

Internet Roots

a Journey through communications history

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Agenda

- > Introductions: Speaker and Audience
- > Approach to each innovation
- > 19th century innovations
- > Seven-layer model
- > 20th century innovations
- > 21st century innovations
- > Ethical issues
- > Where to learn more
- > Questions and Answers



Introductions

- > The audience:
 - I assume you are curious to learn some technical history
 - I suspect that all of you USE the internet
 - I assume you remember some high school physics
 - Does anyone in the audience want to add a particular introduction?
- > Joe Decuir is a part time professor at UW Bothell
 - 42 years in industry: medical electronics, video games, personal computers, dial up networking, operating systems, USB and Bluetooth
 - Beginning 10th year ‘paying it forward’ to the students at UW Bothell
 - IEEE Fellow cited for contributions to personal computer graphics and video games: Atari 2600, Atari PCS, Amiga
 - https://en.wikipedia.org/wiki/Joseph_C._Decuir



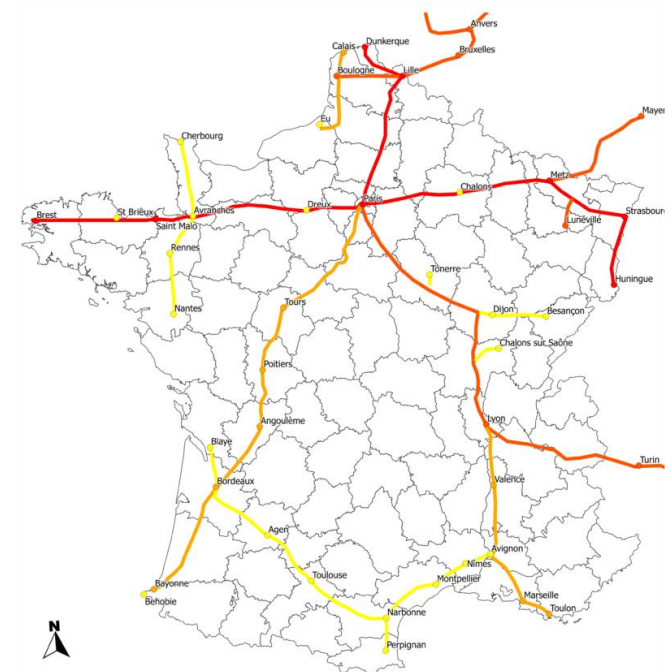
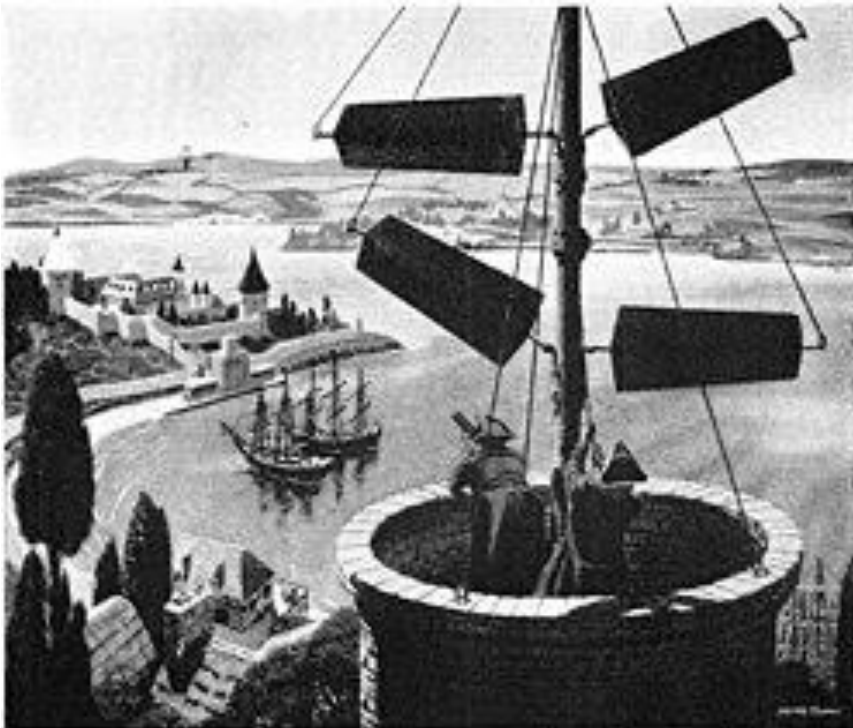
Approach to each innovation

- > The existing internet is based on a series of engineering innovations, accumulated from the early 19th century until today.
- > In each case, I will attempt to highlight:
 - What the significant changes were
 - Sketch out how it works
 - What was the value?
- > Examples of changes:
 - Physical layer: wired, wireless or optical
 - Logic layers: unstructured or packetized, communication routing
 - Presentation: raw bits, analog voice, compressed video



First long distance communication: optical telegraph

- > https://en.wikipedia.org/wiki/Optical_telegraph
- > There would be a string of towers in mutual view



Le réseau Chappe en France

Directions (date de création)

- 1793-1800
- 1800-1815
- 1815-1830
- Après 1830

Lignes (date de création)

- 1793-1800
- 1800-1815
- 1815-1830
- Après 1830

Electronical Telegraphs

- > Electronic telegraphs were simple: current on or off
- > Long range, around obstructions (not just line-of-sight)
- > Downside: users must learn coding method:



International Morse Code

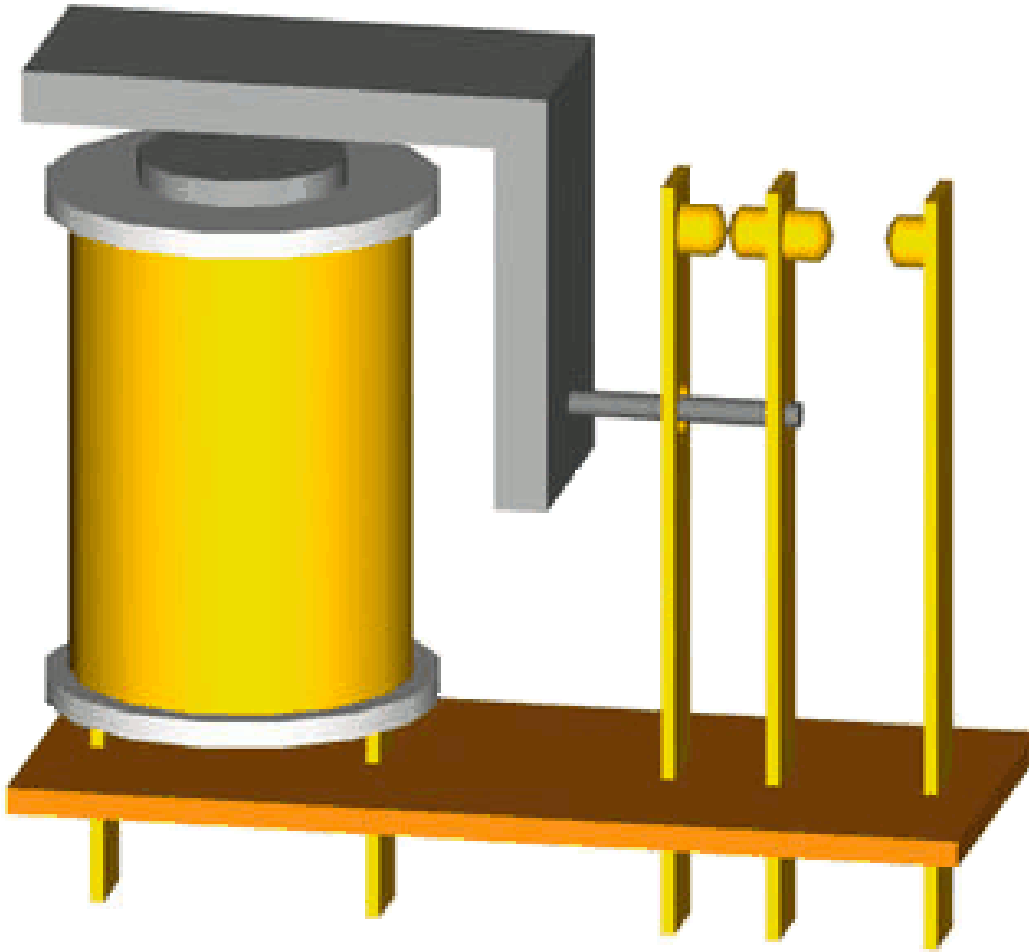
1. The length of a dot is one unit.
2. A dash is three units.
3. The space between parts of the same letter is one unit.
4. The space between letters is three units.
5. The space between words is seven units.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • — —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— • — —
R	• — • •
S	• • •
T	—

U	• • —
V	• • • —
W	— • — —
X	— • • —
Y	— • — —
Z	— — • •

1	• — — — —
2	• • — — —
3	• • • — —
4	• • • • —
5	• • • • •
6	— • • • •
7	— • — • •
8	— • — • •
9	— • — • •
0	— — — — —

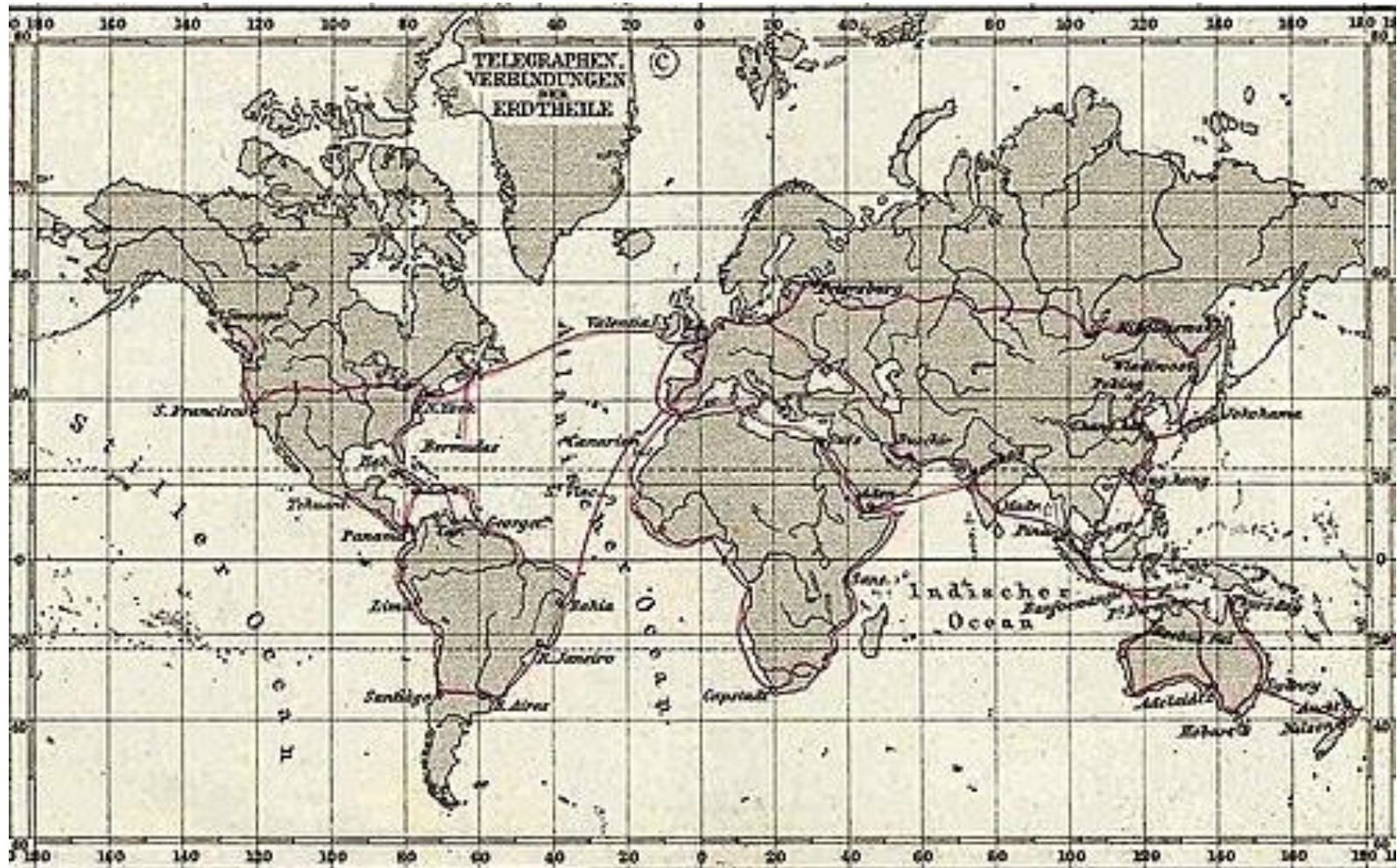
Electronic relays



- > Electromagnetic switching
- > Amplify weak currents
- > Enabled longer distances

Geographic telegraph extension

- > Relays allowed very long electric telegraph connections on land
- > Trans-oceanic cables were laid, starting in the mid-19th century



Voice telephones

- > Enough bandwidth for voice
- > Anyone can use it: speak and listen
- > telephone calls were routed by operators



Teletype

- > encoding keys as bit streams
- > Receiver decodes keys
- > anyone who can type can send!



LETTERS FIGURES		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	CARRIAGE RETUN	LINE FEED	LETTERS	FIGURES	SPACE	ALL-SPACE NOT IN USE
CODE ELEMENTS	1	●	●		●	●	●				●	●						●		●		●		●	●	●				●	●		
	2	●		●				●		●	●	●	●				●	●	●			●	●	●	●	●			●	●	●	●	
	3	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	4		●	●	●	●	●	●			●	●		●	●	●			●				●		●	●		●	●	●	●	●	
	5		●					●	●				●	●		●	●	●			●		●	●	●	●	●						○

- INDICATES A MARK ELEMENT (A HOLE PUNCHED IN THE TAPE)
- INDICATES POSITION OF A SPROCKET HOLE IN THE TAPE

The International Telegraph Alphabet

Vacuum tubes

- > generate and modulate electron flow
 - Reused techniques to make light bulbs
- > enabled: telephone range, radios, analog computers and early digital computers.

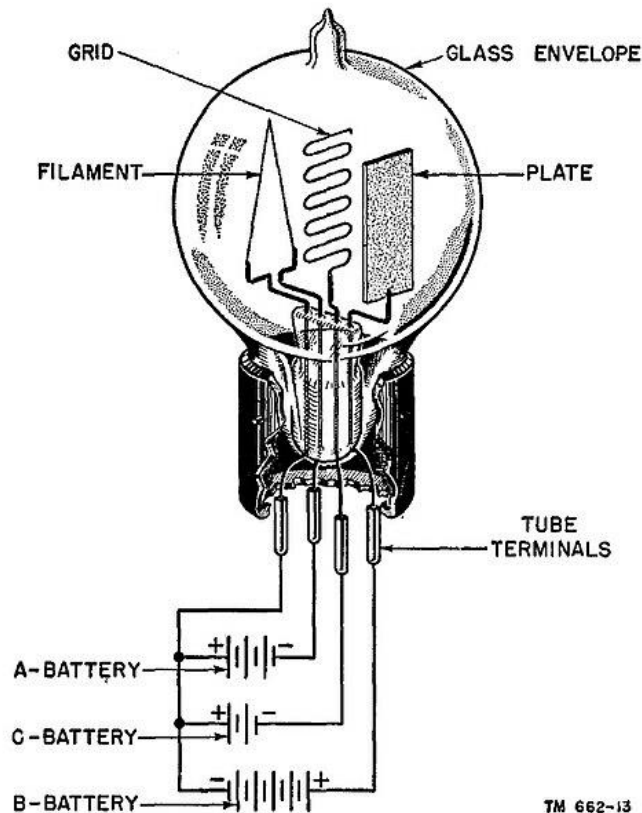
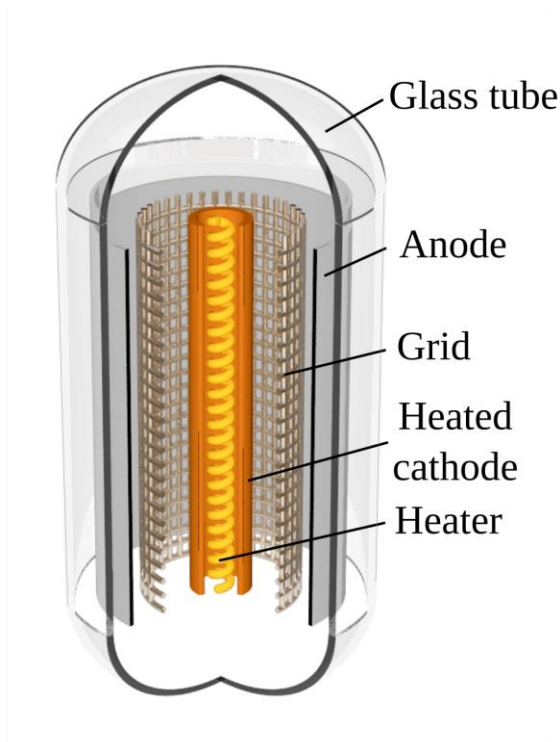
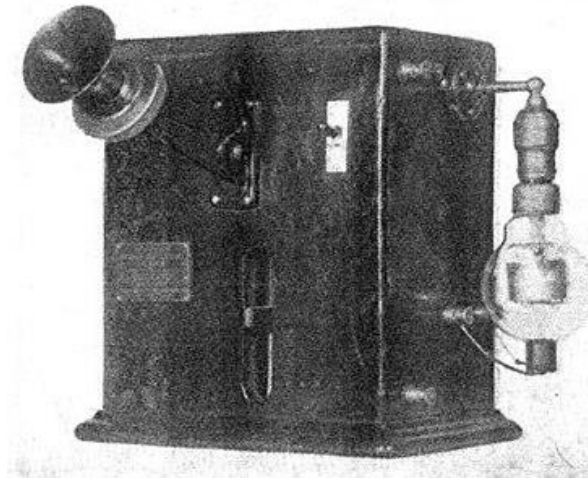
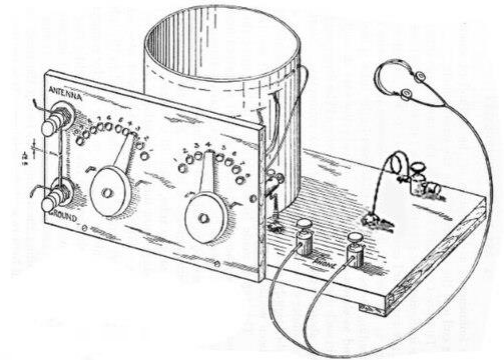
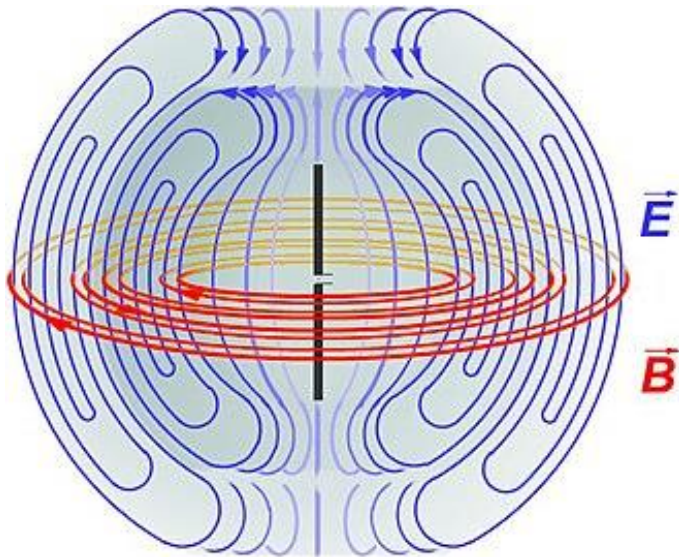


Figure 4. Construction of DeForest's three-element tube, or triode.

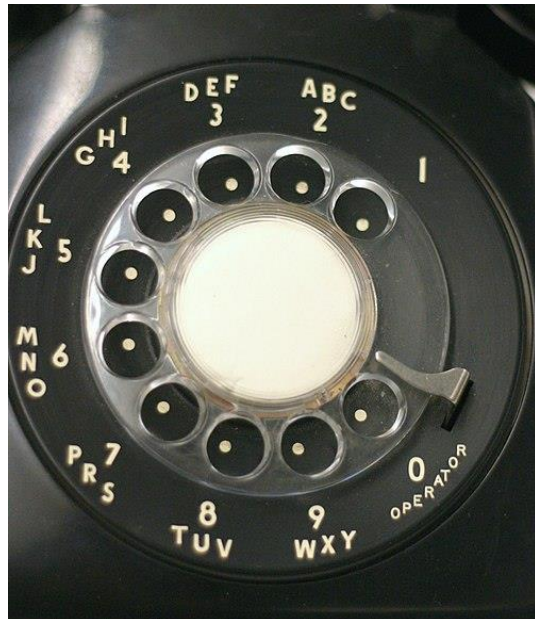
First radios

- > Electromagnetic waves can travel without wires.
- > First radio transmitters: on and off
- > The first radio receivers detected signal on and off
- > First application: wireless telegraphy



Pulse dialing

- > Automatic call routing:
 - pulse dialing generator for phones
 - distinguish strings of pulse codes
 - capture those pulse dial digit strings
 - stepping relay that adjusts to each digit
 - apply these strings to a series of relays



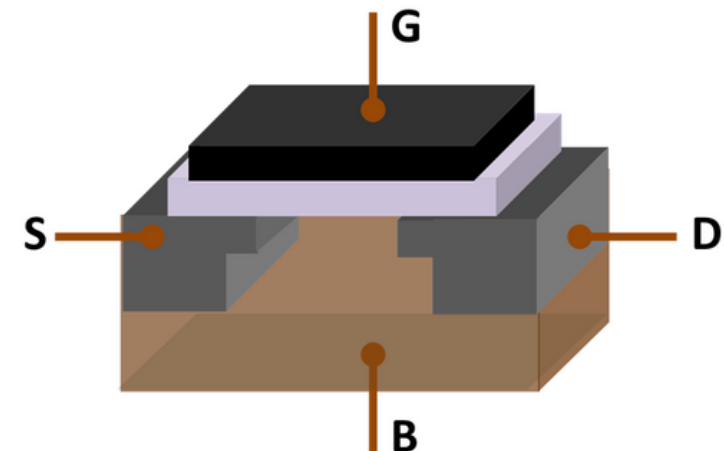
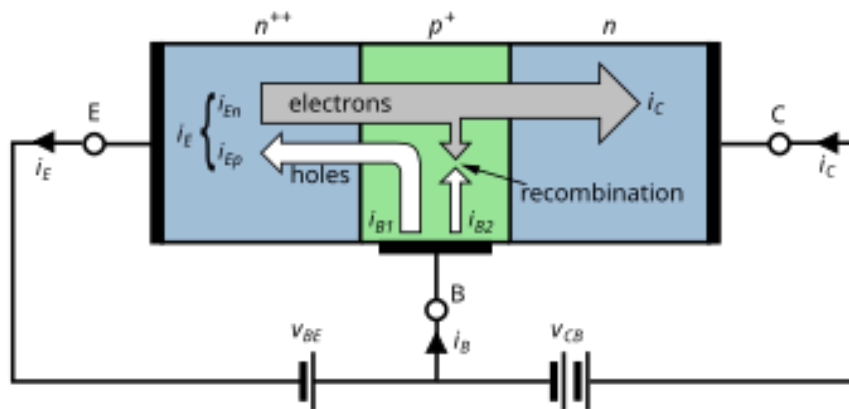
Open Systems Interconnection Model

1. Applications: user operates the system (HTTP, FTP)
2. Presentation: what the information looks like (MP4)
3. Session: start, continue and end a communication session
4. Transport: end-to-end communication (TCP)
5. Network: route and forward information (IP)
6. Data link: how information is sorted into bits, data structures (IEEE 802.11-series)
7. Physical: how messages travel, e.g. wired, wireless (802.3 Ethernet vs 802.11 WiFi)



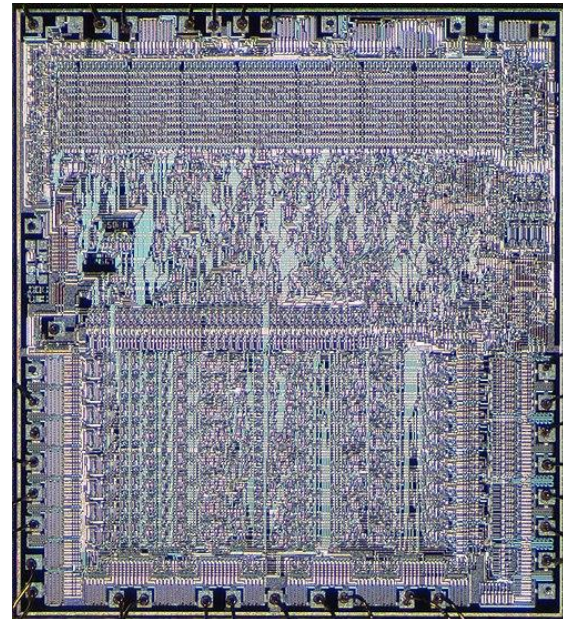
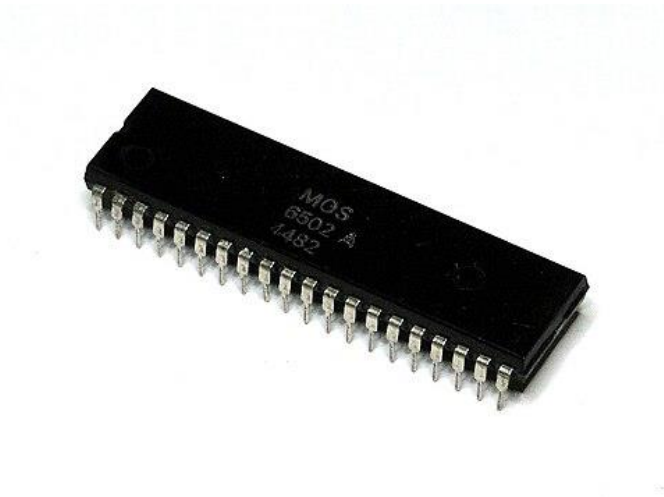
Transistors

- > Solid state devices to controlling currents
 - smaller, faster and more reliable
- > two types: voltage controlled or current controlled
- > make analog amplifiers and digital logic



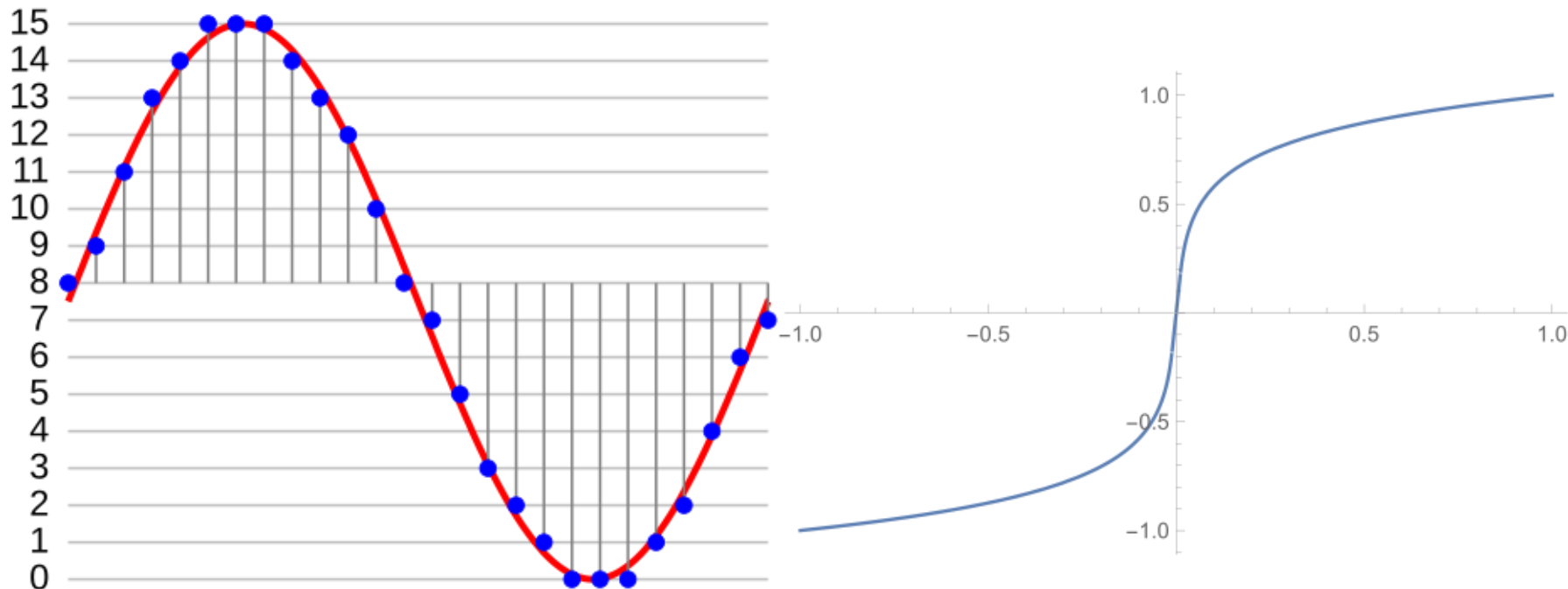
Integrated circuits

- > Multiple transistors on a chip
 - Amplifiers and comparators
 - Digital logic gates & Microprocessors (shown here)
- > Specialized communications circuits:
 - Dual Tone Multifrequency dialers and detectors
 - Pulse Code Modulation: encoders and decodes (in switches)



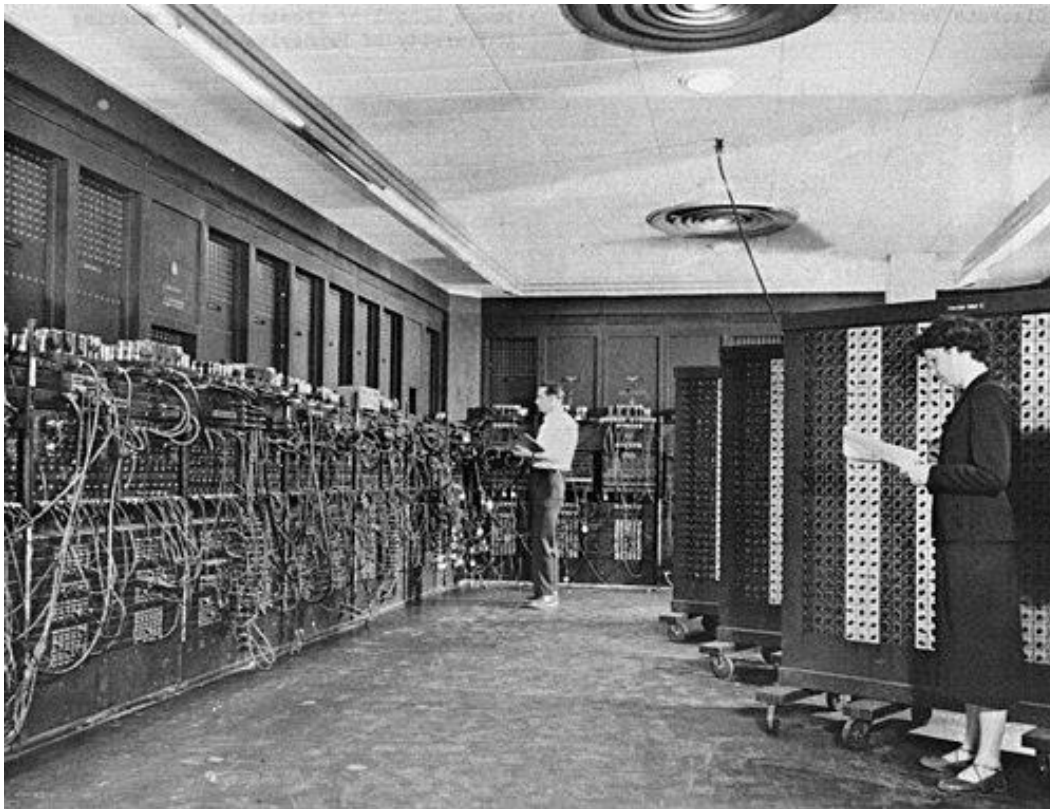
Digital Network: Pulse Code Modulation

- > Sample the 4000 Hz voiceband at 8000 Hz
 - The converter is companding
- > Send the digitized 64000 bit/second signal
- > Convert back to analog at the receiving central office



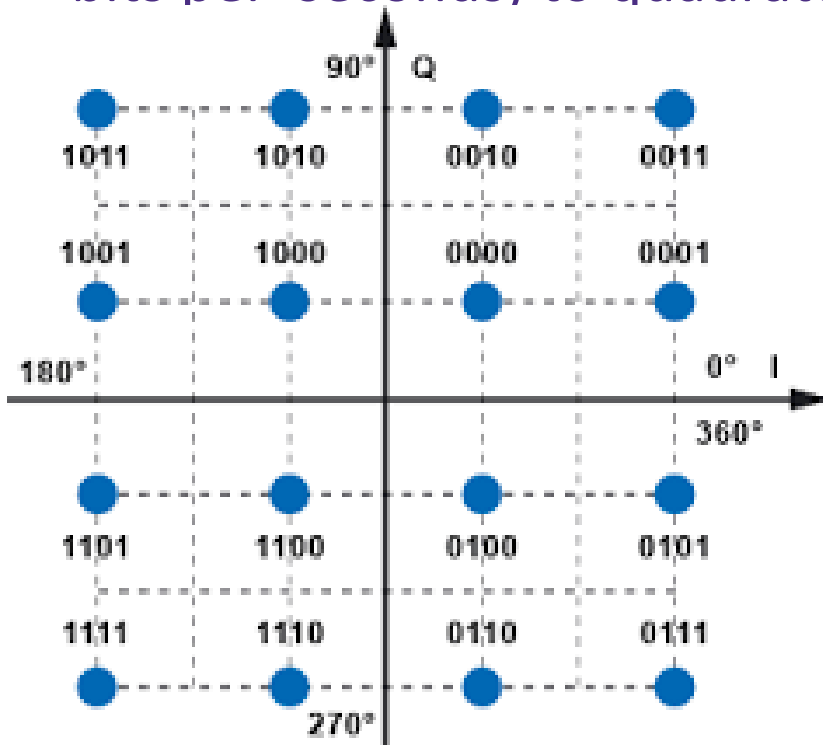
Electronic Digital Computers

- > Early digital computers were built with relays and vacuum tubes
- > They were replaced with transistors and integrated circuits.
- > Telephone switches were specialized digital computers that had multiple digital communication connections



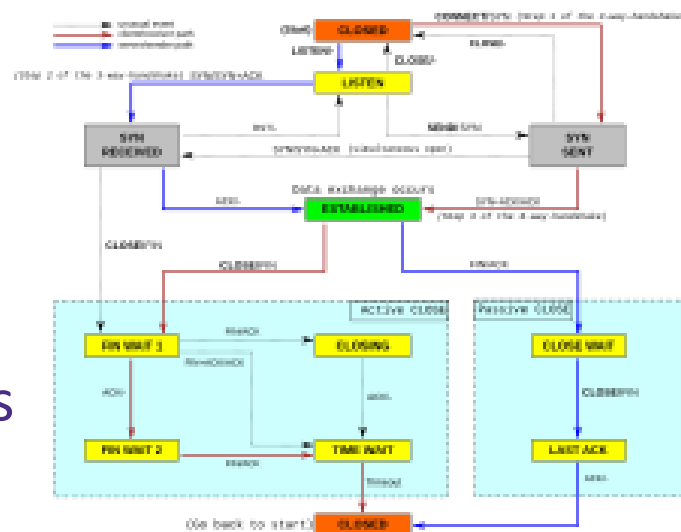
Modems on the Digital Network

- > The international landline network allowed digital data to be exchanged between computers.
- > Modulation methods advanced: frequency-shift-key (100-300 bits per seconds) to quadrature-amplitude (33600 bits/second)

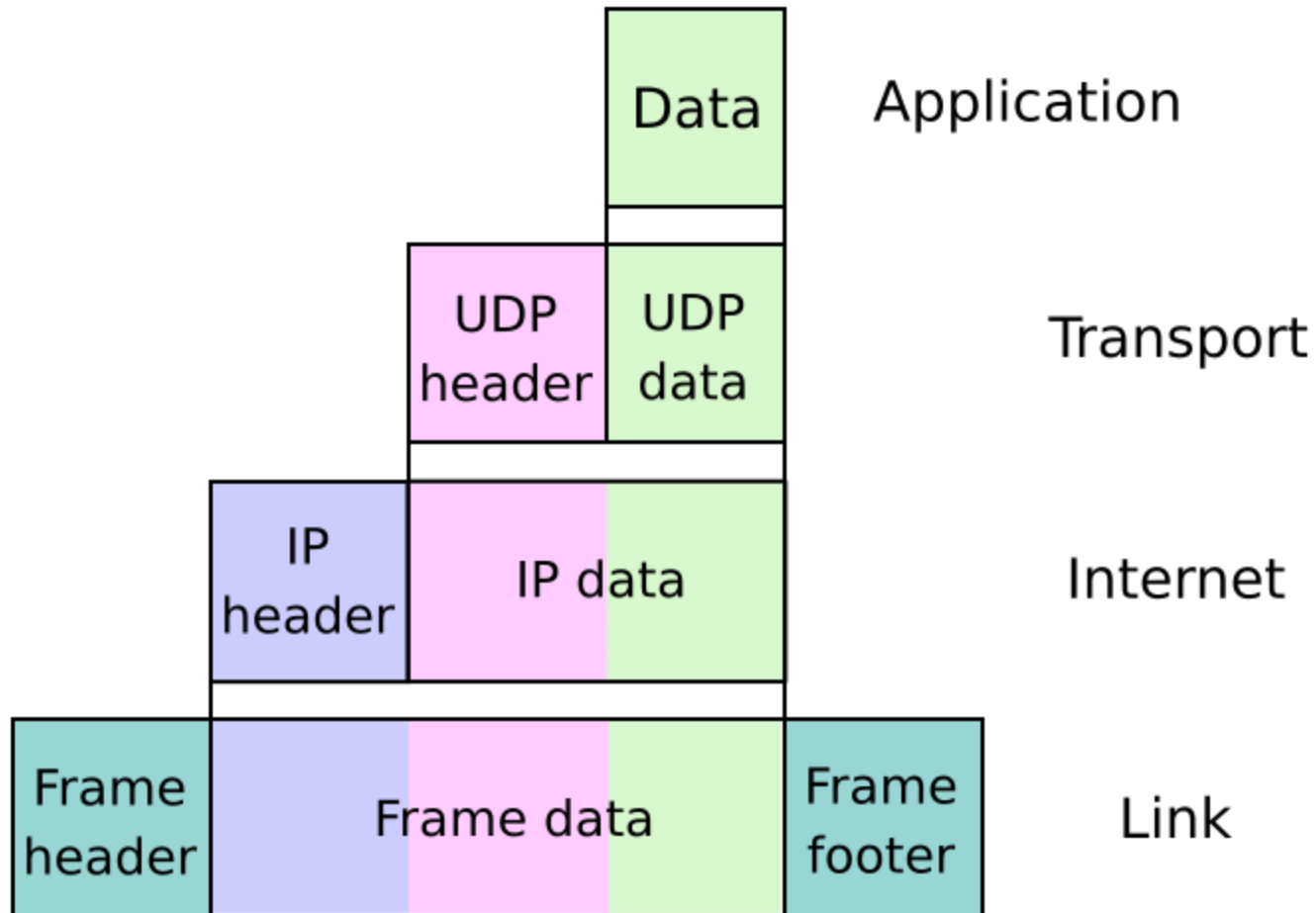


Internet Logical Protocols

- > Internet Protocol (IP) is the most common solution for computers addressing each other (OSI model layers 3 & 4)
 - Each IP packet contains a source address and a destination address.
- > Special purpose computers called routers receive these packets and dynamically determine the best way to direct each packet to the appropriate destination
 - IPv4 address is a 32-bit number, >4 billion addresses
 - IPv6 address is a 128-bit number
- > Transmission Control Protocol (TCP):
 - Reliable and in order
 - Integrity – error check & retransmit
- > TCP/IP computers exchange messages
 - Send requests, receive replies

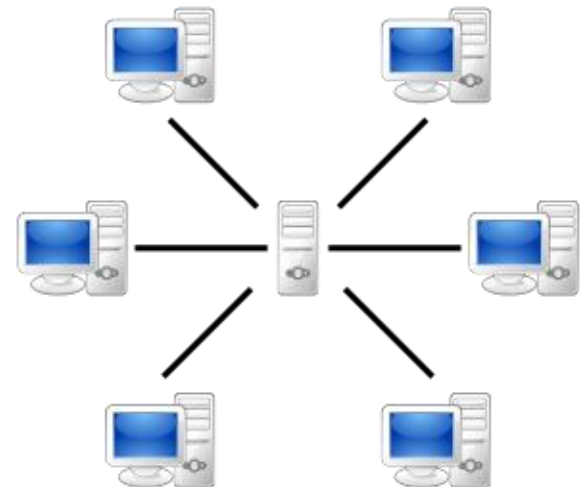
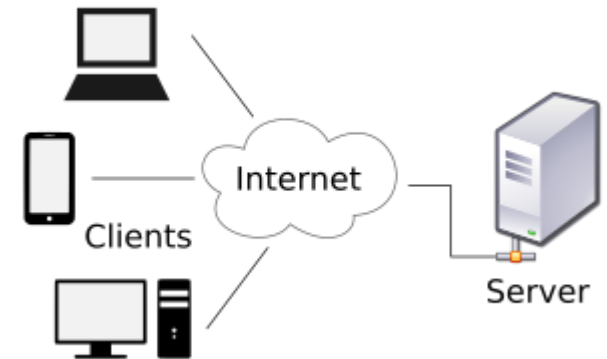


TCP/IP contents illustrated



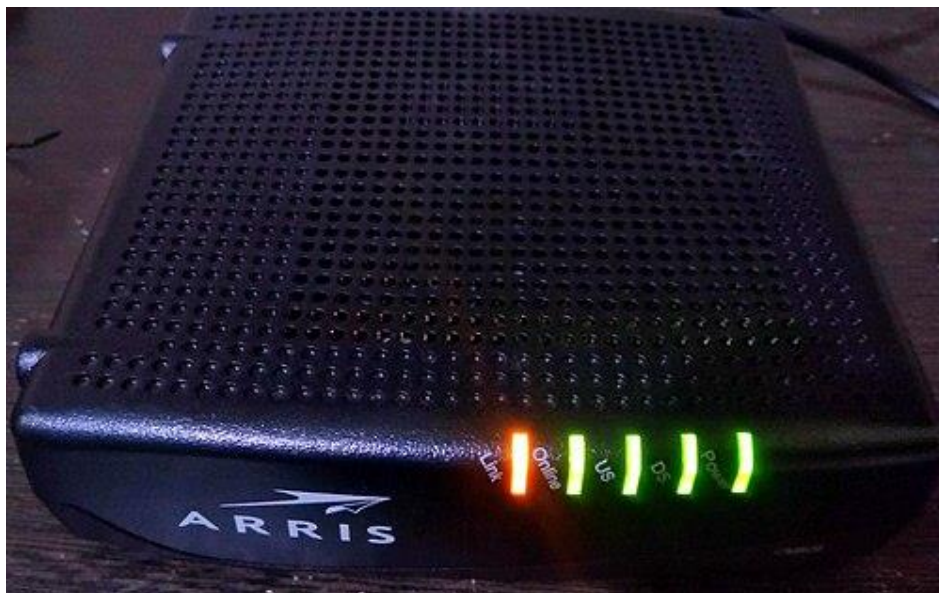
Internet Servers

- > Internet-connected computers can contain file structures
 - Those files can have any form: raw bits, images, audio data, video data, etc
- > The devices connecting to these file structures are called clients
- > Hypertext transfer protocol is a commonly used application that connects to these file structures
 - This is the primary function of a web browser
- > Today, large collections of servers are referred to as clouds.
- > Your mobile phones are clients



Broadband

- > “the internet is too slow!”
- > Two industries responded to accelerate the ‘last mile’:
 - The telephone companies abandoned ISDN replacing it with Digital Subscriber Loop (DSL), starting at 250 000 bits/sec
 - The cable companies allocated bandwidth on their co-axial cable for two-way data communication: DOCSIS (Data Over Cable System)



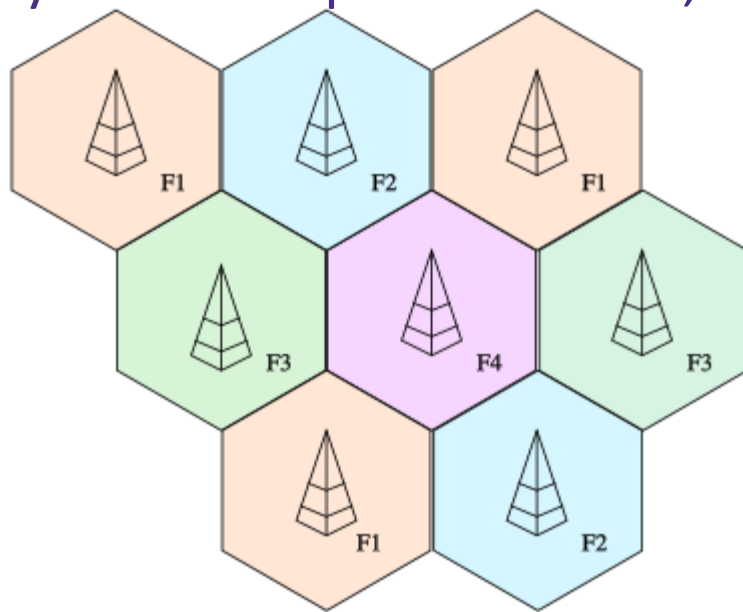
Data within a Building

- > In the mid-1970s Ethernet became the dominant method for local area networks, IEEE 802.3 standard
- > Starting in the mid-1990s, the success of Ethernet inspired efforts to create a wireless version, the IEEE 802.11-series standards
 - They started at 1 Mb/s
 - Current : over 1 Gb/s
- The upper layers of this system come from the Wi-Fi Alliance
 - We all depend on it



Analog Mobile Phones

- > People have always wanted more mobility
- > We developed short range wireless extensions to our landline phones
- > Starting in the late 1980s the 1st-generation wireless phones were made:
 - A pair of 30 kHz FM channels carried voice
- > Layout of cell phone towers, reusing spectrum



Optical fiber

- > semiconductor lasers generate coherent light.
- > Instead of communicated in open air and line-of-sight, the light is inserted into a thin glass fiber.
- > The light is reflected from the interior surface of the glass fiber (if the bends are not too severe)
 - Most of the light in reaches the far end
- > Glass fibers can be 100s of kilometers long
- > Over time, wired undersea communications cables have been replaced by optical fiber



Digital compression

- > Use a coder/decoder (codec) to increase the carrying capacity
- > 2nd generation mobile phones digitize spoken sound
 - Audio bandwidth: <4kHz, same as landline phones
 - The codecs include a model of the human vocal tract
 - The resulting data rates are around 10000 bits/sec, not 64000 bits/sec
- > MP3 is widely used to digitize music
 - Audio bandwidth: <20kHz
- > MP4 is widely used to digitize video
 - MP4 is widely used on optical storage (DVD, BluRay)
 - Digital television requires MP4 as of 2005, replacing analog TV
 - Most internet traffic now is streaming MP4 video



Digital Mobile Phones

- > Following the analog 1st generation phones, the second generation could serve perhaps 8 customers in the same channel that covered 1 customer before
- > There were three incompatible 2nd generation designs. They converged on a common design for the 3rd and 4th generations (LTE)
- > Ongoing work defined the 5th generation (in service now) and a 6th generation is being imagined.



Ethics: Truth vs Lies

- > The Internet allows users to generate *any* content
 - Users can be people or robots
 - Google web search is fed by crawling the web
- > Some of this is accurate; some of it is not
 - You can lie with the internet
- > You cannot lie to an electron
 - It has no mind to deceive



Ethics: Privacy vs Authentication

- > The Internet was designed by trusting people
- > It is overused by untrustworthy people
- > To avoid accountability, bad actors hide their identities – privacy
 - OTOH, all of us need some level of privacy
 - Example: we do not want to be ‘doxed’, exposed to threats
- > Therefore, we all must work to authenticate ourselves:
 - the login names and passwords to remember
 - proving to remote systems that we are not robots
- > Two factor authentication: using a different pathway to prove who we are.



Where to learn more

- > I use Wikipedia extensively:
 - https://en.wikipedia.org/wiki/OSI_model
- > Books:
 - The Victorian Internet, Tom Standage
 - A Brief History of Communications, IEEE Communications Society
 - Signals, the Telephone and Beyond, John Pierce
 - The Race for Bandwidth, Cary Lu
- > Disclaimer: I joined the IEEE Communications Society in 1980
 - I served as the chair of the Seattle chapter from 1994 to 2003.



Questions?



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