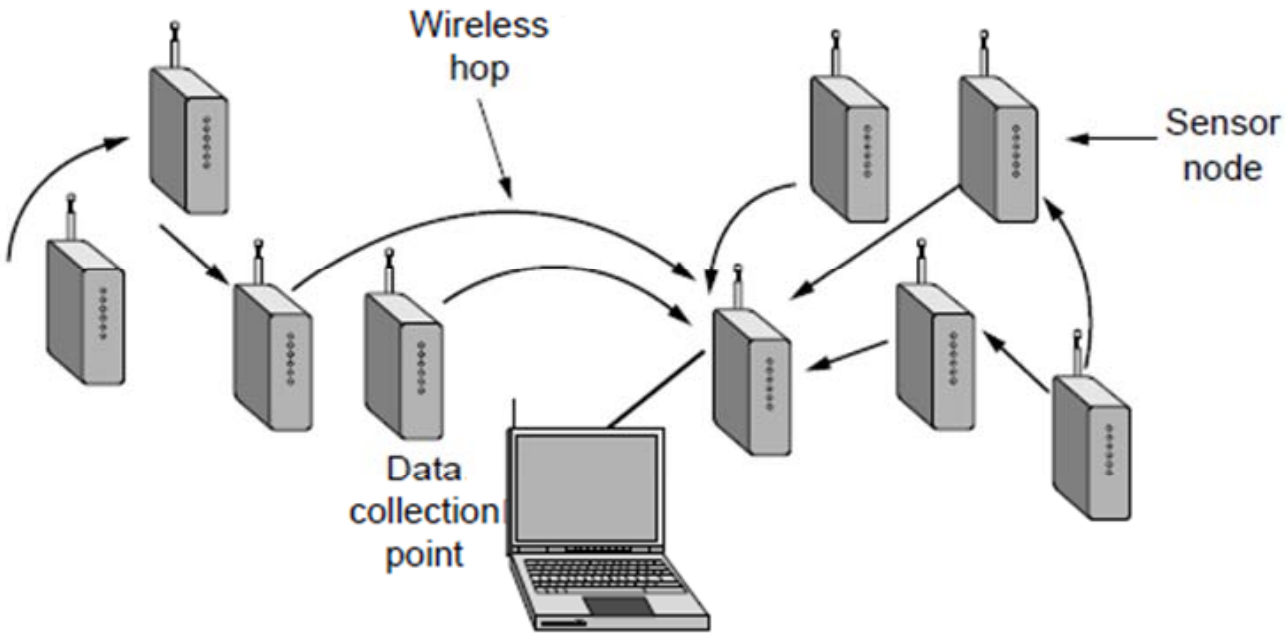
- Tags (stickers with not even a battery) are placed on objects
- Readers send signals that the tags reflect to communicate



RFID and Sensor Networks (2)

Sensor networks spread small devices over an area:

- Devices send sensed data to collector via wireless hops



Network Standardization

Standards define what is needed for interoperability

Some of the many standards bodies:

Body	Area	Examples
ITU	Telecommunications	G.992, ADSL H.264, MPEG4
IEEE	Communications	802.3, Ethernet 802.11, WiFi
IETF	Internet	RFC 2616, HTTP/1.1 RFC 1034/1035, DNS
W3C	Web	HTML5 standard CSS standard

Metric Units

The main prefixes we use:

Prefix	Exp.	prefix	exp.
K(ilo)	10^3	m(illi)	10^{-3}
M(ega)	10^6	μ(micro)	10^{-6}
G(iga)	10^9	n(ano)	10^{-9}

- Use powers of 10 for rates, powers of 2 for storage
  - E.g., 1 Mbps = 1,000,000 bps, 1 KB = 1024 bytes
- "B" is for bytes, "b" is for bits

End

Chapter 1