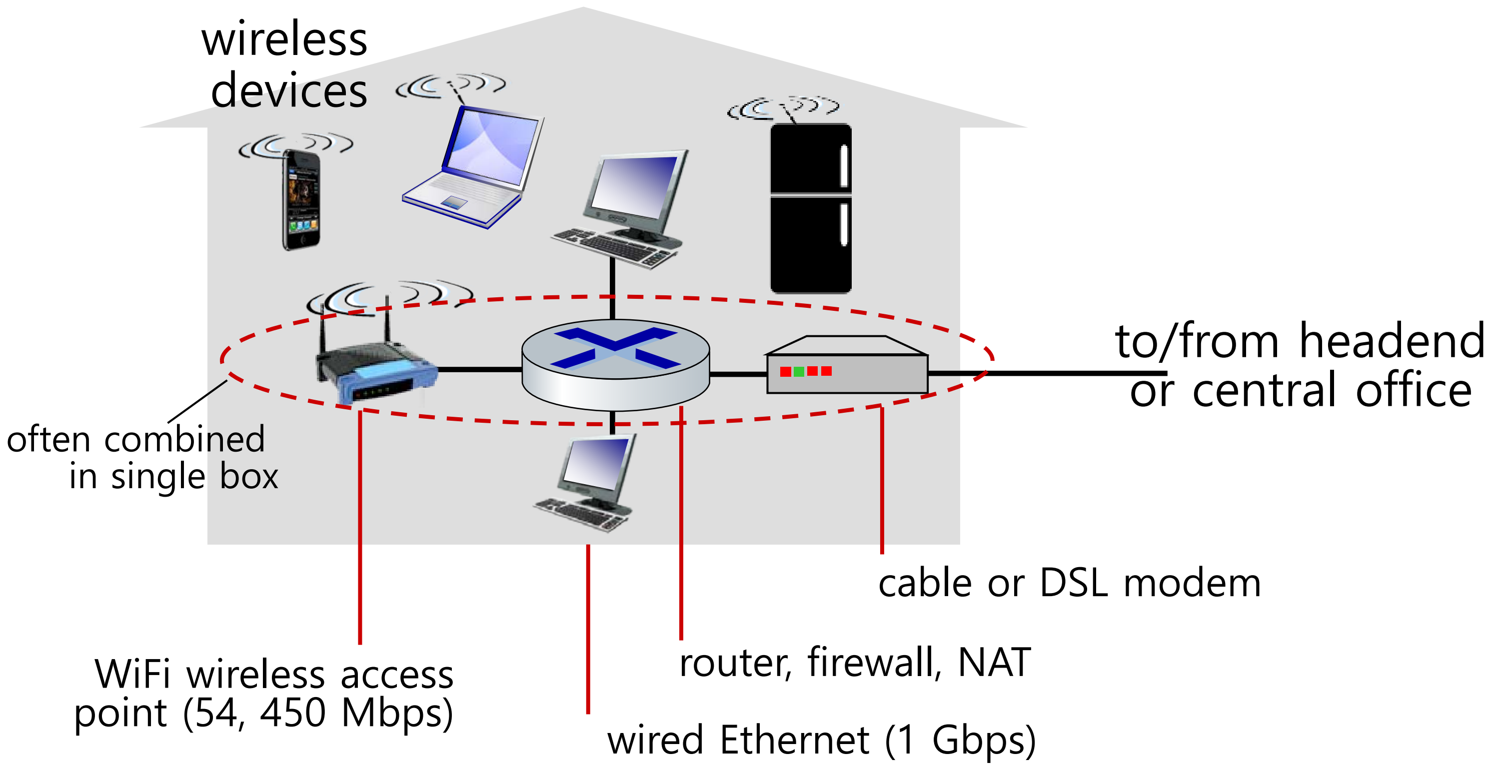
Access networks: home networks



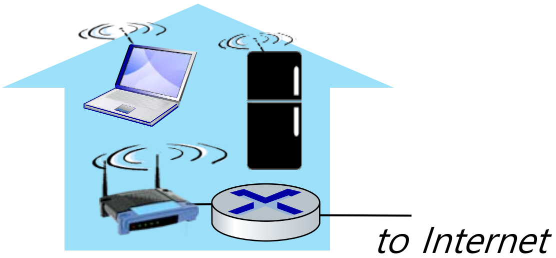
Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka "access point"

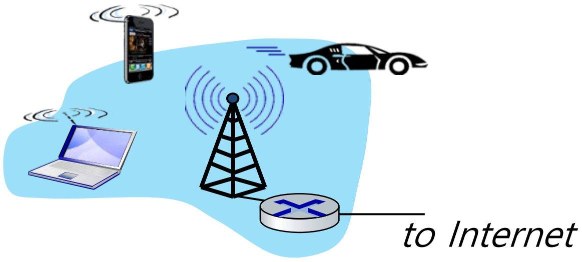
Wireless local area networks (WLANs)

- typically within or around building (~100 ft)
- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate



Wide-area cellular access networks

- provided by mobile, cellular network operator (10's km)
- 10's Mbps
- 4G cellular networks (5G coming)

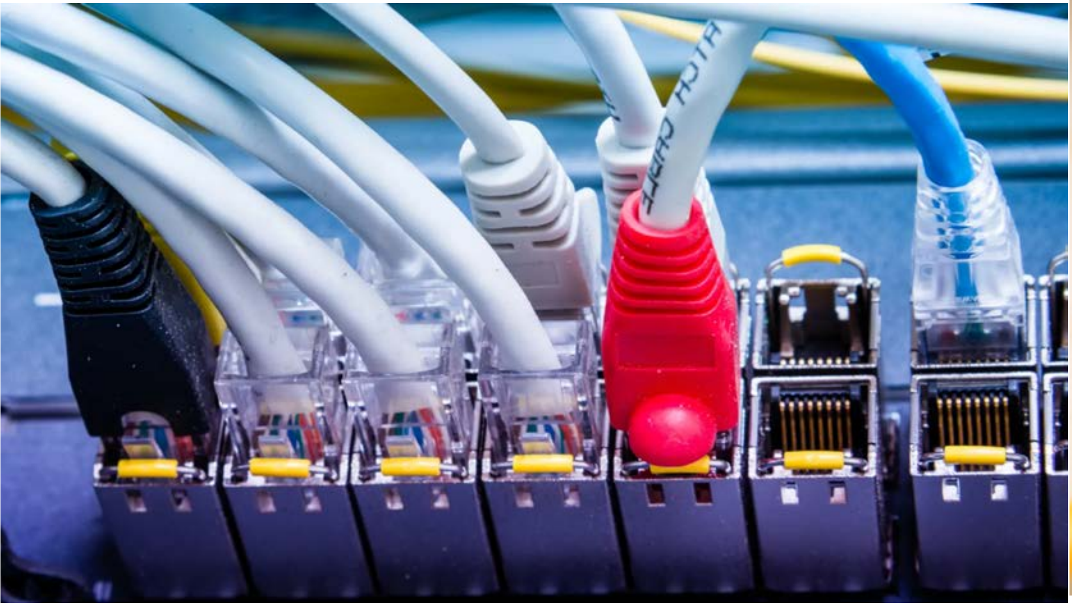


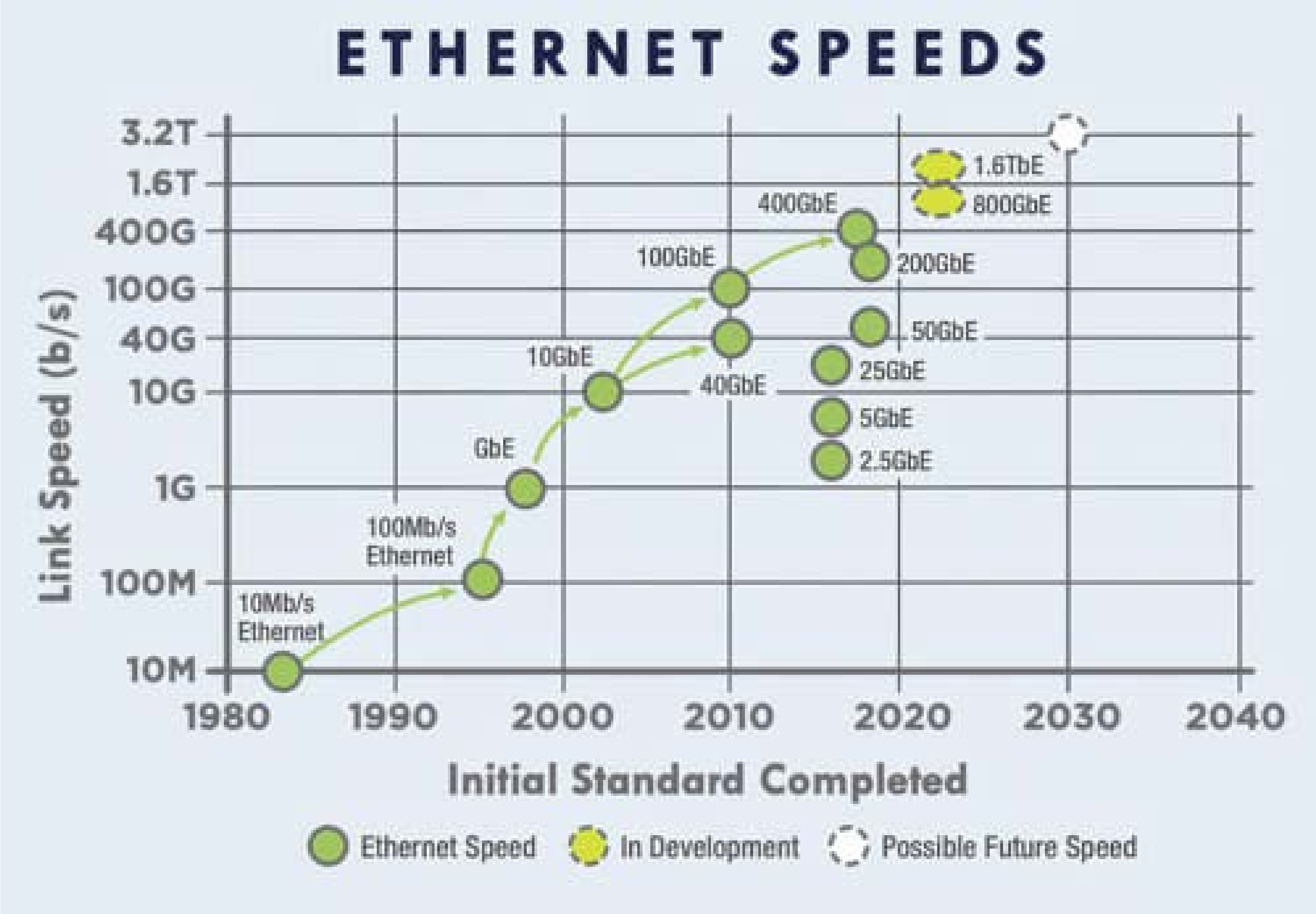
The New York Times

Turing Award Won by Co-Inventor of Ethernet Technology

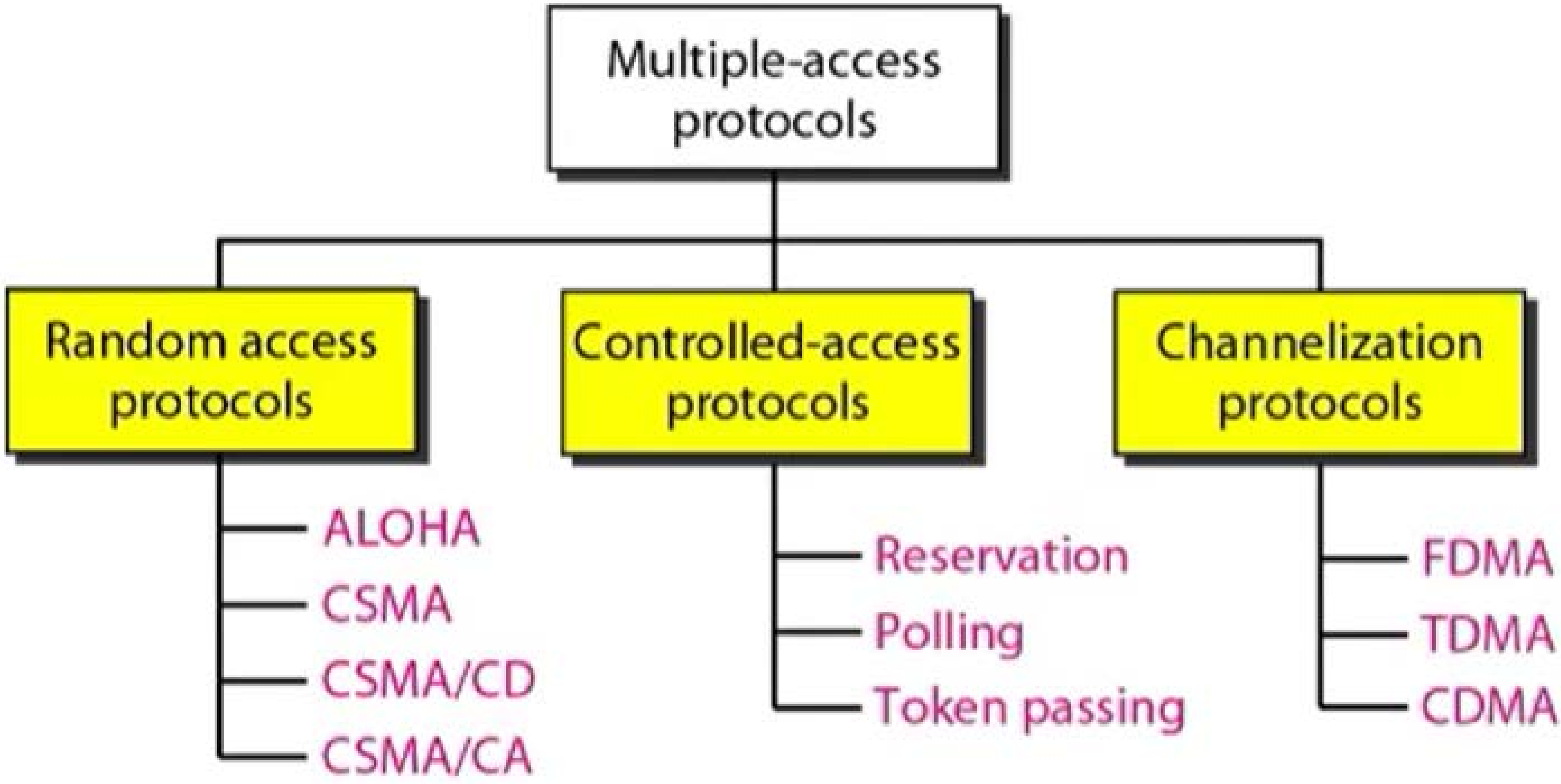
In the 1970s, Bob Metcalfe helped develop the primary technology that lets you send email or connect with a printer over an office network.

Ethernet, Terabit Ethernet





ETHERNET SPEEDS
3.2T
1.6T
400G
100G
40G
10G
1G
100M
10M
Link Speed (b/s)
1980
1990
2000
2010
2020
2030
2040
Initial Standard Completed
10Mb/s Ethernet
100Mb/s Ethernet
GbE
10GbE
40GbE
100GbE
400GbE
200GbE
50GbE
25GbE
5GbE
2.5GbE
800GbE
1.6TbE
Ethernet Speed
In Development
Possible Future Speed


Multiple-access protocols
Random access protocols
Controlled-access protocols
Channelization protocols
ALOHA
CSMA
CSMA/CD
CSMA/CA
Reservation
Polling
Token passing
FDMA
TDMA
CDMA

The Aloha Protocol (Wireless Network, Star Topology)

The Aloha protocol was implemented in '70 also in a satellite network, named ALOHAnet.

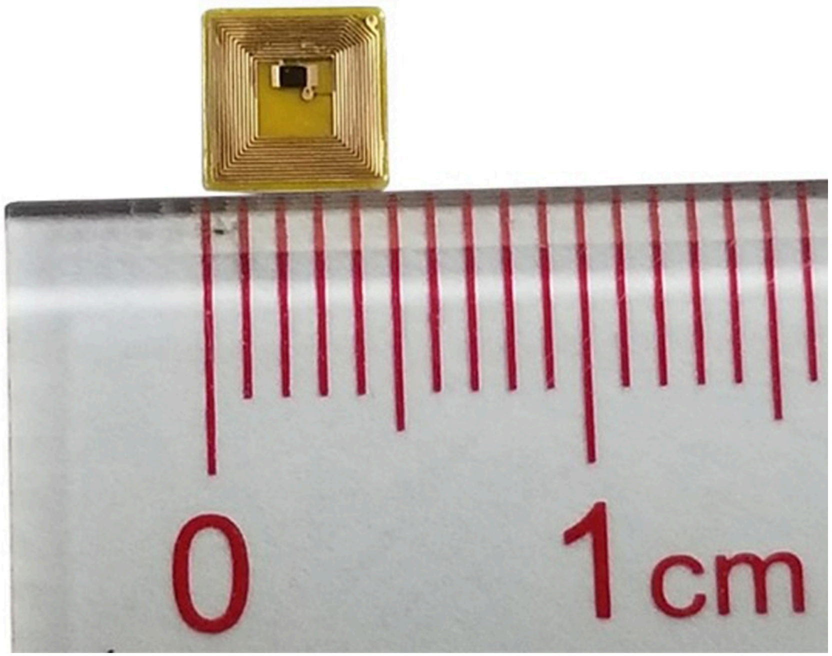
The Aloha protocol was proposed at the beginning of '70 by Professor Norman Abramson who needed to connect terminals dispersed among different islands and a central host (= controller) at the Hawaii University in Honolulu (Oahu island).

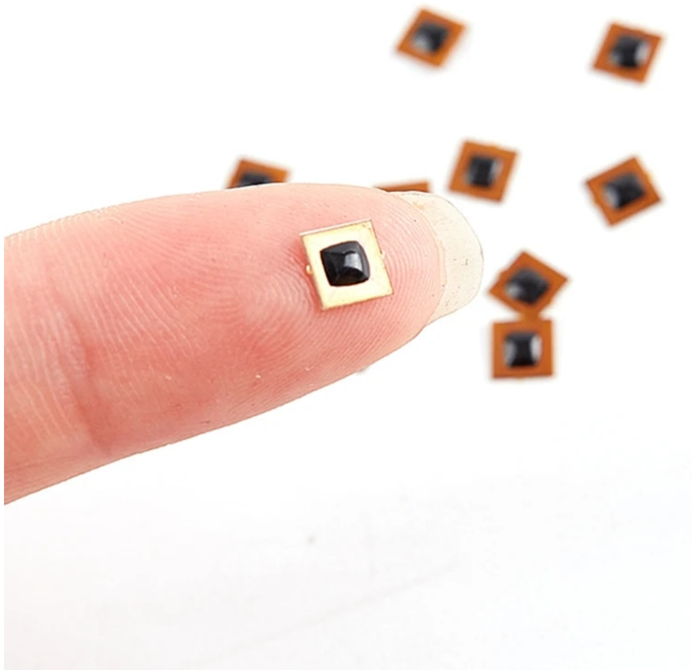
The main idea is **allowing terminals to transmit to the central controller as soon as they need to do so**.

- Collisions
- Mechanism to reveal collisions (The Aloha protocol is reliable: ACK and timer based on the round trip propagation delay or use of a broadcast channel)
- Retransmission attempts after a collision are rescheduled using a random **backoff** time

Note: Aloha is not an acronym, but the classical Hawaiian welcome expression.

N. Abramson, "The ALOHA System-Another Alternative for Computer Communications", *Fall Joint Computer Conference*, 1970.


0
1 cm



ATM

- **Asynchronous Transfer Mode** (**ATM**) is a telecommunications standard defined by the American National Standards Institute and ITU-T (formerly CCITT) for digital transmission of multiple types of traffic. ATM was developed to meet the needs of the Broadband Integrated Services Digital Network as defined in the late 1980s,[1] and designed to integrate telecommunication networks.
- It can handle both traditional high-throughput data traffic and real-time, low-latency content such as telephony (voice) and video.[2][3]
- ATM provides functionality that uses features of circuit switching and packet switching networks by using asynchronous time-division multiplexing.[4][5]
- ATM was seen in the 1990s as a competitor to Ethernet and networks carrying IP traffic as it was faster and was designed with quality-of-service in mind, but it fell out of favor once Ethernet reached speeds of 1 gigabits per second.[6]

Asynchronous Transfer Mode: ATM

- **1980s/1990's standard for high-speed** (155Mbps to 622 Mbps and higher) *Broadband Integrated Service Digital Network* architecture
- Goal: *integrated, end-end transport of carry voice, video, data*
  - meeting timing/QoS requirements of voice, video (versus Internet best-effort model)
  - "next generation" telephony: technical roots in telephone world
  - packet-switching (fixed length packets, called "cells") using virtual circuits

ATM Layer

Service: transport cells across ATM network

- analagous to IP network layer
- very different services than IP network layer

Network Architecture	Service Model	Guarantees ? Bandwidth	Loss	Order	Timing	Congestion feedback
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

Network-layer service model

Network Architecture	Service Model	Quality of Service (QoS) Guarantees ?			
		Bandwidth	Loss	Order	Timing
Internet	best effort	none	no	no	no

Internet "best effort" service model

No guarantees on*:*

i. successful datagram delivery to destination
ii. timing or order of delivery
iii. bandwidth available to end-end flow

IBM Turboways ATM 155 PCI network interface card

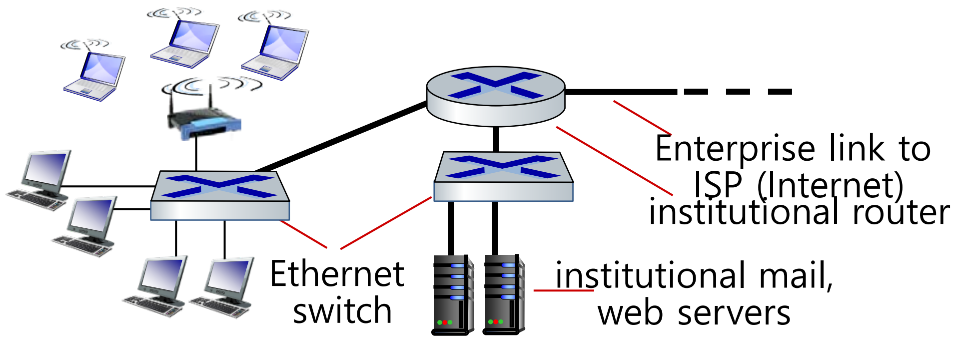
GigE Vs ATM

Network Resilience

Gigabit-Ethernet	ATM
• Spanning Tree Protocol blocks parallel links - stability issues? • No standards based load-sharing - Mostly proprietary • Use of OSPF / RIP with Layer 3 switching	• Build-in Redundancy • Parallel Load-sharing links for resilience & aggregate bandwidth • Full Meshed Topologies

Ethernet - Here to Stay

Access networks: enterprise networks

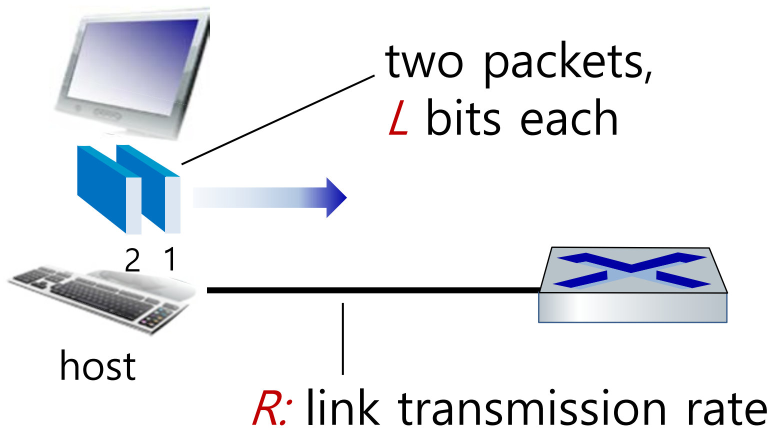


- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
  - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps

Host: sends *packets* of data

host sending function:

- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate, aka link *capacity, aka link bandwidth*



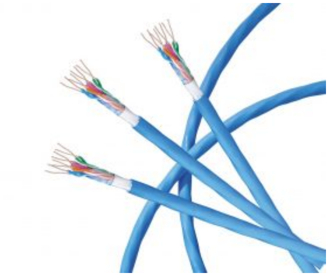
$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

Links: physical media

- bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- guided media:
  - signals propagate in solid media: copper, fiber, coax
- unguided media:
  - signals propagate freely, e.g., radio

Twisted pair (TP)

- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gbps Ethernet
  - Category 6: 10Gbps Ethernet



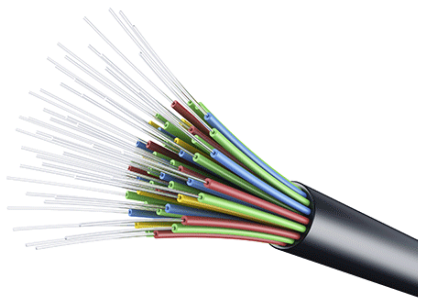
Links: physical media

Coaxial cable:

- two concentric copper conductors
- bidirectional
- broadband:
  - multiple frequency channels on cable
  - 100's Mbps per channel

Fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (10's-100's Gbps)
- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise



Links: physical media

Wireless radio

- signal carried in electromagnetic spectrum
- no physical "wire"
- broadcast and "half-duplex" (sender to receiver)
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:

- terrestrial microwave
  - up to 45 Mbps channels
- Wireless LAN (WiFi)
  - Up to 100's Mbps
- wide-area (e.g., cellular)
  - 4G cellular: ~ 10's Mbps
- satellite
  - up to 45 Mbps per channel
  - 270 msec end-end delay
  - geosynchronous versus low-earth-orbit

Chapter 1: roadmap

- What *is* the Internet?
- What *is* a protocol?
- Network edge: hosts, access network, physical media
- **Network core:** packet/circuit switching, internet structure
- Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History

The network core

- mesh of interconnected routers
- packet-switching: hosts break a pplication-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity