1-12-2020 Internet for Dummies [that's us]

Today is a "Trip Down Memory Lane" ++
Proposed Course Outline? 1-19 Sun 3:30 ff

Bits/addresses/DNS/install Wireshark
-------*bring your laptop if you can!!!*
Ethernet Frames/Access technologies
IP packets/Networks/Routing
TCP packets/Services
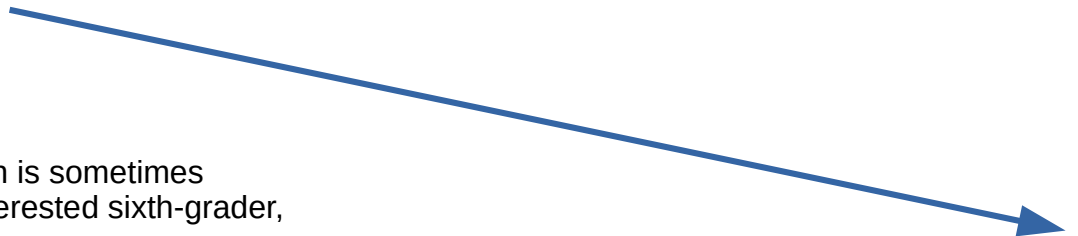Computers/OS's/Data comm
DNS,Web,email,apps
Dangerous Internet/safe computing

John Loop pccitizen@gmail.com

This talk at https://johnloop.com/VGs2impress.pdf
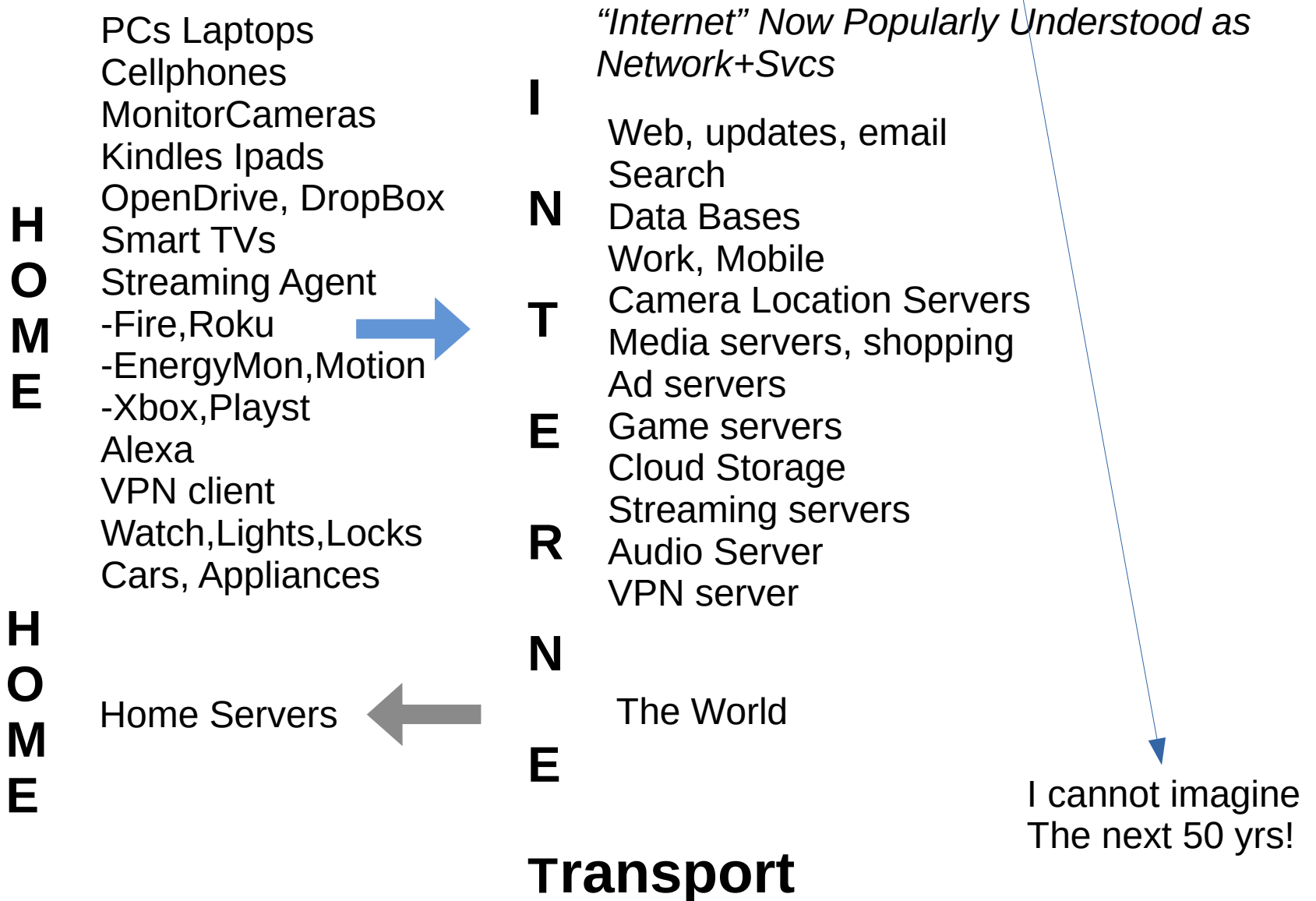
Let us start at the "TOP"

Signup at "Box Office"

Richard Feynman's technique for learning a topic, which is sometimes
summarized as "if you can't explain something to an interested sixth-grader,
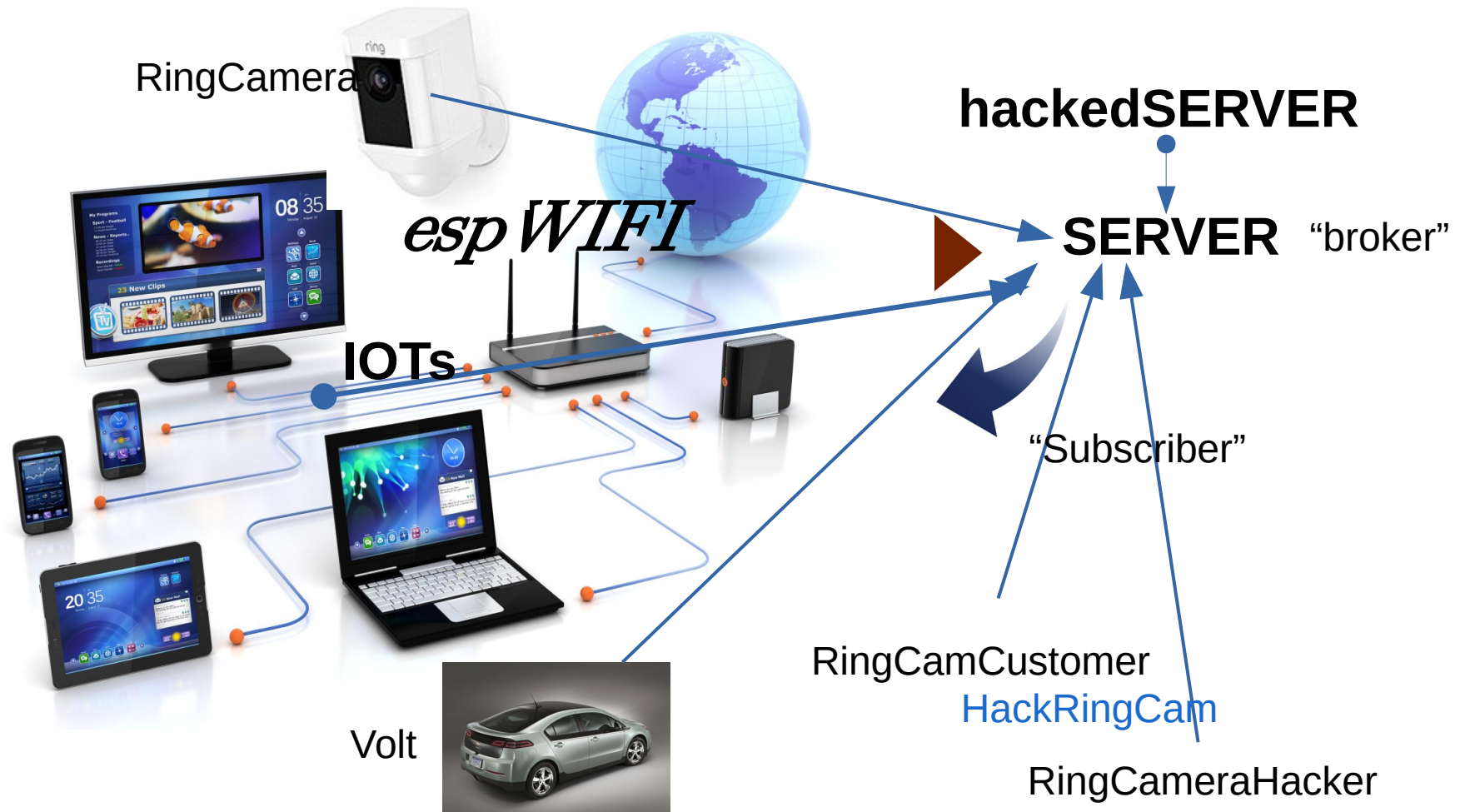you don't understand it yourself."

The **Internet** or….

What in the world did we do to ourselves in the last 50 years?

HOME

PCs Laptops
Cellphones
MonitorCameras
Kindles Ipads
OpenDrive, DropBox
Smart TVs
Streaming Agent
-Fire,Roku
-EnergyMon,Motion
-Xbox,Playst
Alexa
VPN client
Watch,Lights,Locks
Cars, Appliances

HOME

Home Servers

INTERNET

"Internet" Now Popularly Understood as Network+Svcs

Web, updates, email
Search
Data Bases
Work, Mobile
Camera Location Servers
Media servers, shopping
Ad servers
Game servers
Cloud Storage
Streaming servers
Audio Server
VPN server

N

E

The World

Transport

I cannot imagine
The next 50 yrs!

Prettier picture:

RingCamera

hackedSERVER

esp WIFI

SERVER "broker"

IOTs

"Subscriber"

Volt

RingCamCustomer

HackRingCam

RingCameraHacker

Food for thot:
Once you have an account/login on a server,
It can now access your network, esp if wifi!!
Do these servers ever get compromised/hacked?
Do they have your wifi passwords?
----They can potentially listen to every conversation (promiscuous port)
----I still like Ethernet! But FEW IOTs use ethernet :-(
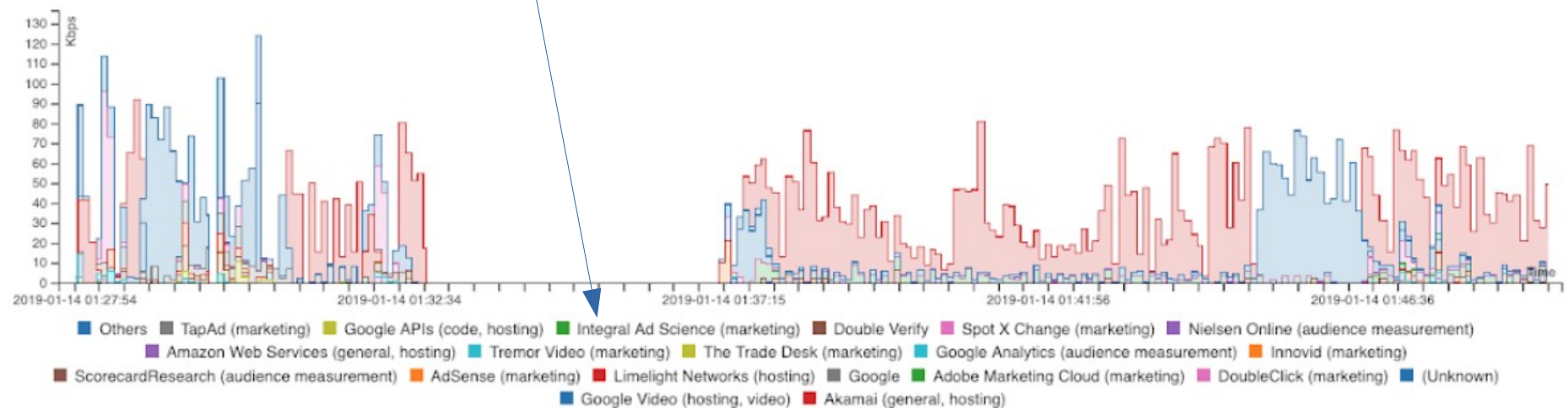Good passwds/2FA needed/httpsOnly!

BESIDES the "KNOWN" IOT Clients, there are the "UNKNOWN" clients
This is from iot-inspector.princeton.edu

Insight: trackers/ads on Roku TV

Trackers

Outbound/Sending Bandwidth

Just to get your attention!!!!

---do you have upnp enabled on your router :-(

SamsungIOT

A Teaser...

Actual 30 min capture of my home network: Destinations
Using win10 on HP laptop….. F12/network on FFox

https://motls.blogspot.com

Wireshark · Endpoints · JohnHome9AM12-10.pc ator Server 236 4 Dashboar... https://192.168.254.25... M Inbox (

Ethernet · 16		IPv4 · 48		IPv6 · 21		

Address	Packets	Bytes	Tx Packets	Tx Bytes	Rx Packets	Rx Bytes	Country
0.0.0.0	8	2,766	8	2,766	0	0	—
13.64.245.120	273	156 k	124	98 k	149	58 k	United States
18.208.5.78	18	1,722	8	686	10	1,036	United States
23.32.66.222	41	14 k	21	11 k	20	2,786	United States
23.32.67.192	11	2,512	5	1,961	6	551	United States
35.186.224.53	19	6,472	10	5,522	9	950	United States
40.69.216.73	24	5,603	11	3,654	13	1,949	Ireland
40.69.216.129	24	5,594	10	3,594	14	2,000	Ireland
40.69.216.251	24	5,595	10	3,595	14	2,000	Ireland
40.69.223.198	22	5,485	10	3,594	12	1,891	Ireland
52.33.42.218	29	19 k	13	8,988	16	10 k	United States
52.89.183.237	95	12 k	47	6,374	48	6,258	United States
52.114.128.8	19	8,262	9	4,954	10	3,308	United States
52.114.132.73	49	28 k	21	10 k	28	17 k	United States
52.177.165.30	3	380	1	174	2	206	United States
52.177.166.224	130	14 k	46	8,008	84	6,328	United States
52.178.192.146	25	5,648	10	3,595	15	2,053	Ireland
54.213.232.186	52	31 k	21	12 k	31	19 k	United States
68.67.179.164	33	10 k	14	8,110	19	2,501	United States
72.21.91.29	15	1,877	7	1,195	8	682	United States
104.95.11.191	13	5,575	7	5,026	6	549	United States
162.241.225.105	365	389 k	283	379 k	82	10 k	United States
169.254.104.1	26	8,227	26	8,227	0	0	—

Who are these people

☐ Name resolution   ☐ Limit to display filter

Help

183 URLs

More ▼

Veritas

thursday, decem

Sydney meet

☐ Inspector ▷ Console ▢ Debugger ↑↓ Network { } Style Ed

🗑 ▽ Filter URLs

Status	Method	Domain	File
200	GET	🔒 ⊘ ton.twimg.com	syndication_bundle_v1_733
	GET	🔒 ⊘ pbs.twimg.com	ycMWUu7W_normal.jpg
	GET	🔒 ⊘ pbs.twimg.com	ELinPNyVUAA6Hxr?format
	GET	🔒 ⊘ pbs.twimg.com	ELhtGVbU4AApJkP?format
	GET	🔒 ⊘ pbs.twimg.com	ELW1THsUcAA3KzI?format
	GET	🔒 ⊘ pbs.twimg.com	ELRr04cUcAAEHwz?forma
	GET	🔒 ⊘ pbs.twimg.com	ELMiHoHU0AI5raW?forma
200	GET	🔒 ⊘ pbs.twimg.com	ELCO8TMUcAAUWg9?forn
200	GET	🔒 ⊘ pbs.twimg.com	EK9p-c_UEAA1sgj?format=
200	GET	🔒 ⊘ pbs.twimg.com	EK9FWfDVAAAzCgP?form
200	GET	🔒 ⊘ pbs.twimg.com	EK4gYXAUcAA63n8?forma
200	GET	🔒 ⊘ pbs.twimg.com	EKpDnNTUEAAT8G4?form
	GET	🔒 www.blogger.com	368954415-lightbox_bundl
	GET	🔒 www.blogger.com	3596687072-lbx.js
200	GET	🔒 ⊘ cdn.syndication.twimg...	profile?callback=__twttr.ca
304	GET	🔒 ⊘ cdn.syndication.twimg...	profile?callback=__twttr.ca
200	GET	🔒 ⊘ cdn.syndication.twimg...	profile?callback=__twttr.ca
304	GET	🔒 ⊘ cdn.syndication.twimg...	profile?callback=__twttr.ca

⏱ 183 requests   5.10 MB / 1.29 MB transferred   Finish: 2.08 min   DOMConter

The last 50 years have seen something marvelous. Compare
-When "we" grew up no Int, only library, barely, not even TV till I was a teenager. I
listened to Sky King and The Lone Ranger on the radio. The thot of having ANY question
answered by typing it in google blows my mind what it is doing to kids today.
-As well as we have adapted these last 50 years, if you're getting old like me, VERY
hard to navigate some these gadgets. SmartPHONES are even getting more difficult!
We need "smart smartphones" I think!!! In the race for AI and smart stuff, it has become
complex again. I feel more like a dummy every day.   It has come to this…...

                              An Internet dummy   John, how do I make a phone call?
                                                   John, how do I turn the TV on?

Voice input may solve a lot of this, but…. Many -like me- may never xtion to voice input,
but our children certainly will! But they will have NO CLUE about how this all works! At
least I, and many of us, have a clue! I am going to pass on some of those today I hope.

-Asked son to take intro computer course at UGA to learn SOMETHING about this stuff.
He has a degree in Foreign relations? My two other children are engineers!
---- I don't see any education about any of this :(

-Let's look at its origin and development of the Internet.
This will be a trip down memory lane, lots of images to
Invoke memories, with some explanations later
Intro to short course which will go into more detail

We of course started "using" it in about 1980 when PCs started appearing on the scene
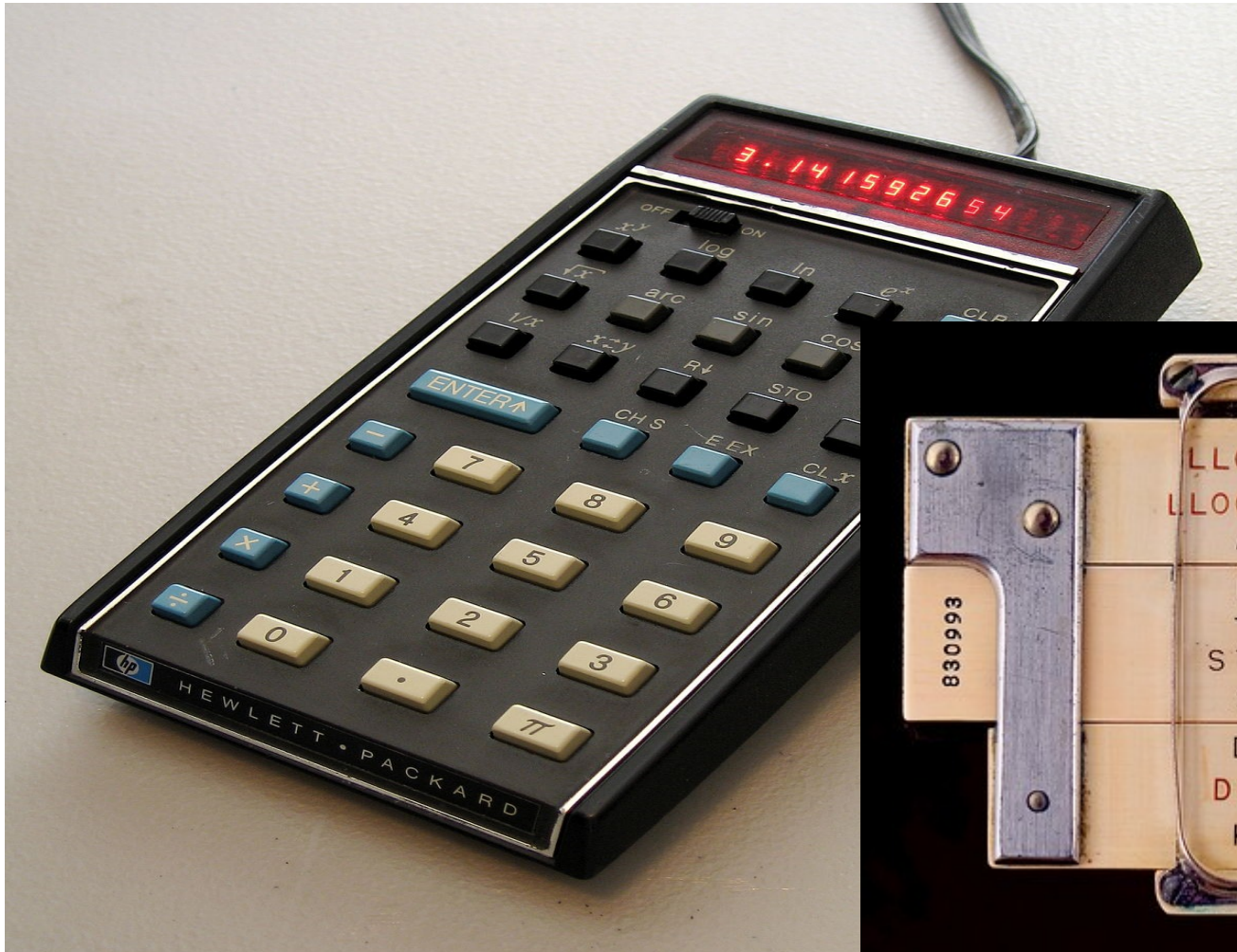-at work you were using terms to mainframes in the 70's, MAYBE late 60s if you in on it.

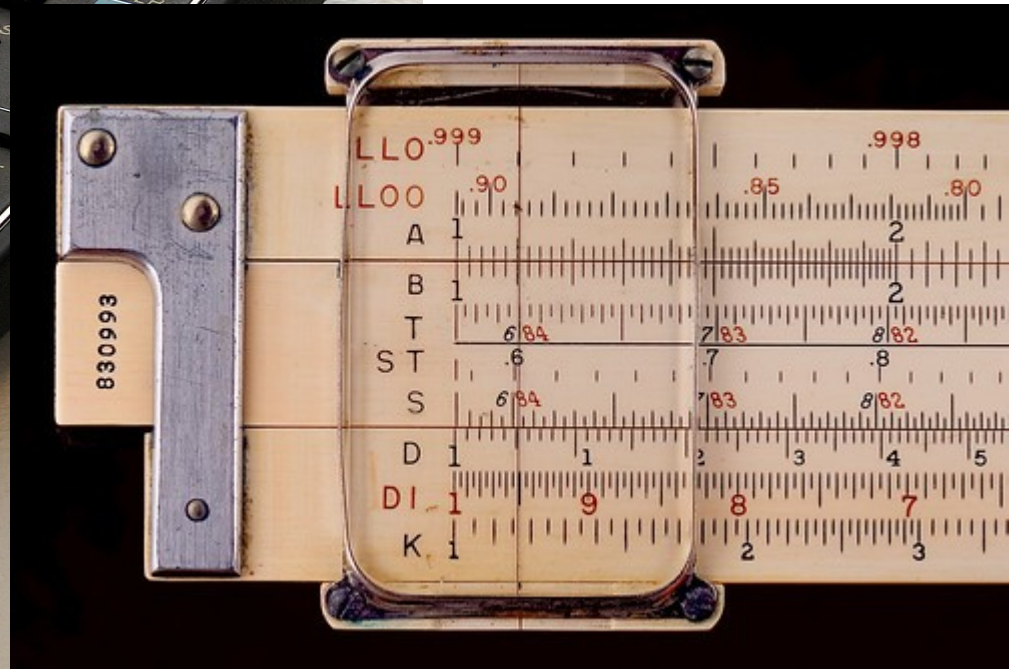A Hint of what was to come! 1972
            "four function calculators"
            1972 HP35 Scientific calculator DEATH of the slide rule
            -used "reverse polish!"
            -Simulator HP35 simulator Calculator History

What is this??

WHEN/WHERE did this all start?? --probably at school/work with "computers"

My first experience:

AT SCHOOL
EE Seminar at Stanford 1971
4004 uP presented by Intel
-forerunner of 8008 and 8080
-"first" computer on a chip
Space Invaders on Mainframe
I programmed HP 2116 to play ping
pong with the lights and switches.

AT WORK
Intel 8080 MCS
1975 – development system
--8080 assembly code
--editor
--assembler
--linker/loader → srec
--8" floppy storage
--EPROM burner

I was a digital system designer
For 5ESS. We designed processors
And code on this.

--Many of you had similar experiences

WHEN/WHERE did "networking" start?? --probably at work

Terminal with built-in modem with acoustic coupler to access company "mainframe"
TI Silent 700 -late 1970s gave us easy remote access

Many corporations had
On-site "PBX" dedicated to
Connect your modem to on-site
"mainframes"

Roomfuls of these…..

Work at work (use above sw)
Work from home in 1977
(use town central office):

Dial in ...bzzzz…
CR,CR   modemsound
Login:
Ed doc.txt, programs
--at 300 baud!! later 1200

-most people's experience of Int was this
-prob started late 1970s, early 80s
-prob at work, standalone
-word processor wordperfect, spreadsheet, DB prog
-later you connected with a modem to work
Silent700 1971 (rooms at work with silent 700s for people
Developing code for #2 or #3 ESS)
H89 1978, TRS80 1977, AppleII 1977-tape drive, IBM PC 1981
8in, 5.25,3.5in Flopppy drives, 10MB disk drives about 1983
Used term program to connect to serial port
--could you do this with BASIC OS?
Xmodem, Ymodem, kermit
Where you emulated a DEC VT100 term
-talked to a unix machine at work, ed your docs

-maybe some of you worked at comp centers
IBM 360s DEC pdp8,10,11 running unix by 1980

And **THEN AT HOME**….by Late 70's, early 80's we had "computers" connecting to a "network" to access a "mainframe" at work or public

Carterphone 1968 allowed modem connection
Modems developed by ATT for SAGE -
early 60's radar tracking. 1st commercial
Connection 1966 -they had to use voice
Network to collect data(no other way!)

Computer Center
Work -editor
Public -BB
Ftp, usenet

**H
O
M
E**

Serial RS232c

Standalone ~1980
-word processing
Modem

**PSTN
Switched
Voice
Ckt**

TI Silent700
Late 70s
Logon--
--ed doc
--troff

PDP11/70 e.g.

Our first **"network" device** was an acoustic-coupled modem

Phone Line

Remember this?…..allowed remote access to computers
Over phone lines. Still needed terminal of some kind.

Our first **"network"** was the phone system -"**PSTN**"
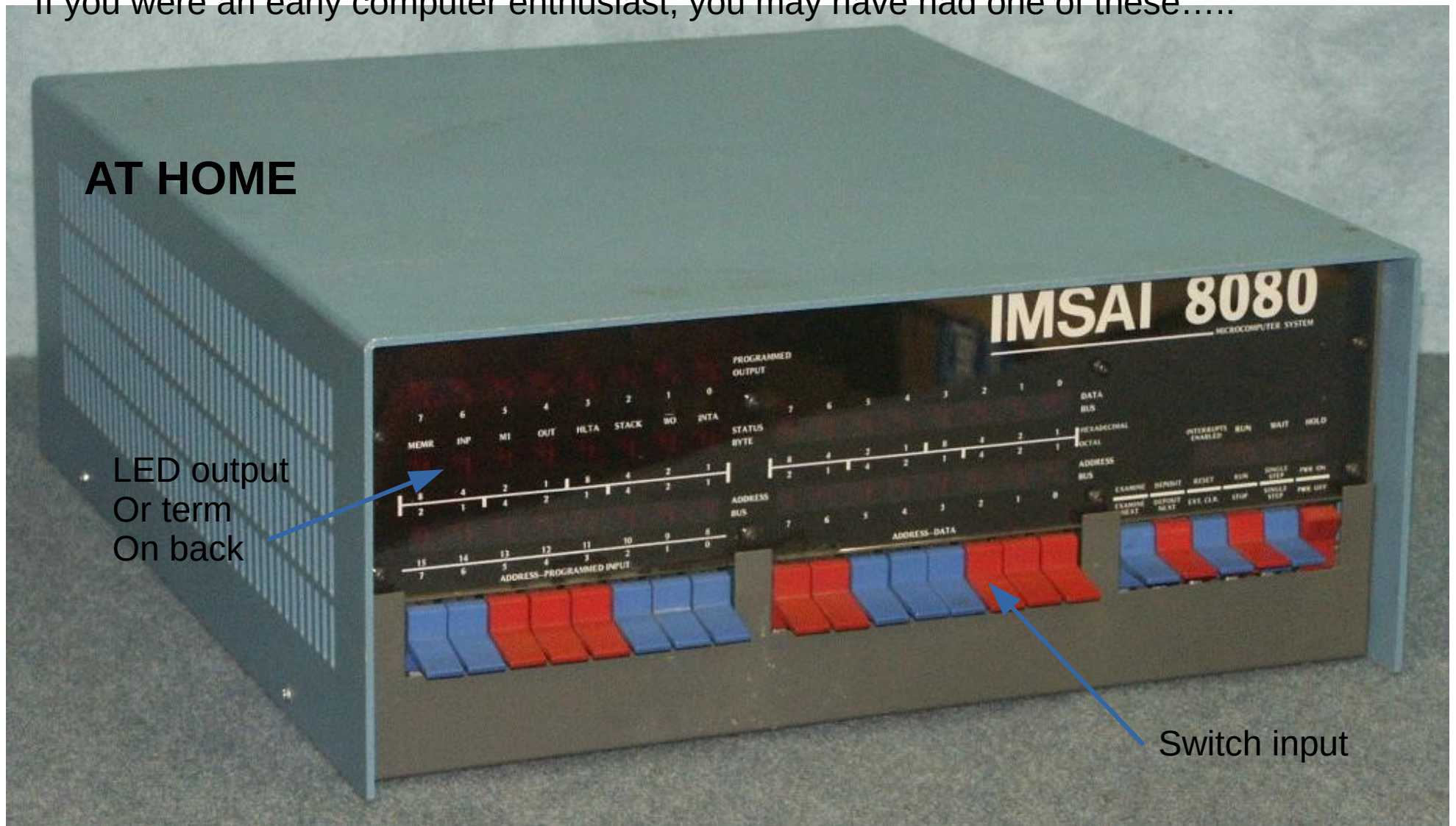   Public Switched Telephone Network
---computer data was modified to essentially make it look like voice!
      --we will talk about that

If you were an early computer enthusiast, you may have had one of these…..

AT HOME

IMSAI 8080

LED output
Or term
On back

Switch input

Many consider the IMSAI 8080 the first personal computer – intro'd 1975
S100 Bus, early "CP/M" --maybe TV as terminal

IMSAI site
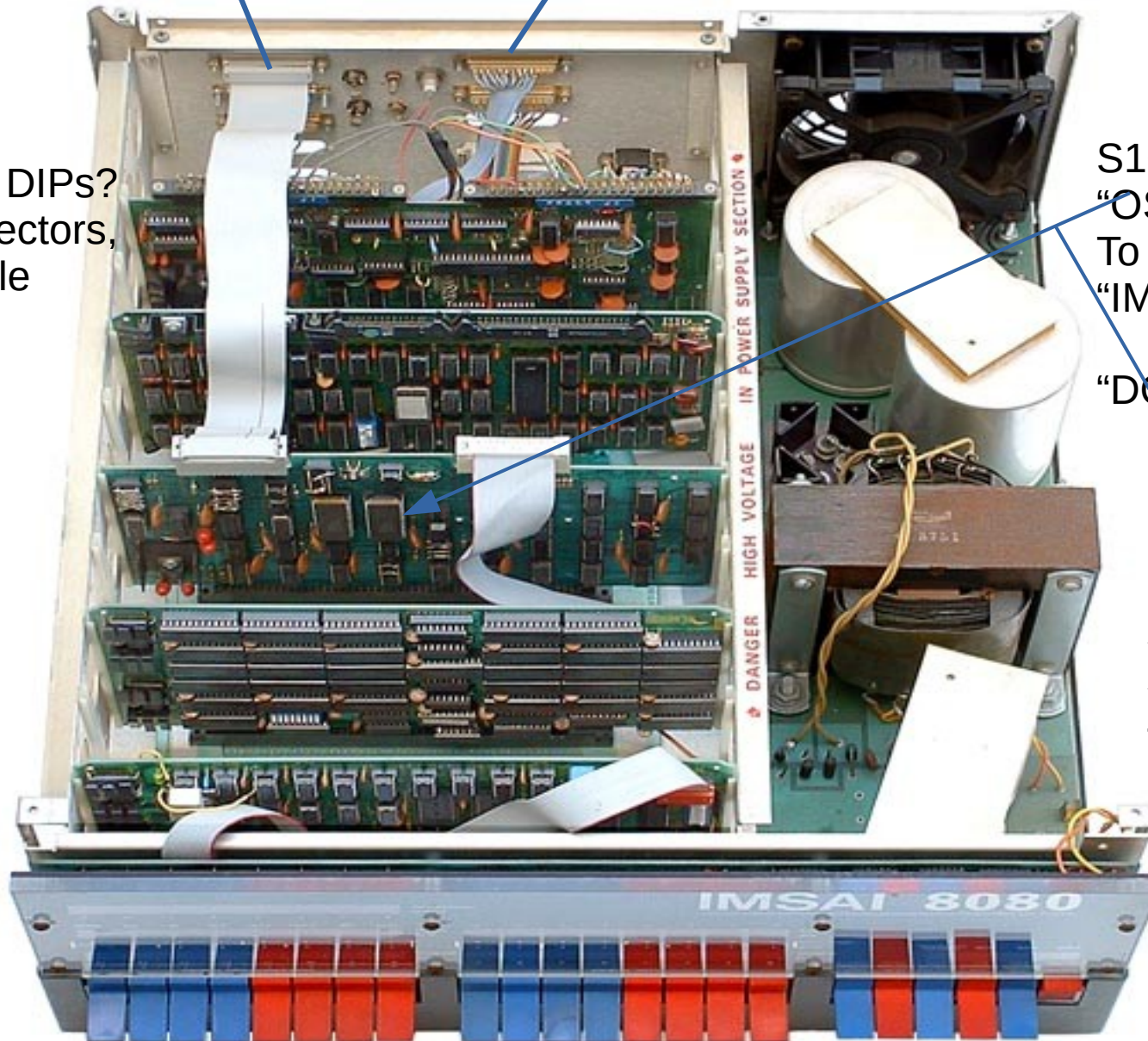
Descendant of 4004,4040,8008, TI calculators

Storage?

Terminal/Keyboard?

Remember DIPs?
DB25 connectors,
Ribbon cable
EPROMs

S100 Open Bus
"OS" was likely
To be early DOS
"IMDOS"

"DOS?"

Hint of "Open
Source
Software"
--most of
Internet today!

IMSAI 8080

Terminals/Storage were added, to give us "PC"

Later, we started to acquire "Personal Computers"
--we used them for games, WP.
We could use them to "dial in" also to work….

8in to

5.25"
Disk for
Storage

OS was usually early "DOS"
TRDOS, CP/M, DOS

Did we use BASIC to
Run a terminal program??

TRS80 1977 4KB RAM, no HD $600, DOS or BASIC OS
-standalone? Run BASIC programs NO HARD DISK –
storage was the floppies!!

Anybody remember BASIC? It's still around, like Fortran!

I was never an Apple person: could never see spending double money for this stuff :)
--so you won't get too much Apple knowledge from me [CLOSED universe]

5.25"

Apple II 1977 BASIC OS
--no GUI yet, just cmd line AppleDOS 1978

I was a DIYer!

Heathkit!!

I think I put about HALF the Heathkits
together!!
-TVs
-Receivers
-printer
-pong
-oscilloscope
-sig generators
-ham gear
-pwr supplies
-testers

5.25floppy

H89 intro'd in 1978 -add a modem and a term program 48KB RAM $2200
CPM or BASIC

But our work bought IBM PC for everybody……(such was IBM's name back then)
IBM entered game "late" ...BUT…
They introduced an open computer BUS! And standards for it.
ANYBODY could design a plugin card for bus!
--completely new paradigm, led to - OpenSSoftware
...of course the "IBM name" lent legitimacy to "Personal Computers"

5.25"

Dir
Type
Load prog
Run prog

...

IBM PC intro'd 1981 – add modem and term program PC DOS
16K RAM, OPEN architecture bus! $1600
IBM DOS, Win 3.0 1990, Win 3.1 1992 NO HARD DISK till ~1990

Apple was the first to get serious with GUIs
Famous ONE button mouse
--and of course started their "designer" computers
And OS's and CLOSED architecture!!
-even the processor was "closed" until they eventually
Switched to Intel stuff.

3.5in floppy

"Famous" ONE button mouse

Apple MacIntosh intro'd 1984 – Graphical user interface -GUI
No BUS, no way to add internally CLOSED architecture inside.

OldPCs   ← Check out old PCs

And **THEN AT HOME**….by Late 70's, early 80's we had "computers" connecting to a "network" to access a "mainframe" at work or public

Carterphone 1968 allowed modem connection
Modems developed by ATT for SAGE -
early 60's radar tracking. 1st commercial
Connection 1966 -they had to use voice
Network to collect data(no other way!)

Computer Center

Work -editor
Public -BB
Ftp, usenet

**H
O
M
E**

Serial RS232c

Standalone ~1980
-word processing
Modem

PSTN
Switched
Voice
Ckt

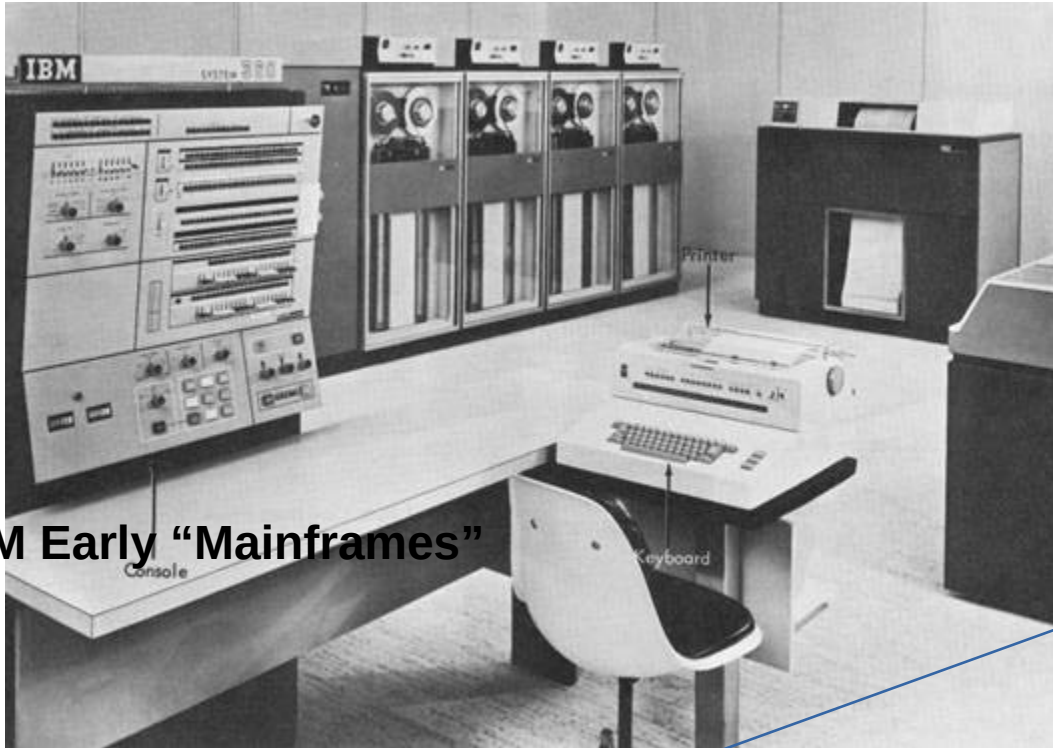TI Silent700
Late 70s
Logon--
--ed doc
--troff

PDP11/70 e.g.

Meanwhile, at WORK…… 60's into 70's

IBM introduced time sharing to their computers in 1970 or so so MULTIPLE users
Could be on at same time. It was a BATCH machine before that!
Connect modem bank to it and people could dial in! FORTRAN!!

IBM Early "Mainframes"

IBM360/195 1969 1-4MB 10^6
core memory $10M
"fancy calculators"
until time sharing OS.

Amazon
$300
3.5inches
10TB
10x10^12 bits
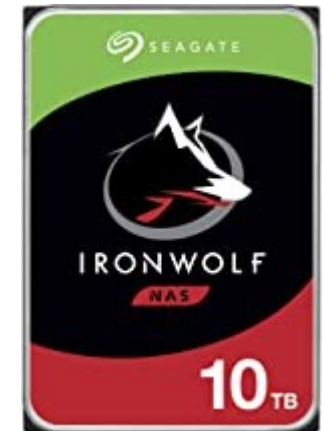
10 million million bytes
80 million million bits

Something to Think about:

1 10TB disk drive 10^13 bits can contain 1000 bytes+ about every person in
The world. Google/Gov/etc data banks may contain thousands of these drives.
There are hundreds of these data banks.. So there is no shortage of storage
For all the tracking/info -now images.
1MB = 10^6 1 million
1GB = 10^9 1 billion
1TB = 10^12 1 trillion (a million million)
1PB = 10^15 1 quadrillion

Think of a "byte" as a "letter or number"

The "other mainframe" at work/university: Unix Early "Mainframes" 70's

DEC was famous as the first REAL home of UNIX, the OS that is
STILL king – Unix/Linux/BSD.
---we won't say much about UNIX -"Operating system" that allows multiple programs
 to run. Some variant of UNIX runs on EVERYTHING! Even your TV.
 Even Apple went to BSD unix
 Microsoft Windows is still NT, you can run Linux on it!
 C compiler implemented here first to allow C programming ~1965
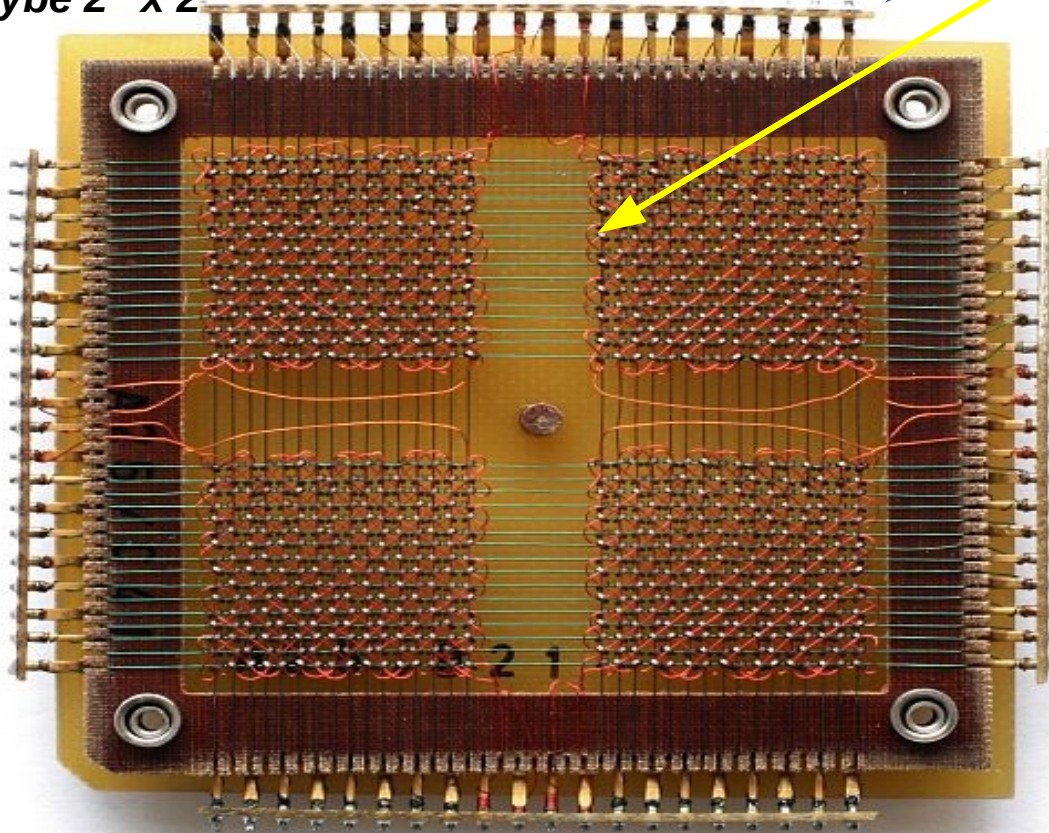 C or its derivatives is still around

1975 PDP11/70 4MB memory 16bit machine -Unix!
Time Sharing OS!!
VAX 32 bit machine

A few words about these early computers -BEFORE Integrated Ckts!

RAM -same as disk back then

-maybe 2" x 2"

1970: 128Bytes (10^3)bits
"bit" -mag core

2019: 256GBytes 4 Tbits (10^12)

SanDisk Ultra
256 GB microSDXC U1
C10 A1

9+ orders of magnitude
Increase -Moore's Law

32x32=1024 bits 1960s a density of about 32 10^3 bits per cubic foot
2020 RAM density is Terabits 10^12 bits per cubic inch. MicroSD Disk density is more

Storage History

"order of magnitude=10x bigger"

Early **Talking** to Computer Mainframes (input) -card punch deck

One line <-80 characters→ per card

---HOW many people wrote Fortran programs using these cards?

I asked Emily….
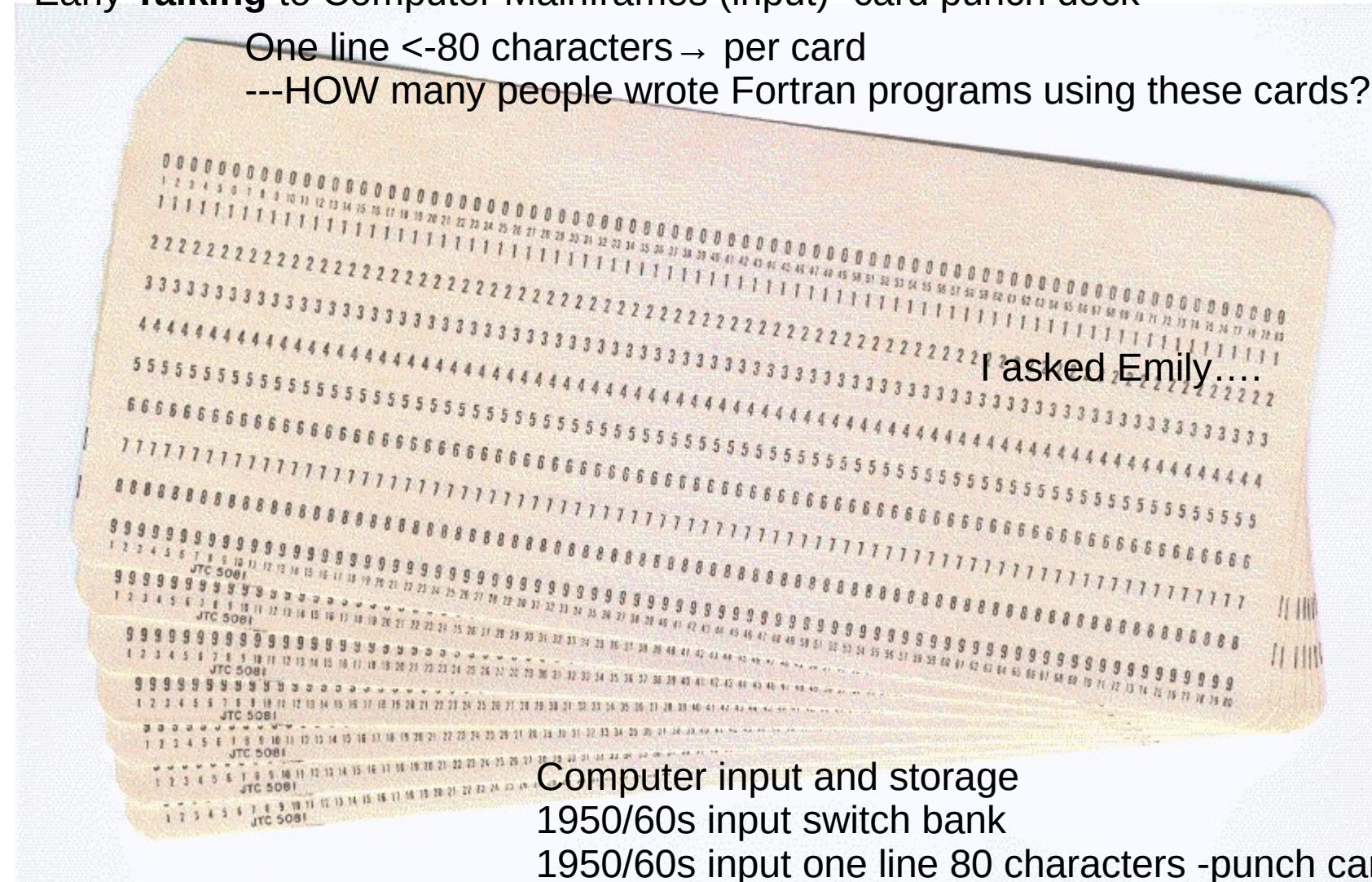
Computer input and storage
1950/60s input switch bank
1950/60s input one line 80 characters -punch card deck
1960/70s paper tape/casette
1970/80s floppy diskettes 8in, 5.25in, 3.5in 100sKBs
1990/2000s CDs 700MB
2005 DVDs 4-16GB
2010 Memsticks 4-1000GB

Card Punch Machine

Input card deck   key punch machine to create card deck

Later **Talking** to Computer Mainframes (input)

Teletype Machines -lifted from Telegram/Telephone COs

Interface to
    IBM
    DEC
    HP   RS232
    DG

DB25
Serial cable

Interface to
    IBM
    DEC
    HP   RS232
    DG

Paper tape
reader/printer

TTY Input and output device
to "talk to computer"
--universally used in telephone offices

Each row is an ASCII character
--a-d-d-r-e-g------- [program]
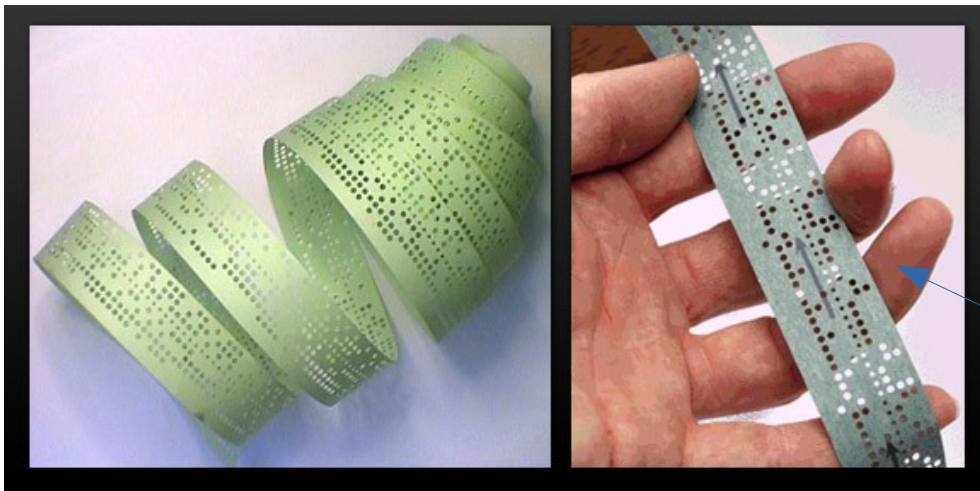
Later **Talking** to Computer Mainframes (input)   commands
Data/program input was card deck/paper tape/casette/floppy

IBM
DEC
RS232c   HP
DG

DEC vt100 terminal introduced 1978

Later **Talking** to Computer Mainframes (input)

IBM
DEC
RS232c HP
DG

19200 baud
If you were lucky!!

ADM3A terminal 1978

Output from Computer Mainframes -if not on terminal

Output likely
To be printouts!

This must be the 70's!

The Personal computers predated any "networks" -they were largely standalone devices, later connected to a "mainframe" via a serial line. Fancy calculators

You wrote programs in Fortran ….or BASIC -, command in DOS/BASIC

They were initially batch mode [one program at a time], then multiuser TSS, later unix, many programs running "simultaneously," and talking to each other. Programming techniques developed to let programs "talk to each other" [why not programs on diff computers!?]

As we have seen, we could connect to Computers using modems and the PSTN. But we had to make data look like voice to do this.

The next big evolution was a "network" to connect the computers together -let programs talk to each other *over a network.*

You need a STANDARD communication language! TCP/IP

NETWORKS to connect computers together "seamlessly"
were not seriously pursued commercially till 80's

Here is the "first" Internet [tho BBN developed it]
Internet "officially" invented in 1969, when
Programs communicated between machines
over a packet network   BBN given contract to develop IMP

Honeywell DDP516   Honeywell DDP516

SDS Sigma7

DS0 Leased Line
56Kbs

RS232
PDP

RS232

RS232

Part of PSTN

RS232

"packets"

UCLA IMP   SRI IMP

LoAndBehold
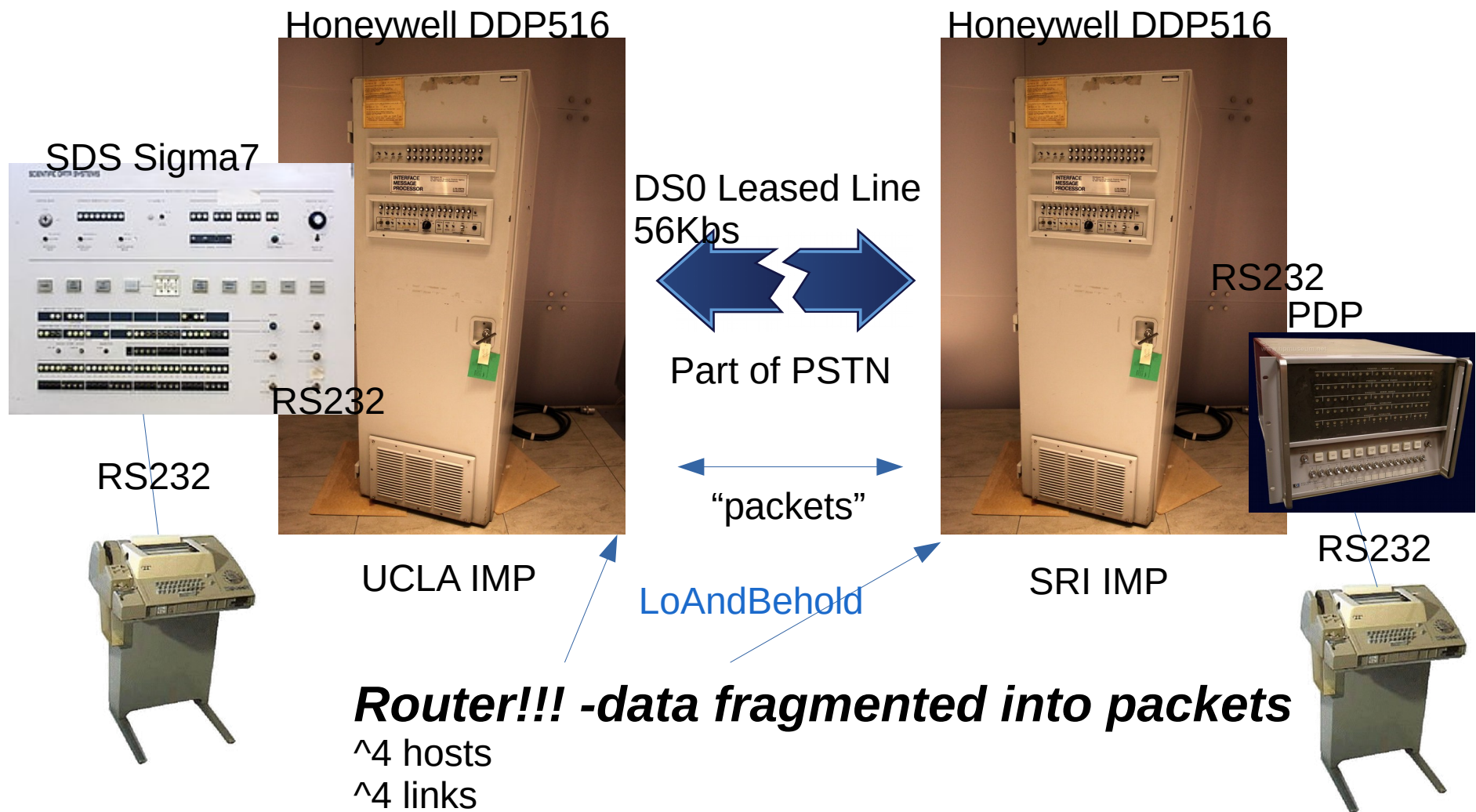
Router!!! -data fragmented into packets
^4 hosts
^4 links
--used a prestandard communication language

Important concept enabled Internet:
"Packetization" of data. Each pkt easier to get across "network"
Combined at far end back into contiguous "data"

Old paradigm used CIRCUITs – our experience 1980
1. Computer send data to modem [RS232C] 1 bit at a time!
2. Modem made data look like voice [FSK]
3. Dialup circuit to destination
4. Intervening PSTN network "switched" voice
--circuit FIXED for length of call
5. Communicate data, 1 character[number/letter] at a time, via bits
6. "transport" was digital (in analog form) using PSTN facilities

New paradigm used VIRTUAL CIRCUITS – by 2000
1. Computer created "packets" -literally like a letter -with address!
2. Computer sent packets to "router" [could be over modem :-)]
3. Intervening router "switched" packets
(according to Destination IP address) **IP ADDRESS!**
4. Communicate data, 1 packet at a time.
--circuit was VIRTUAL for length of TCP session
-LITERALLY like dropping a letter in the mail!
5. "transport" was digital, could be old PSTN digital facilities
---this could be "simulated" over modems

And it looked like this in 1973
--military and academic institutions and contractors

ARPA NETWORK, LOGICAL MAP, MAY 1973

"TIPs" are term access nodes
-allow modems on ARPAnet

Prob 1.544Mbs
All copper

USER

No fiber Anywhere!!!!

Lines are Transport
-leased/switch PSTN lines
Ellipses are Computers
Squares are "Routers"

RS232c
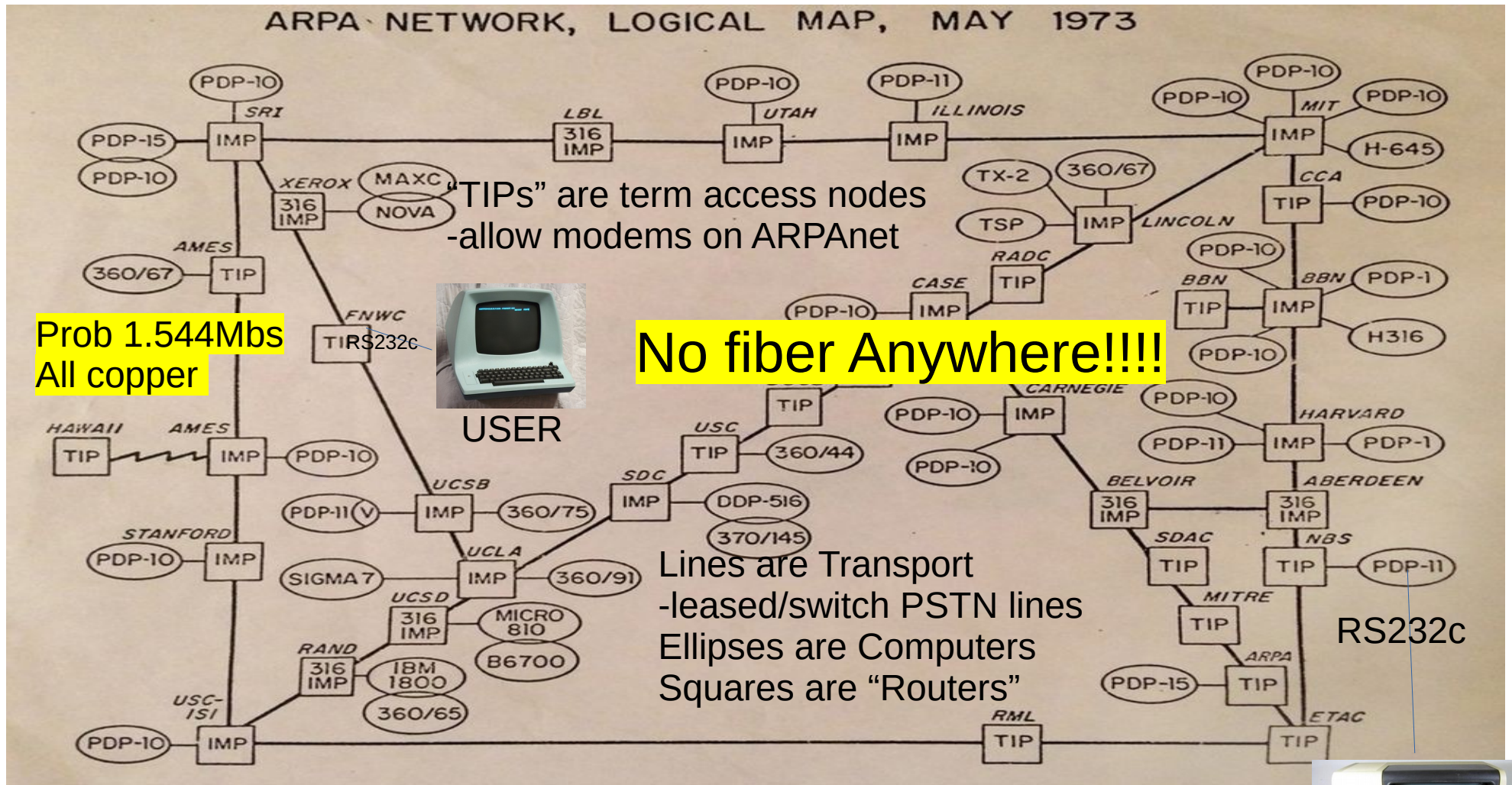
Neat Link

VoxMap

Routers!!! move packets around
Black lines are often T1 DDS ckts
Routers at endpoints -none in "network"

OPERATOR

IMP is that packet router
TIP is IMP used to connect simple terminals
-ellipses are computers -IBMs, DECs
-Lear Siegal [as replacement for TTY] into'd in 1976 cranked those to 19200
-we must have had 100 of these things sitting around!
-- it was a STRAIGHT RS232C serial connection to the computer
--RS232C was how you connected to computers before ethernet.
--these still exist as the serial port on your PC [tho you willlook in vain to find them
On many new computers [need usb dongle to get one]
--virtually ALL complex gadgets still have an RS232C ifce as a backup access.

The black lines are the transport, which was largely dialup and leased DDS lines
Using the phone PSTN network! Mostly 1.544 Mbs [maybe nx64kbs] rarely 44Mbs
-There was NO Internet transport yet, I.e packet based
-nothing that "knew" about packets IN the network.
-DEDICATED ckt for the transport of the packets. Just BITs to the circuits.

It was **decades** before the 1973 Internet became "today's Internet that offloaded
The data traffic (packets) from the PSTN
-analog transmission became digital
-physical facilites xtioned from air/copper to fiber
-speeds on dig facilites increased from 1.5Mbs – 10?gbs/Tbs 1000 fold increase
-SONET fiber transport std
-wavelengths multiplexed on the fibers increased it firther
-cellular/wifi speeds

Routers are needed to switch/process IP packets.

TCP/IP officially adopted Jan 1, 1983 – entire "Internet" switched -overnite!

We can look ahead before we look back…...

Transitioned to ARPAnet and the NSFnet, and then commercialized 1992
--6000 networks were connected to this backbone by 1992

NSFNET T3 Network 1992
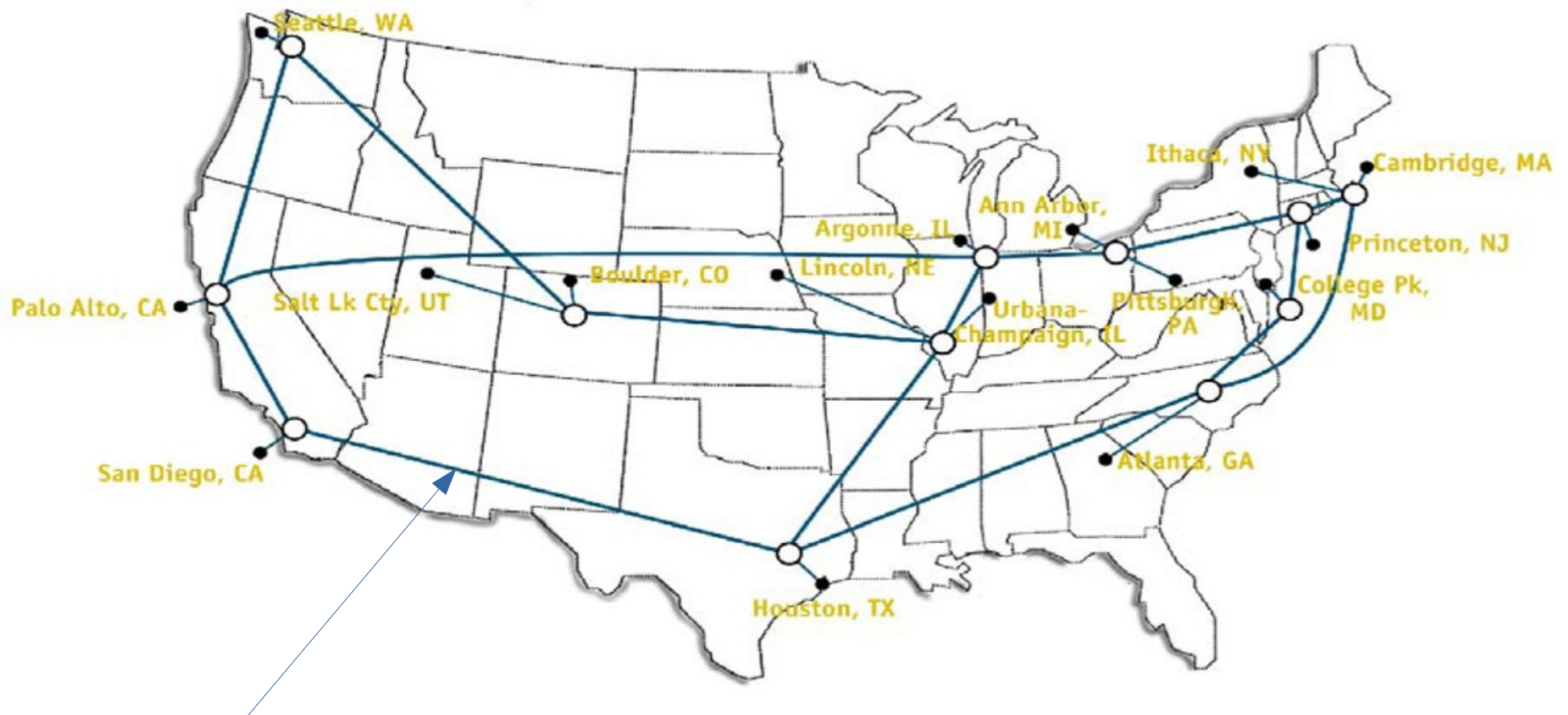
Lines are DS3 (45Mbs) not DS1 (1.544Mbs) PSTN leased lines mostly

By 2000 private networks provided backbones

This is just SE Windstream ISP -tho they may lease facilites from other carriers!
ILEC CO: CO; POP: Point of Presence

PeeringDb

VoxMap

https://he.net/ip_transit.html

Legend

Active POP

Windstream ILEC CO

Core Network Access Point

New Regional Network (Active)

Regional Network (Active)

Regional Network (In-Progress)

Regional Network (Un-Lit)

Core Network Active

Core Network In-Progress

Future Core Network

ILEC
Incumbent Local
Exchange Carrier

DIA POPs

There is NO PSTN in this picture…. Tho these links may use
Leased PSTN digital facilities and Data network equipment may
Often reside in PSTN Cos (esp ISPs like ATT, Verizon, Centurylink)
Which offer Data services as well as PSTN services

- **Shannon** developed "information theory" -coding, PCM followed
--Analog voice could be "represented" by digital coding
PSTN [Bell Labs] invented digital transmission systems
-T1/DS1, DS2, DS3 1961! 1.544Mbs/6.1Mbs/44Mbs
-Sonet 155Mbs/622Mbs/2.4Gbs 198
              10^6   10^9

Back to the **Network** .
-Precursors of the network protocols used to to implement "data communications"
-Telephone (PSTN) circuits used to connect them
-"digital" telephone circuits were just coming online
(digital revolution in telecommunications predated general computing)

10^15 is Petabit/s or 1000TBs
FiberOpticsFutures

For a sense of the numbers, consider a recent fiber system by Ciena Corp., a Hanover, Md.–based company. The system can transmit 96 channels, each carrying 100 Gb/s, across hundreds to thousands of kilometers. All together that amounts to 9.6 Tb/s— enough for 384,000 people to stream Ultra HD from Netflix. And that's just one fiber; today's fiber-optic cables can carry anywhere from about a dozen to several hundred fibers.

10^12bs =1Tbs
100GBs
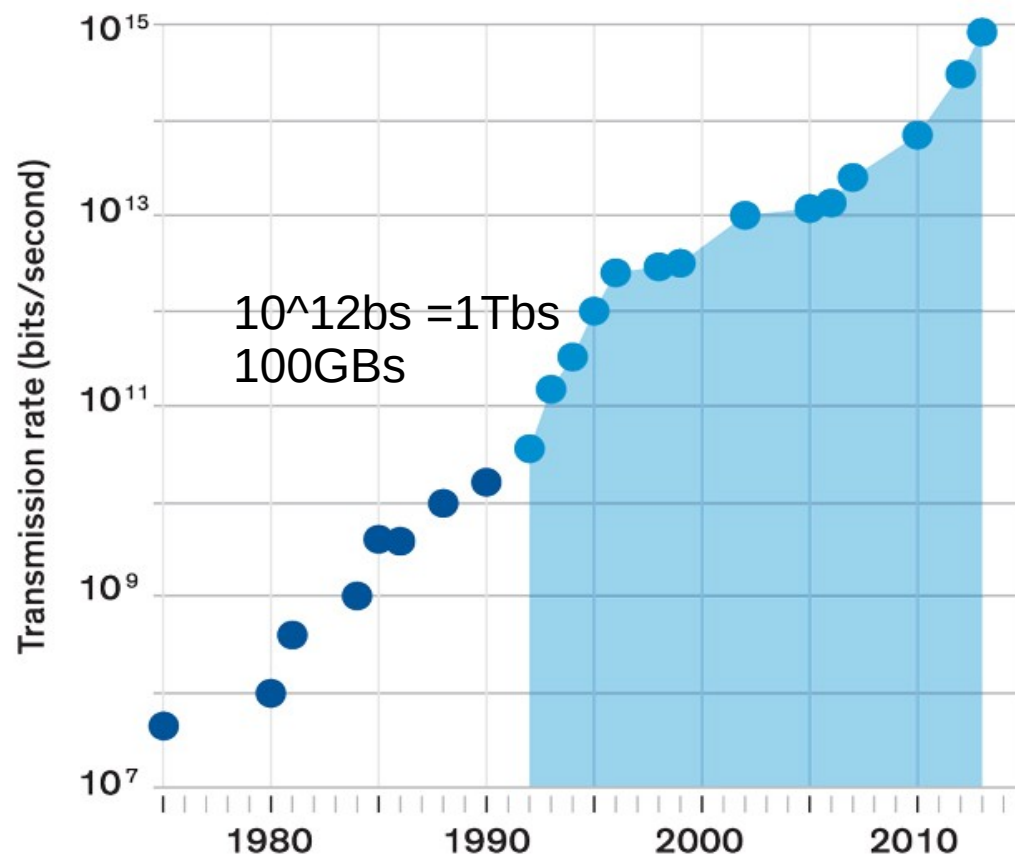
We have to take a detour first….. the phone network will be the first "network"

But what is this "PSTN" ?

Public Switched Telephone Network "Ma Bell" prior to 1984
-Leonard conveniently neglects to mention it!
-"Monopoly" on voice communications Local & LD
-Switched nationwide VOICE Network, envy of world in 1960s
-Also offered Leased [not switched] transport
-Direct Dial using pulses/dial tones to signal
697 Hz + 1209 Hz was a "1" ;941 + 1477 was a # ; 941+1336 was a "0"
-used simple wire pair in the loop "POTS"
-battery provided by PSTN -48V
-connect only "phones" to network, or "spec ckts" via leased lines
-voice frequency xport 100-4Khz

Anything connected to switched PSTN:
--had to "look like voice"
--signalled using pulses/dial tones

Thus "modems" used by computers:
– upstream 1 and 0: 1270 and 1070Hz
– downstream 1 and 0: 2225 and 2025Hz
--FSK, PSK, QAM, 300bs → 56Kbs, 1960s→ 1990
– user signalled in normal way, or via Hayes set
– modem used in SAGE, 1958,59 [earlier "versions"]
– Bell 103 modem intro'd in 1962 [special DD, ARPA]
– 1977 Hayes modem

Let us recapitulate in pictures

Millions of miles of copper   Thousands of COs   Hundreds of Toll Offices

Structure of the PSTN

CPE   **Local Loop**   **Backbone, or Core Network**

Individual User Station Lines, or Extensions

PBX

Local Exchange Trunk

Interexchange Trunks

International Gateway for routing calls between countries

Subscriber Line

Each CO or Toll Office is a voice switch computer

Toll/Transit Switch (Class 4) for routing calls to or from other cities

Residential Service

PBX

Local Exchange Trunk

Tandem/Junction Exchange: for routing calls between local exchanges within the city

Subscriber Line

Local Exchange, Class 5 Switch, Central Office

Tandem Trunks

CentralOffice

COBldgs

Hundreds of thousands of miles of transmission facilities

PSTN Transmission facilities offered for [non switched] lease

Brooksville CO
--you can always tell with no windows!

Listing Updated:

July 2014

Operating Company:

**at&t/BellSouth/
Southern Bell**

CLLI:

BKVLFLJFDS0

Switch Type:

Alcatel/Lucent 5ESS

Prefixes Served:

**(352) 540, 544, 754, 796-
7, 799, 848**

Notes:

Source: Larry P
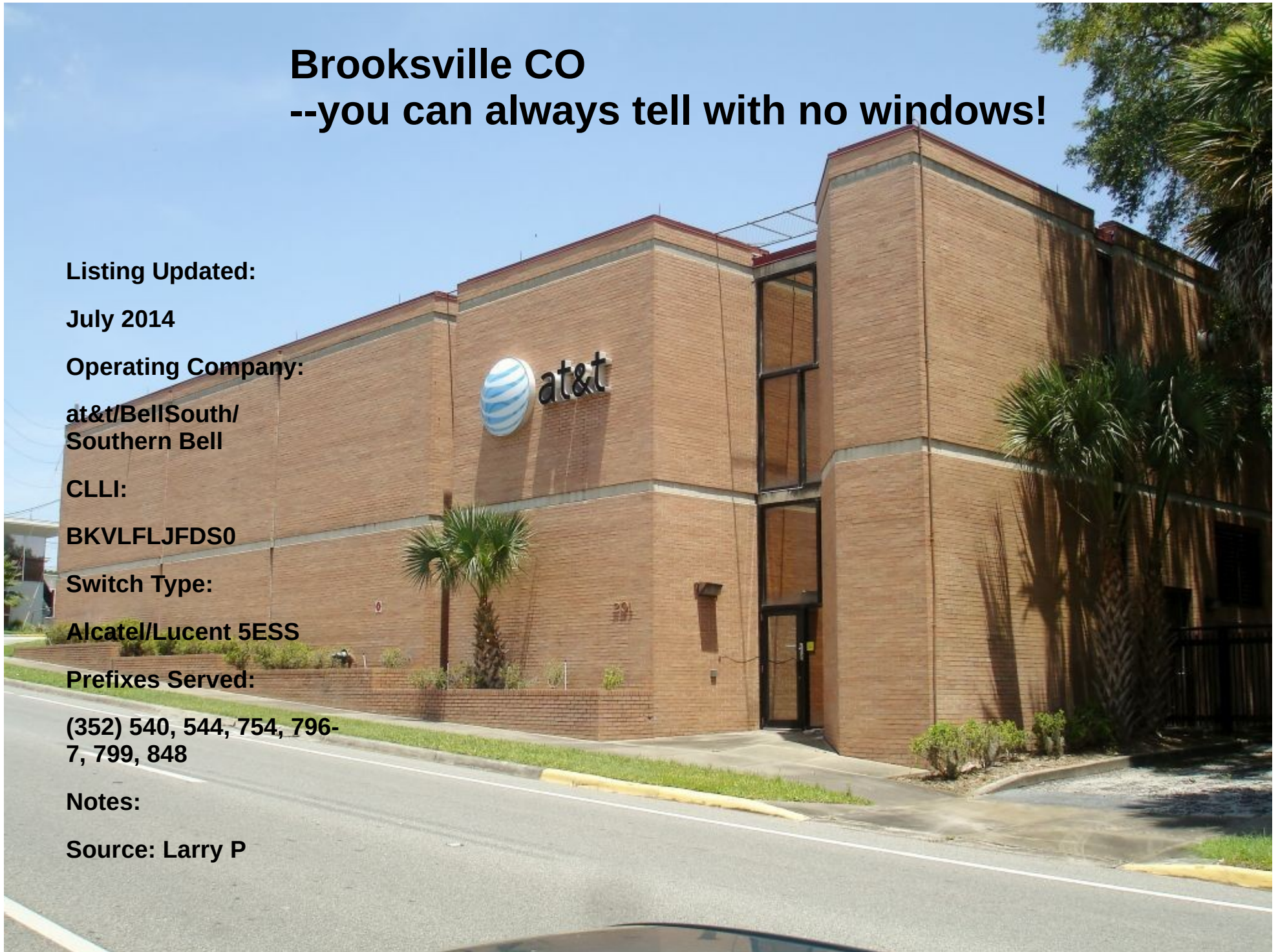
PSTN enabled VOICE calls made on "Telephones" to be connected,
Almost universally
-US Dial up network of "Ma Bell" and some independents was the
Envy of the world.
-voice only
-use "Ma Bell" approved device only
-no special tones or anything which might interfere with control
-special research labs dedicated to Telecommunication
transport/switching: Bell Labs
(just like Computer Processing had IBM Labs)

Two separate worlds were about to collide!!
Computing and Telecommunications →
        Data Communications

We need a network!! -and all we had was a VOICE network!!

And Voice traffic DID NOT LOOK like computer (data) traffic!!!!
---but we made data traffic LOOK like voice and shoved it onto voice network
---for SEVERAL DECADES!

There are probably millenials and certainly generation X people
WHO DON'T KNOW WHAT THIS IS!!

You can actually buy this on amazon!
---and I THINK you can still do a rotary dial!!!!! call
--doubtful on cable….. and VoIP

Of course these "COs" were used to switch telephone calls
using "phones" – predated "smartphones" of course!!
Prior to 1984 you had to get your phone from "Ma Bell" -
There were only a few designs and colors

I had to include pictures of a "phone" - they are becoming like
Slide rules – nobody will know what they are in a few more years!!
(someone under 20 may not know today!)

They probably recognize a TT keypad?

Used to be:
Power supplied from CO,
So you could be without
Power at home and still
Make phone calls….

I was going to say….. you need to buy one of these at the thrift store so you will
Have a phone when the power goes out…. BUT with cable and "VoIP" [you need
power for these] and esp Cell phones, this is increasingly less useful! [good reason
To have a UPS on your cable/ADSL router!!]

The cell phone is now the emergency vehicle [keep it charged!!!!!]
---have you tried getting the "phone co" to repair your voice line lately???
The rest of the [at least] third world runs on cellular – no landlines!!
The US was all landline in 1990. It may be all cellular by 2030?

"Remote Switch" Telephone and ADSL interfaces

Each card terminates
A number of phone
 lines

Splits Voice/Data

"Inside" a Remote
Switch

CABLE VAULT

MAIN DISTRIBUTION FRAME

FRONT OF
MAIN DISTRIBUTION
FRAME

VOICE SWITCHING COMPUTERS In the Central Office

"Internet" -as we used it- worked over switched PSTN for many years!

-up till almost 2000

We forced data to "look like" voice

Remotes

Local Central Offices

Toll Offices

Signal (dial) ->

Computer Center

Structure of the PSTN

CPE Local Loop Backbone, or Core Network

Interexchange Trunks

Individual User Station Lines, or Extensions

PBX

Local Exchange Trunk

Subscriber Line

Residential Service

PBX

Local Exchange Trunk

Subscriber Line

Local Exchange, Class 5 Switch, Central Office

Tandem Trunks

International Gateway for routing calls between countries

Toll/Transit Switch (Class 4) for routing calls to or from other cities

Tandem/Junction Exchange: for routing calls between local exchanges within the city

Computer centers used PSTN DDS DS0+ leased lines for inter communication

Ma Bell was very reticent about carrying data traffic over its VOICE network

Uncontrolled CPE phones, modems, nerd-things
Tones of computers could interfere with in-band signalling
-Remember Don Draper, Kevin Mitnick "cap'n crunch"
NAILED up connections DESTROY traffic engineering

BUT....
Signalling was transitioning to Out-of-Band
Entire Switches added for datacomm traffic
Transmission facilities going digital
DDS services

SO-- → Divestiture - 1983

CPE owned by customer
"Demarcation" point – NID defined
Local split into 7 regions -Baby Bells
Long Distance Separate company -ATT
--first competition was in LD -MCI

"phone" interface
[CenturyLink here]
If you are cable
This box is not used at all

Telephone NID

Telco ← → Homeowner

Dial remote computer,
Connect handset to
Acoustic coupler, go to
Your terminal/PC

1070Hz tmt 0
1270Hz tmt 1
2025Hz rcv 0
2225Hz rcv 1
FSK

Original Bell 103 modem 300baud intro'd 1962

Modem program on PC: xmodem,ymodem -uses Hayes cmd set (or GUIs later)

RS232c serial cable to PC serial port

Hayes command ex:

ATDT15551234

Dialed Tele #

Plug-in card for *Open Bus PC*

RJ11 phone cable

shared

PSTN

Hayes smartmodem 1981 300baud   Later PC card

Most all modems implemented the "Hayes" command set PC talks to modem via this command set

300, 1200,2400,4800,9600,14400,32000,56000 baud speed progression

WHO remembers working at 300baud!!!???

I did many a circuit design over 1200 baud using a primitive
Graphics program to "draw" digital circuits.

The dialup capabilities are STILL important as the **backup**
Communication medium for a LOT of devices!!
You will find modems connected to many routers allowing
Remote access over the phone (PSTN) lines – no data
Telecomm is needed.

REMEMBER we are still making data look like voice here!

BINARY!!! "1" or "0"

RS232 PC-modem

ASCII 255
011 0010 011 0101 011 0101
0x32 0x35 0x35
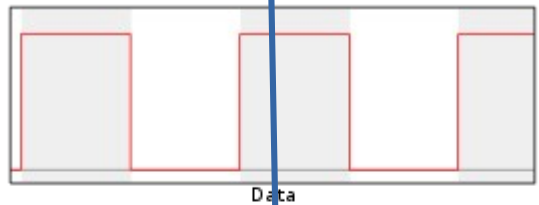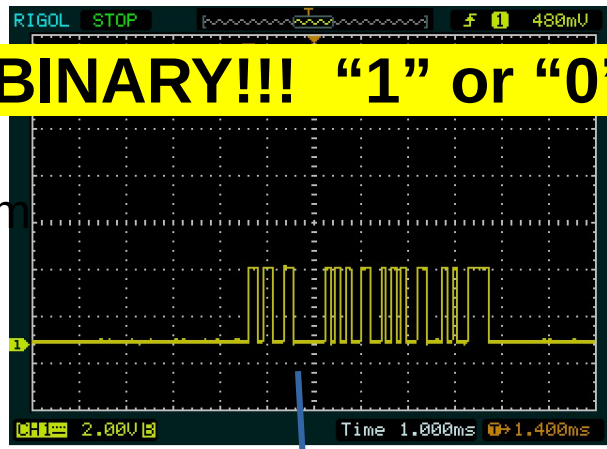
USASCII code chart

STILL BINARY!!!

FSK Modem-PSTN

THESE are '1's" and "0's"

b4 b3 b2 b1	Row	Column 0 (000)	1 (001)	2 (010)	3 (011)	4 (100)	5 (101)	6 (110)	7 (111)
0 0 0 0	0	NUL	DLE	SP	0	@	P	`	p
0 0 0 1	1	SOH	DC1	!	1	A	Q	a	q
0 0 1 0	2	STX	DC2	"	2	B	R	b	r
0 0 1 1	3	ETX	DC3	#	3	C	S	c	s
0 1 0 0	4	EOT	DC4	$	4	D	T	d	t
0 1 0 1	5	ENQ	NAK	%	5	E	U	e	u
0 1 1 0	6	ACK	SYN	&	6	F	V	f	v
0 1 1 1	7	BEL	ETB	'	7	G	W	g	w
1 0 0 0	8	BS	CAN	(	8	H	X	h	x
1 0 0 1	9	HT	EM	)	9	I	Y	i	y
1 0 1 0	10	LF	SUB	*	:	J	Z	j	z
1 0 1 1	11	VT	ESC	+	;	K	[	k	{
1 1 0 0	12	FF	FS	,	<	L	\	l	|
1 1 0 1	13	CR	GS	-	=	M	]	m	}
1 1 1 0	14	SO	RS	.	>	N	^	n	~
1 1 1 1	15	SI	US	/	?	O	_	o	DEL

Data

Carrier

Modulated Signal

We will talk about 1's and 0's in a bit....

This is what appeared on the phone line

Slight digression…………...

Nothing much will be said about cellular/cellphones
--they are "just" "wireless" versions of our wired lives.

The cell towers just "connect" into "COs" like reg phones

--bandwidth in the "air" is still more precious than on cable
--There is ONLY ONE medium for the air, whereas there
Is a medium for EACH cable or fiber -important distinction -fiber will always be with us!

--VERY important distinction between "air" and "wire/fiber/laser"

NONEtheless, our consumer access world is turning into a
mobile wireless world alas!!   ----I say "alas"
But the INTERNET core is all wired/fibered! [cept for satellite stuff]

Have you heard about Musk and Bezos satellite BBand?   MuskBezosSatellite

The third world literally skipped a generation – there are few wired
Networks, they are all Cellular!!!

Divestiture -Split Ma Bell to foster Competition in Datacom/Telecom

AT&T "MA BELL" and the 22 operating companies
Prior to 1984. (included long distance)
Included:
Bell Labs – Research -voice switching/transmission
-telephone computers
Western Electric – Manufacture

PACIFIC NORTHWEST BELL TELCO

BELL TELCO OF NEVADA

THE PACIFIC TEL AND TELCO

THE MOUNTAIN STATES TEL AND TELCO

NORTHWESTERN BELL TELCO

WISCONSIN TELCO

MICHIGAN BELL TELCO

ILLINOIS BELL TELCO

INDIANA BELL TELCO INC

CINCINATTI BELL, INC.

THE OHIO BELL TELCO

NEW YORK TELCO

THE BELL TELCO OF PENNSYLVANIA

SOUTHWESTERN BELL TELCO

SOUTH CENTRAL BELL TELCO

SOUTHERN BELL TEL AND TELCO

— NEW ENGLAND TEL AND TELCO

— THE SOUTHERN NEW ENGLAND TELCO

— NEW JERSEY BELL TELCO

— THE CHES AND POT. TELCO OF MARYLAND

— THE DIAMOND STATE TELCO

— THE CHES AND POT. TELCO (D.C.)

— THE CHES AND POT. TELCO OF W. VA.

— THE CHES AND POT.TELCO OF VIRGINIA

Fig. 1-4. Operating Companies of the Bell System

From p. 9 of the 1977 edition of Engineering and Operations in the Bell System

Upon Divestiture 1984 – 7 ILECs +Bellcore (divested Bell Labs)
ILECS had Long Distance only within their region
ILECS had to use a LONG DISTANCE CARRIER to exit region
Competition was in Long Distance, and then CLECs

--there were always independents around!!

WHO remembers Divestiture??

USWest

USWest

Nynex

Ameritech

PacificTelesis

ATT

BellAtlantic

SouthwesternBell

MCI

BellSouth
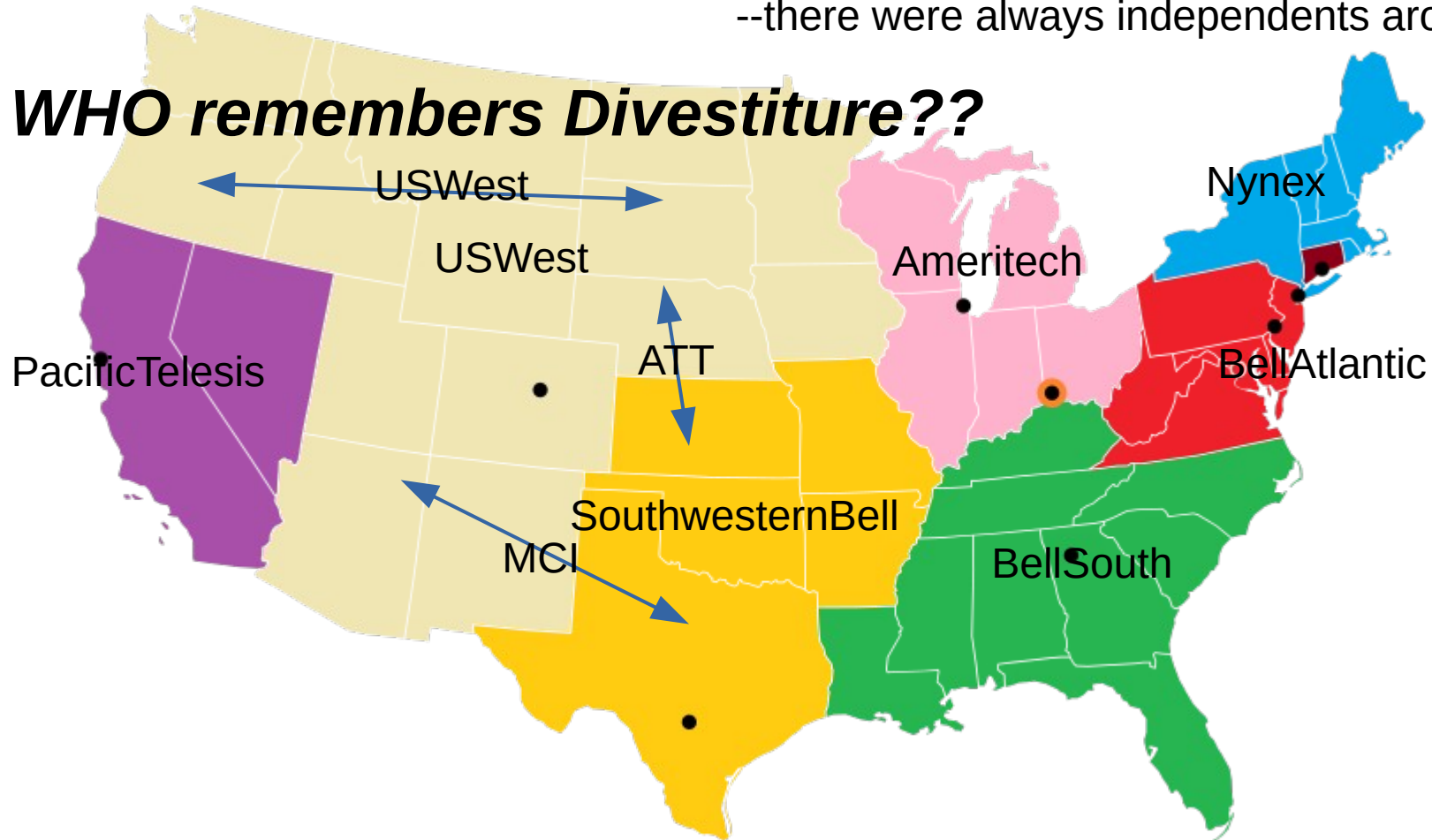
Upon Divestiture in 1984: 7 Regional Bell Operating Cos (RBOCs, ILECs)
Long Distance BETWEEN RBOCs was AT&T or competing co, such as MCI, others
MCI started this whole thing (Divestiture) by building microwave towers to BYPASS AT&T
Long distance monopoly.

About 10 years later, after explosion of DataCom, computing, Telecom

Southwestern (SBC) started to put "Ma Bell" back together as the telecom/datacom
Industry experienced exponential growth in the 90s. Renamed themselves ATT.
Added cellular, even media companies. LOTs of other competition by then!!

AT&T Corporation
RBOCs grouped into "Baby Bells" split off in 1984

Included BellLabs,WesternElectric,Long Distance

1984

| BellSouth | AT&T Corp. (non-LEC) | Ameritech | Pacific Telesis | Southwestern Bell Corp. (later SBC Communications) | Bell Atlantic | NYNEX | US West |

1997

1999

| GTE Corporation (non-RBOC ILEC) | Qwest (non-ILEC) |

| Verizon |

2005

| AT&T Inc. (former SBC) |

2006

| CenturyLink (non-RBOC ILEC) |

DirecTV,TimeWarner ->

People still scream at "monopolies"

| AT&T Inc. | Verizon | CenturyLink |

CableCos!

No hope of cable
Co history!! ATT owns
TW now

No "monopolies" as such remain…. BUT "monopolies" of "tech" remain
Typically, wireline, cable, cellular, satellite can all compete, but…..
Only ONE cable carrier, ONE phone carrier typically because of cost of infrastructure
So cellular, satellite have "NO" infrastructure, compete globally, but air is not like wire!!

As final comment on last few pages….. whoever thot the networks would explode like this. Incredible offerings and infrastructure… Cannot keep track of the commercial Internet world

But should mention ILEC/CLECs initial broadband offerings, quickly outdated!
 ISDN introduced by ILECs CLECs 1990->
 Incremental bit rates nx64kbs over existing lines with
 New terminal adapters
 Largely supplanted by ADSL by 2000

ISDN telephone

T-interface
Nx64kbs coding

INTERNET

X.25 NETWORK

PC

Existing LAN Server

ISDN Router and NT-1

Digital ISDN-Dialup to Pacific Internet

Hub

Nx64kbs available

PC

Telco ISDN Network

PC

PC

Wall-Jack
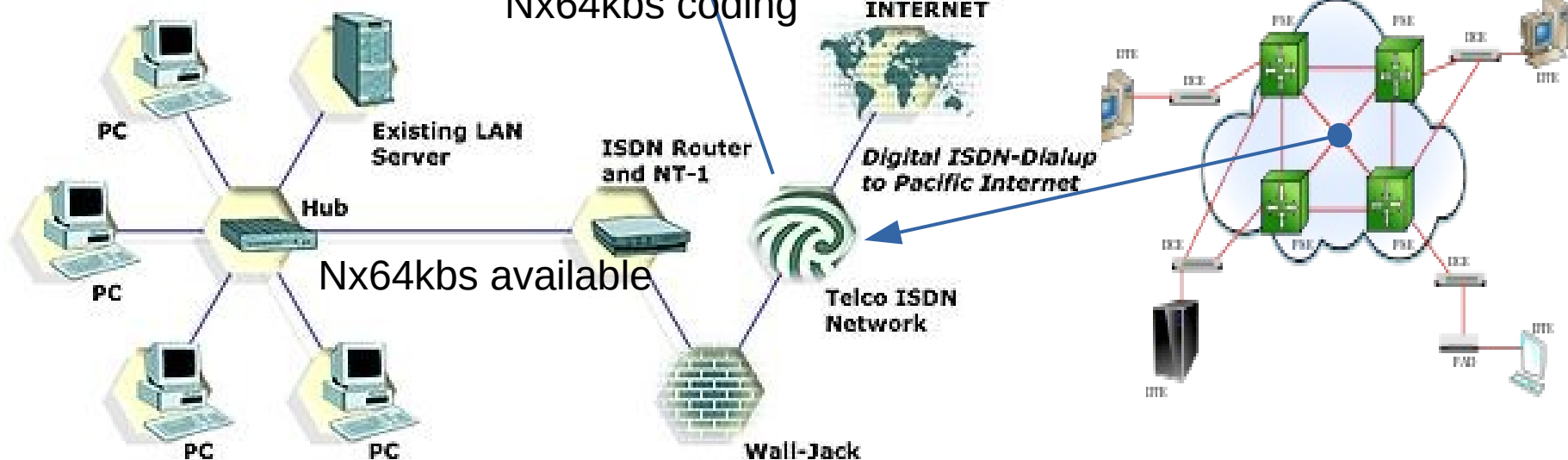
A prettier picture of "present day" architecture

Customer Loop "POTs"
--plus data
OR think of the FAT cable if cableco

VOICE

Central Office

PSTN

Copper Infrastructure

CO located Electronics

Existing PSTN

VDSL/VDSL2

ADSL2plus, with bonding

Home Gateway

Ethernet Switch
7450 ESS
7750 SR

7330 ISAM
FTTN

DATA

"Internet"

Gigabit Ethernet

Alcatel 7330 ISAM FTTN
> Extended temperature
> Line powered
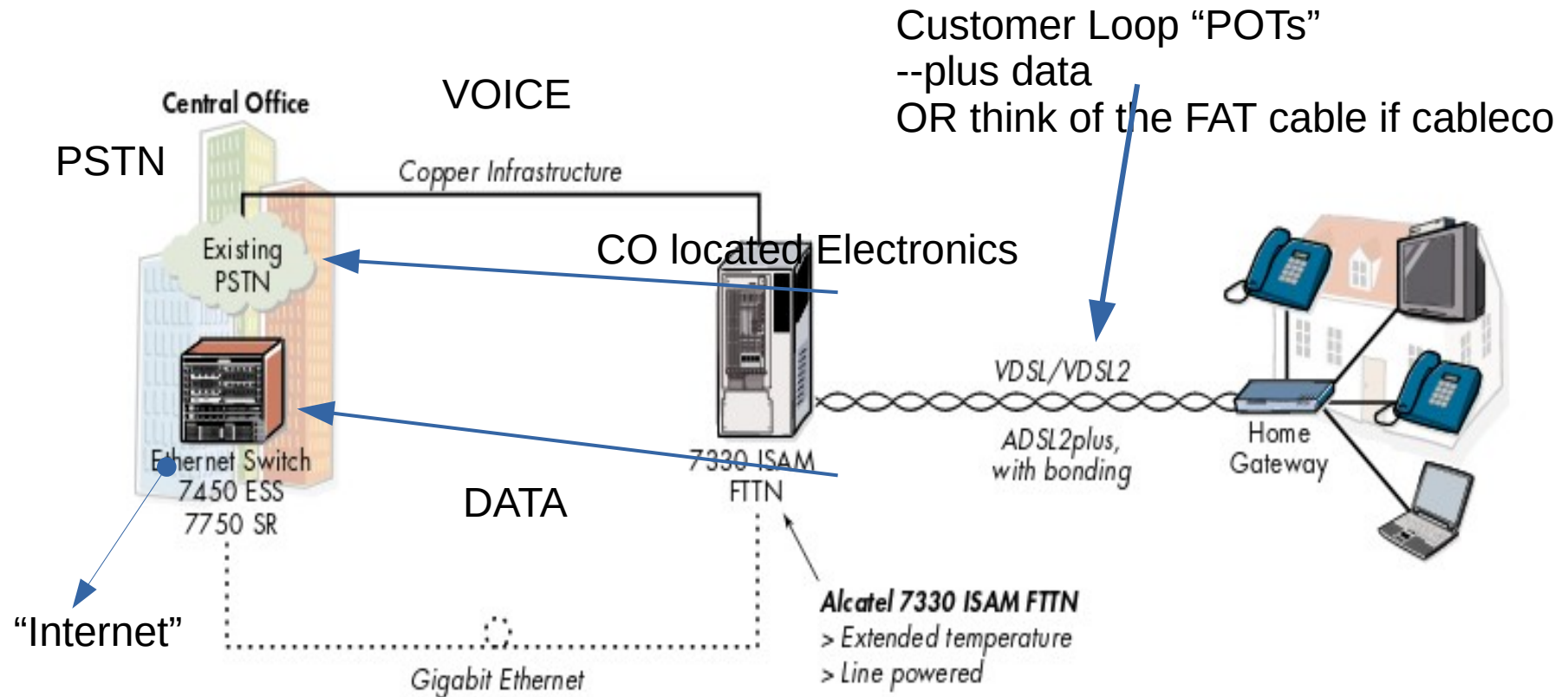
"Internet" started to split from PSTN in 1990s – used PSTN digital facilites to link "routers" to support packet transport [NOT voice transport!]
ISPs started created their own networks with fiber/routers

Internet Transport Getting Split from PSTN by 1990
--Routers routing IP packets over digital facilities, likely located in COs
--TCP/IP pretty well standardized by 1984
-your PC could talk to "ANYONE" "ANYWHERE" using IP packets

What do you mean "Routers route packets?"

**What do we mean by
        "Your PC could talk?"**
---ROUTERS and TCP/IP!

Routers & [ethernet] switches
In ISP/Internet "COs"
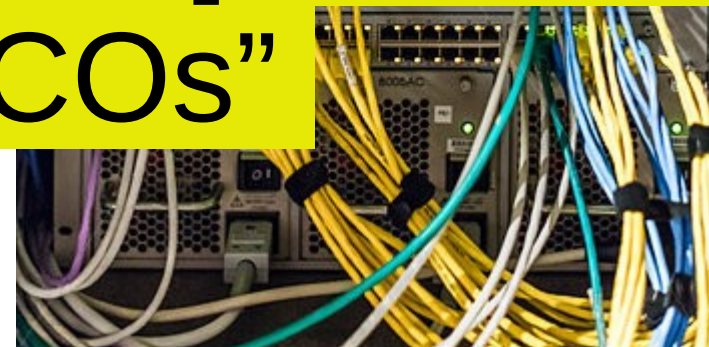
"Internet" split from PSTN gradually

from about 2000 on

Separate Transport
Packet Switching[routing]

DATA

exponential growth

ADSL modem

ENET

Structure of the PSTN

Phone is usually
VoIP on cable, maybe
even on VDSL
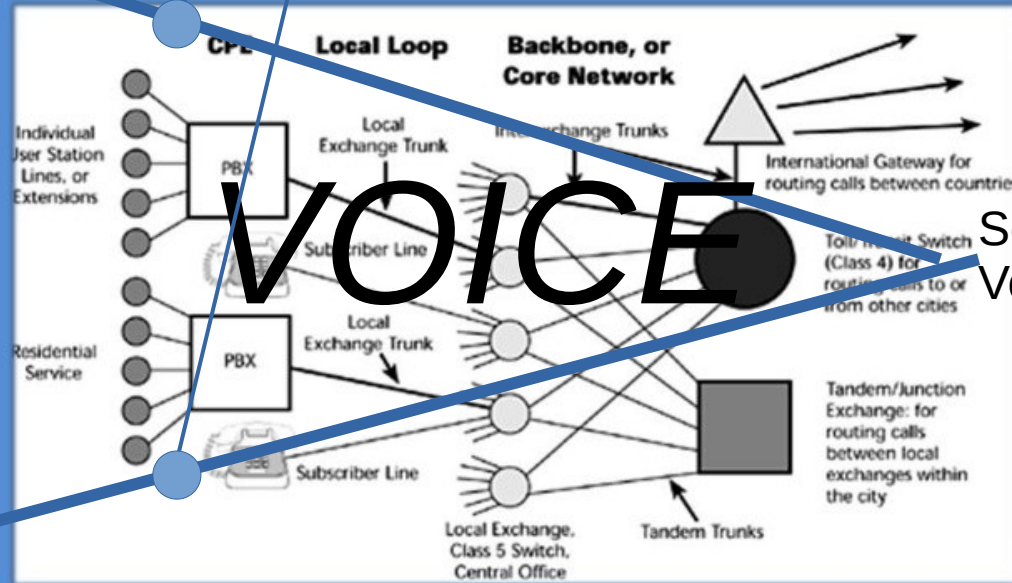
VOICE

Separate Transport
Voice Switching

CPE   **Local Loop**   **Backbone, or Core Network**

Individual
User Station
Lines, or
Extensions

PBX

Local
Exchange Trunk

Interexchange Trunks

Subscriber Line

International Gateway for
routing calls between countries

Toll Transit Switch
(Class 4) for
routing calls to or
from other cities

Residential
Service

PBX

Local
Exchange Trunk

Tandem/Junction
Exchange: for
routing calls
between local
exchanges within
the city

Subscriber Line

Local Exchange,
Class 5 Switch,
Central Office

Tandem Trunks

ENET

ADSL modem

A similar diagram would apply for cable
modems and cable headend
Cable was initially ONE downstream

An attempt at cable architecture:
--Cable companies JUMPED on the
"providing Internet" bandwagon!

INTERNET

BCAST TV

Traditional Coaxial Architecture

Hybrid Fiber/Coaxial Architecture

Head-End

Node

Node

Trunk & Feeder

Node

Feeder Network

Distribution Network

Distribution Network

Amplifier

CMODEM
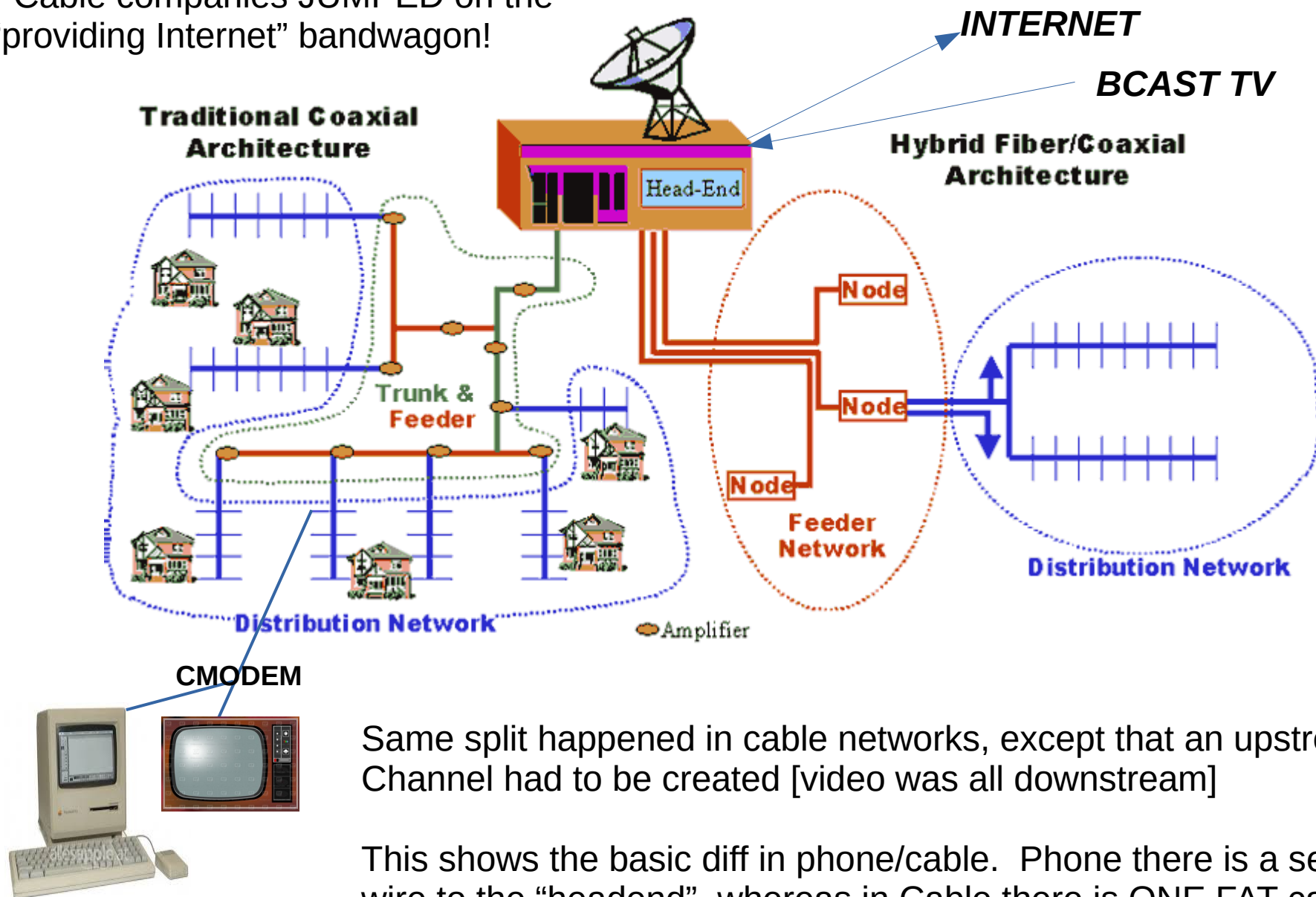
Same split happened in cable networks, except that an upstream
Channel had to be created [video was all downstream]

This shows the basic diff in phone/cable. Phone there is a separate
wire to the "headend" whereas in Cable there is ONE FAT cable with
hundreds/thousands of people on it.

DSP breakthrus 1996 ushered in the split

-technology increased to allow
-small dedicated computers to encode/decode bits
Phone line can carry 12MHz for short distances
Cable coax can carry 100Mhz+ for "long" distances

Telco CO

Data Network

Cable modem
ADSL modem

Ethernet

ADSL 4KHz – 2MHz
-on local loop ONLY
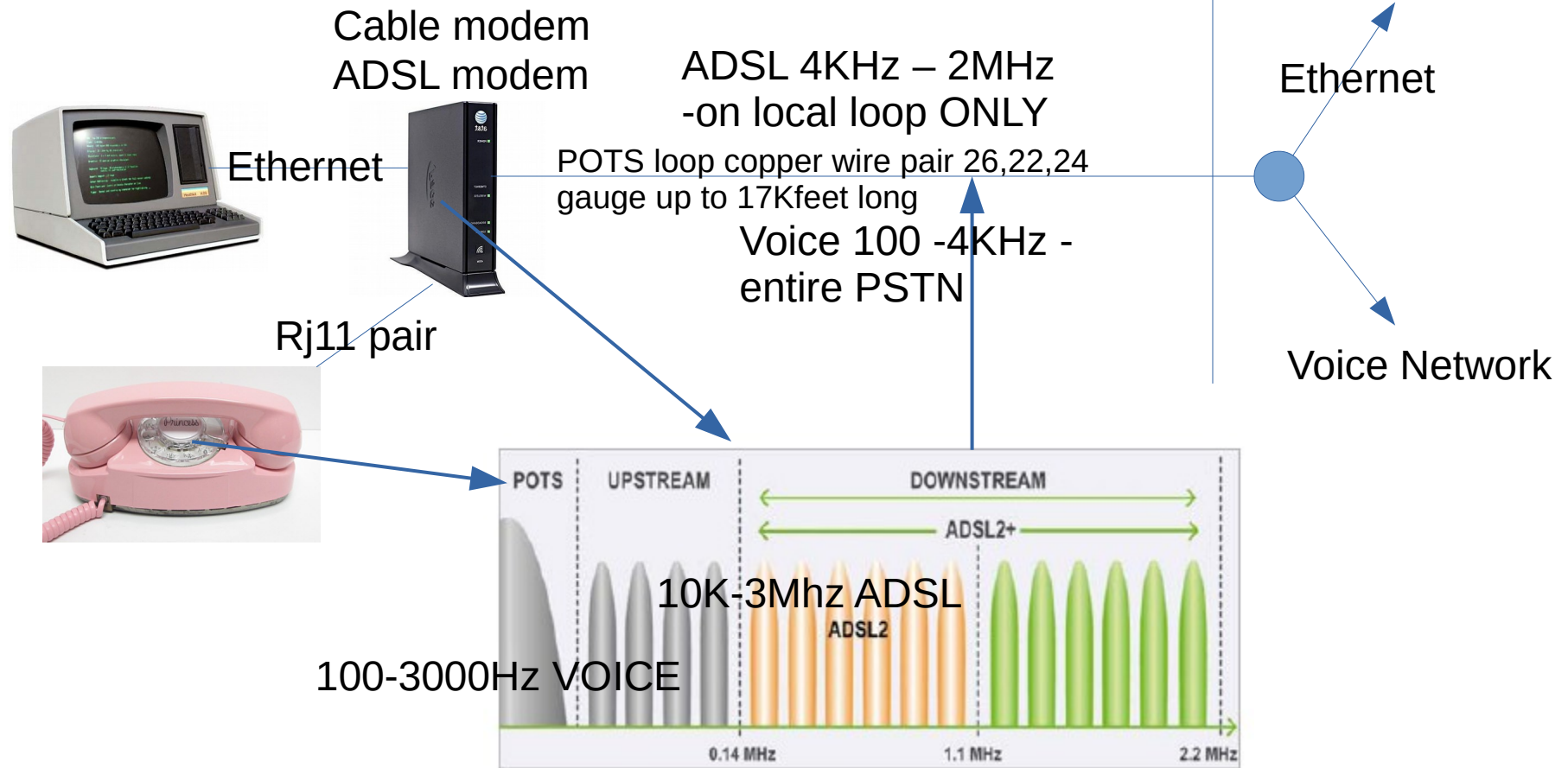
POTS loop copper wire pair 26,22,24
gauge up to 17Kfeet long

Voice 100 -4KHz -
entire PSTN

Ethernet

Rj11 pair

Voice Network

10K-3Mhz ADSL

100-3000Hz VOICE

POTS | UPSTREAM | DOWNSTREAM | ADSL2+ | ADSL2 | 0.14 MHz | 1.1 MHz | 2.2 MHz

Each freq band carries "bits" -like old modems
ADSL processors can check freq bands and use/not use
them depending on noise. COMBINES bands to collect bits

Warning! Detail coming…..

We need to talk about "Computers"

And "bits"

-"1's" and "0's" Integrated ckts/Memory/storage
-OS's developed for PCs DOS/UNIX/MACOS
-Allows programs to appear to execute "simultaneously"
-Computer programs [processes] can communicate -to each other- via
-message passing [same or different machine] "packets"
--using socket [IP address + port] thru localhost
--or **network to other machines!** *Protocols?*
--process "listens" on "port" [local address/IP address]
[-shared memory [same machine] also used]

-Processes create "TCP sessions" to intercommunicate, pass to OS
-OS network stack breaks TCP into "IP packets"
-"service programs" run on/listen on well known ports
-"client programs" talk to these ports
-IP packet is the coin of the Internet realm [medium of exchange]
-Every OS implements a standard TCP/IP protocol stack so it can
Communicate with "everybody else" in the world
-TCP/IP "created" 1977 ["seven layer stack"], adopted 1984
Layered communications
HTTP layer 5
TCP/UDP layer 4
IP layer 3
Ethernet layer 2
wire/air/fiber layer 1
Do F12 on a web page

We need to talk about "Computers"

-From DOS to UNIX, thousands → millions of lines of code
-Computers are so fast, they can do thousands of things "simultaneously"

Programs on computers are communicating with other programs on the computer, and increasingly with programs on OTHER computers.

Some necessary prologue: "anything" can be represented/code with bits [remember Shannon theorem] --computers need bits!!!!

BITS are easy!!!
-Count in binary, represent in HEX
0,1,10,11,100,101,110,111,1000,1001,1010,1011,1100,1101,1110,1111
0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F [representation of above binary]
Example:
-IP addresses 205.152.56.121 CD983879 → CD.98.38.79
-DNS names www.google.com 64.233.176.99 → 40.E9.B0.63
Browse using Decimal or hex
Binary – Hex - decimal
1100 0000 1010 1000 1111 1110 0000 0001 = C0A8FE01 C0.A8.FE.01
   192.168.254.1
Johnloop.com Do an nslookup set type=MX
68.200.57.171

Some people have never seen a "cmd line" – let me introduce you :-)

A little about what computers "Looked Like"
---cmd line [nerds pride themselves on the ability to use this]
---GUI [The GUI was supposed to SIMPLIFY the cmd line interface,
But it has evolved into unbelievably more complexity!!
What is simpler, staring at a single prompt, or finding the button to push in a
COMPLEX page of scrolling, blinking, rotating images and text!! ??

```
C:\Program Files>dir                              In pure MS-DOS 7.10 mode

 Volume in drive C is WIN2003
 Volume Serial Number is 20A1-1627
 Directory of C:\Program Files

.              <DIR>        07/22/2003   7:56a .
..             <DIR>        07/22/2003   7:56a ..
COMMON~1       <DIR>        07/22/2003   7:56a Common Files
WINDOW~1       <DIR>        07/22/2003  10:26a Windows NT
INTERN~1       <DIR>        07/22/2003  10:27a Internet Explorer
COMPLU~1       <DIR>        07/22/2003  10:30a ComPlus Applications
OUTLOO~1       <DIR>        07/22/2003  10:35a Outlook Express        ← LFN
NETMEE~1       <DIR>        07/22/2003  10:36a NetMeeting
WINDOW~3       <DIR>        07/22/2003  10:36a Windows Media Player
MSNMES~1       <DIR>        07/22/2003  10:35a MSN Messenger
CREATIVE       <DIR>        07/22/2003  12:30p Creative
VMWARE         <DIR>        07/22/2003   4:17p VMware
VMTUNI~1 ISU         54,546 07/22/2003   4:18p VMTUninst.isu
         1 file(s)          54,546 bytes
        12 dir(s)    1,224,089,600 bytes free

C:\Program Files>ren "MSN Messenger" "Windows Messenger"   ← Renaming LFN

C:\Program Files>_
```

Computer "interfaces" were initially all "cmd line" until Mac and Windows 3.0 "GUIs"
--programs were invoked from "cmd line"

Quiz: What are these????   coffee coaster pads?

Somebody thot "cmd lines" were too complicated, so they invented GUIs.
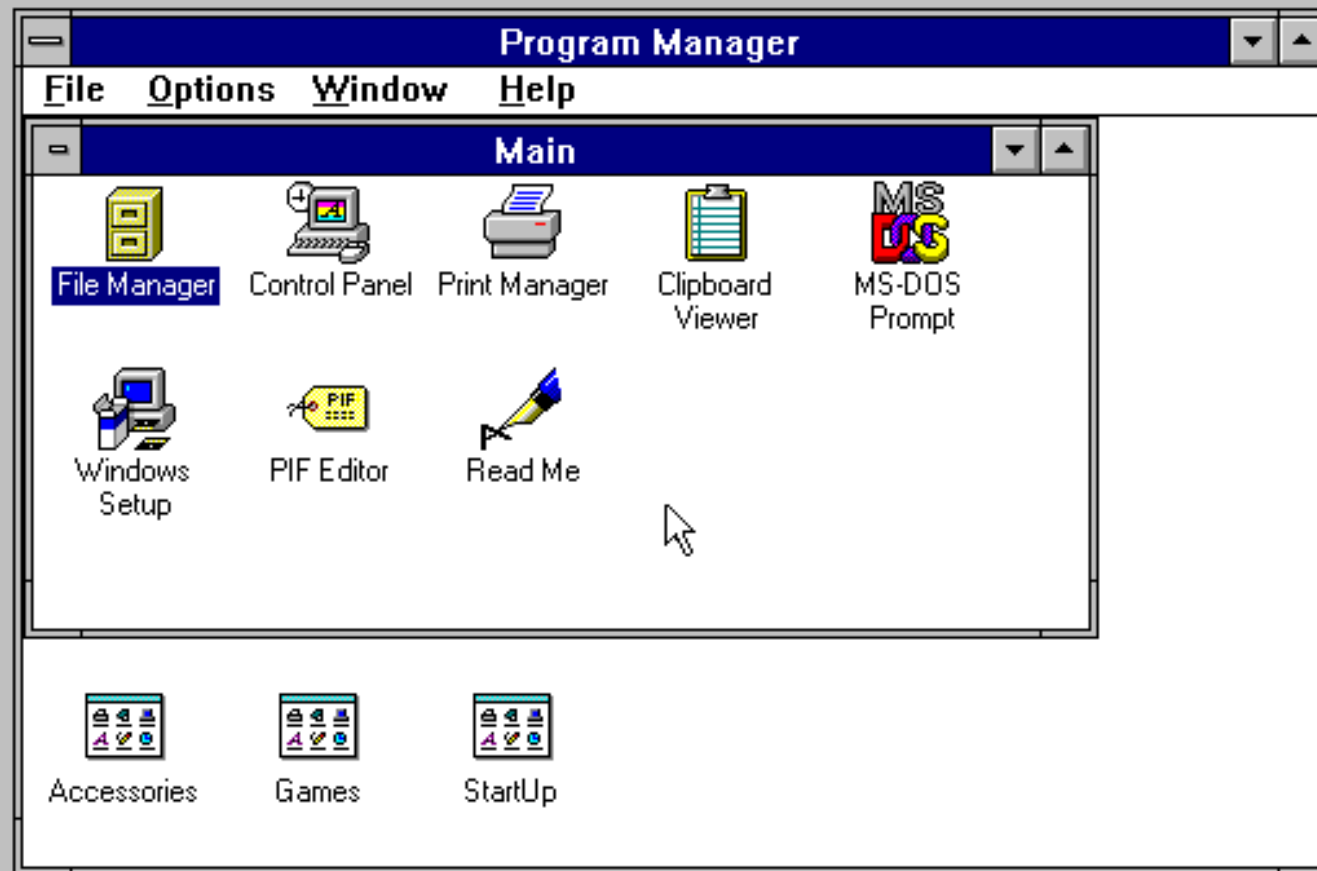
Initial Windows 3.1 and Mac had NO concept of talking OUTSIDE the computer, or of routing. They were standalone/with serial ports for modems.
TCP/IP stack intro'd in ~1990, with "ethernet cards" enabled "data communications"

Apple initial GUI – don't forget ONE button mouse.

We need to talk about "Data Communications"

PSTN was built on physical/actual "circuits"

--virtual WIRE between you and far end

– voice bandwidth always there -there is NO PACKET, data analog or digital

--data path static [PVC vs SVC] for "call"

--depends on fact that phones online [off hook] "sporadically"

--no notion of a physical/actual "circuit" inside network

-**IP address** on each packet to designate eventual endpoint

--"routers" route packets based on IP address

--"Virtual circuit" established" AT THE ENDpoint by computer programs

--bandwidth ? --bigger the better to squeeze "statistical" traffic.

--computers online "permanently" (unlike voice – no "off hook")

--packets, follow "virtual circuit" are "statistically multiplexed"

--each packet "routed" independently of every other one.

--*exactly like dropping a letter in the mail!*

-OUTbound routing can differ from INbound routing

-TWO way needed [unlike broadcast TV]

Called "Virtual circuit" because it "looks" like a circuit if packet can be routed

From one end to the other and vice versa

IP packets are the "coins" of the realm

IP packet:

Header	Data
20 bytes	<1480 bytes

Warning! More detail coming

We need to talk about ip addresses

IP address: ANY of 0.0.0.0 to 255.255.255.255 [FF.FF.FF.FF]
Private ip address: 10.0.0.0/8 172.16.0.0/16 192.168.0.0/16
Real ip address: ANY ip address NOT private, multicast, or anycast
Multicast ip address: 224.0.0.0 Anycast ip address:
IP network address: address of network e.g. 192.168.1.0 /24
IP Broadcast address: address of all devices on network e.g 192.168.1.255
"**Stolen ip address**:" A Real address appearing as src on private network

We need to talk about networks

Network: Specific "**GROUP**" of ip addresses e.g. 10.10.0.0/8, 68.200.57.0/22
--defined by network address/network mask e.g. 192.168.1.1/24

Capital I

Private network: group using private addresses, NOT routed by Internet
internet: network of networks [any type of ip addresses routed]
Internet: network of Real addresses

Axioms:

Route IP packets between networks
Switch IP packets between devices on a network
Internet only routes real addresses
Private networks/internetworks ifce to Internet using [NAT]
Every network [typically] has a gateway [way out]
Every network has a broadcast address
Real IP addresses do not appear on private networks as SOURCE ip addresses
Private IP addresses do not appear on Internet [src or dest]
IP addresses of a Pkt do NOT change in transit [except for NAT]

IP packets are the "coins" of the realm
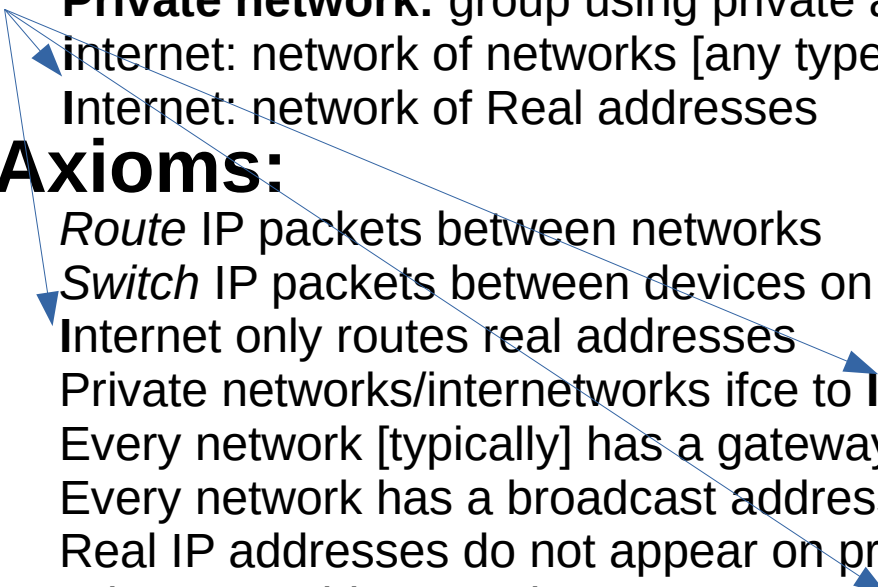
Master this to understand IP addressing

comp/school/activityCenter/home?/countries?

Small I internet

Private network

Router Or NAT

Router Or NAT

Private network

Private network

NAT

NAT

Private network

Router

Router

NAT

Big I Internet -the WORLD

Private network

Router

Real network

Router

Just to add confusion:
You can build private
Networks out of REAL
Addresses! Ex 90

Router

Real network

IP packets are the "coins" of the realm
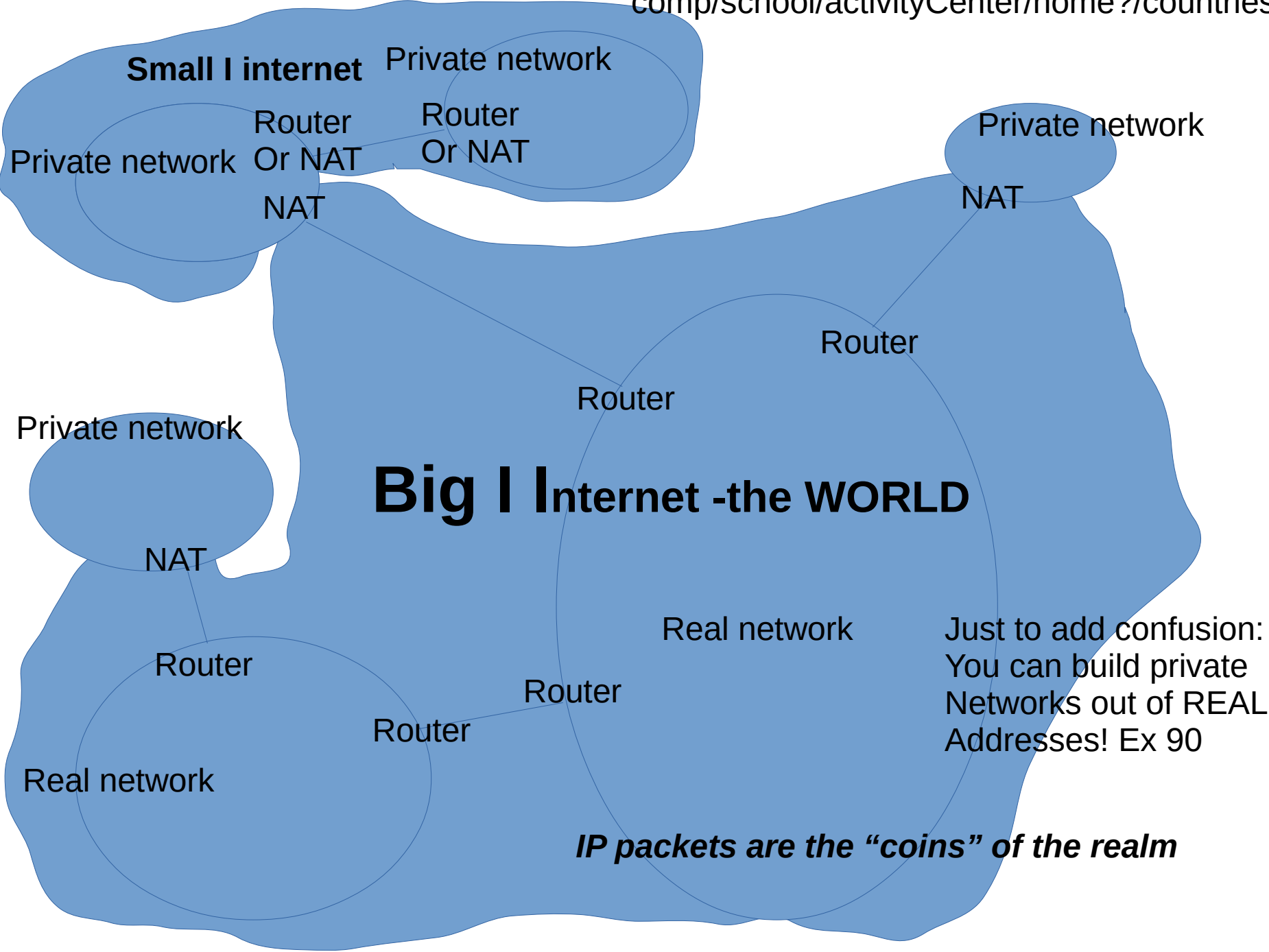
Warning! Still more detail coming [everybody cover their ears and eyes]

IPv4 Header

Byte Offset				
0	Version	IHL (Header Length)	Type of Service (TOS)	Total Length
4	Identification		IP Flags x D M	Fragment Offset
8	Time To Live (TTL)	Protocol	Header Checksum	
12	Source Address			
16	Destination Address **DEST**			
20	IP Option (variable length, optional, not common)			

20 Bytes

IHL (Internet Header Length)

Bit: 0 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8

← Nibble → ← Byte → ← Word →
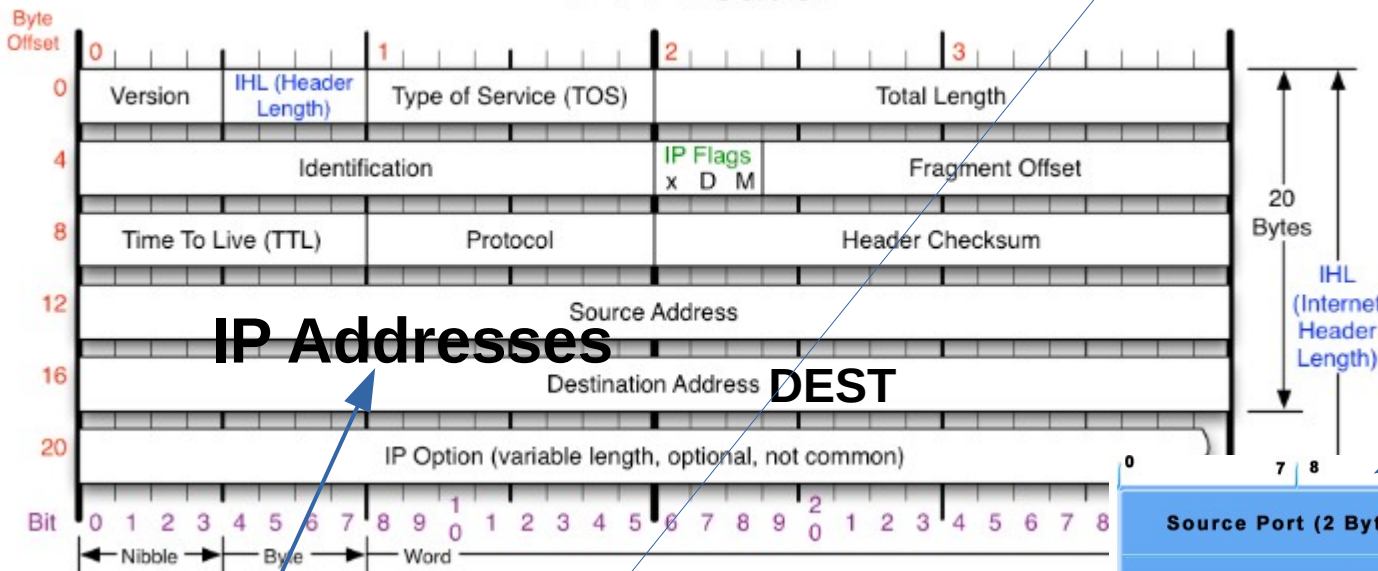
IP Addresses

12.24.250.24
192.168.1.1

Service Port
Http,https,smtp
Ftp…....

TCP HEADER

0	7	8	15	16	23	24	31
Source Port (2 Bytes)				Destination Port (2 Bytes)			
Sequences Number (4 Bytes)							
Acknowledgement Number (4 Bytes)							
Header Length (4 Bits)	Reserved (6 Bits)	U R G	A C K	P S H	R S T	S Y N	F I N	Window Size (2 Bytes)
TCP Checksum (2 Bytes)				Urgent Pointers (2 Bytes)			
Options (Optional)							

© OmniSecu.com

START HERE

Bits on wire/air

Wifi frame

Ethernet II Frame

Gap	Preamble	DST MAC	SRC MAC	Type	Payload	CRC
12	8	6	6	2	46-1500	4

IPv4 Packet

IP	TCP	Payload
20	20	6-1460

MAC Addresses
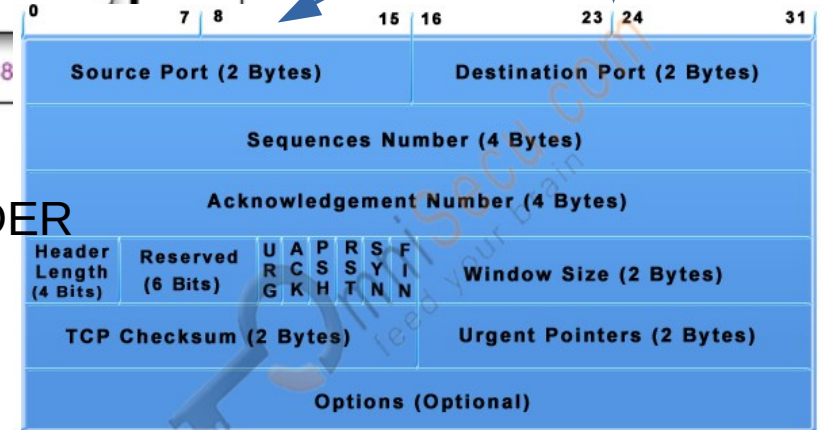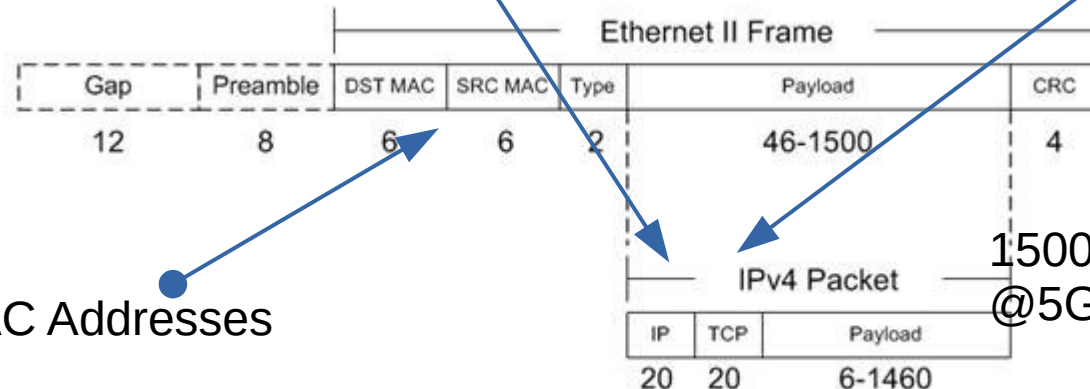
1500bytes/12000 bits
@5Ghz, 2.4usec, ½ mile

Warning! More detail coming

"Inside computer"

Bits in medium

Sending Process

| Application |
| Presentation |
| Session |
| Transport |
| Network |
| Data |
| Physical |

Application protocol — Data

Presentation protocol — AH | Data

Session protocol — PH | AH | Data

Transport protocol — SH | PH | AH | Data

Network protocol — TH | SH | PH | AH | Data

Data-link protocol — NH | TH | SH | PH | AH | Data

Bits — DH | NH | TH | SH | PH | AH | Data | DT

Receiving Process

| Application |
| Presentation |
| Session |
| Transport |
| Network |
| Data |
| Physical |

Client A

Client B

Actual data transmission path

Physical Medium

TCP packet
IP packet
Ethernet data link
Wire,fiber,air,coax

TCP Session
TCP port
IP Routing
MAC add

IP Packet

Ethernet Frame

Lo and Behold the Seven Layer Stack
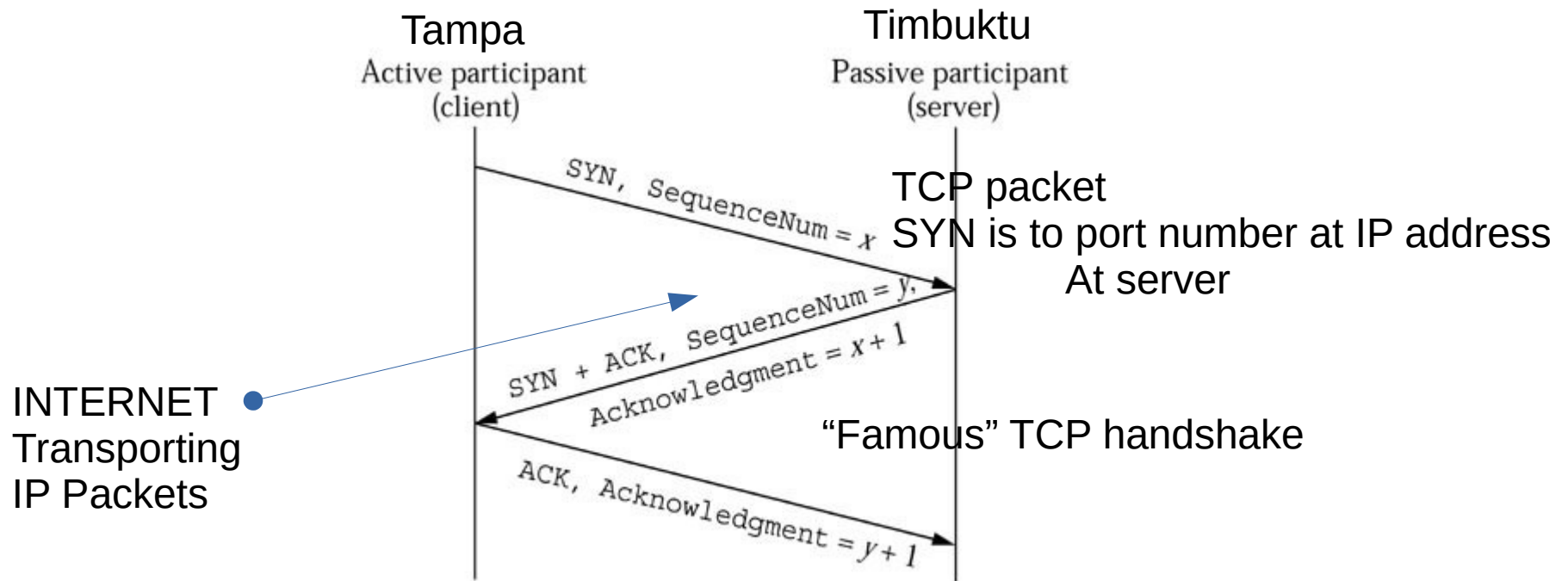
Warning! More detail coming, but this is SIMPLE!

We need to talk about "Data Communications"

Establishing a (virtual) CIRCUIT in packet/data communications:

Tampa
Active participant
(client)

Timbuktu
Passive participant
(server)

SYN, SequenceNum = x

TCP packet
SYN is to port number at IP address
At server

SYN + ACK, SequenceNum = y,
Acknowledgment = $x+1$

INTERNET
Transporting
IP Packets

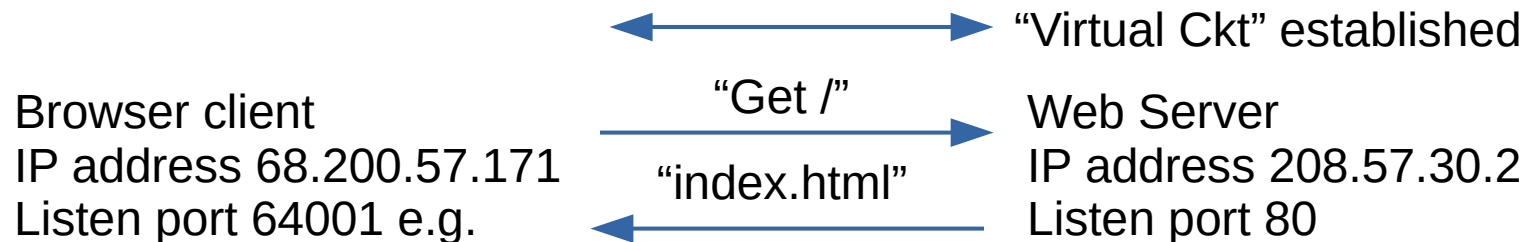"Famous" TCP handshake

ACK, Acknowledgment = $y+1$

And just like that ---- a [virtual] "circuit"
--Service endpoints can exchange data!
e.g browser client and web server!

The client program on one end writes data to a buffer, and voila, it appears
At the far end server, and vice versa – all thanks to TCP/IP transport -universal
Data communications language. Even Chinese servers speak TCP/IP in English.
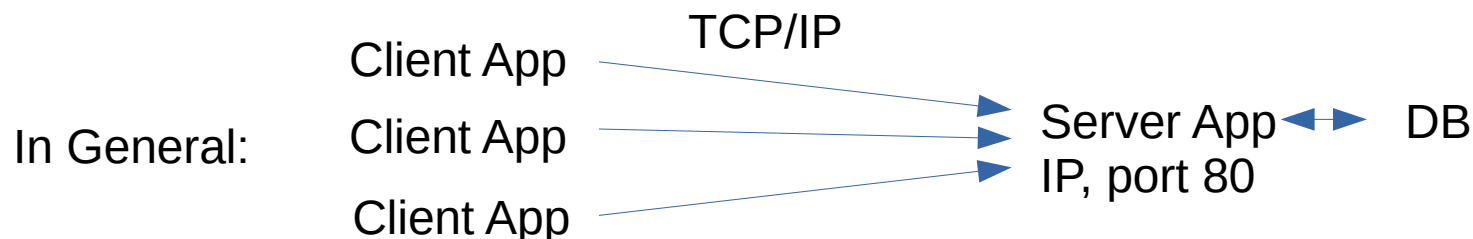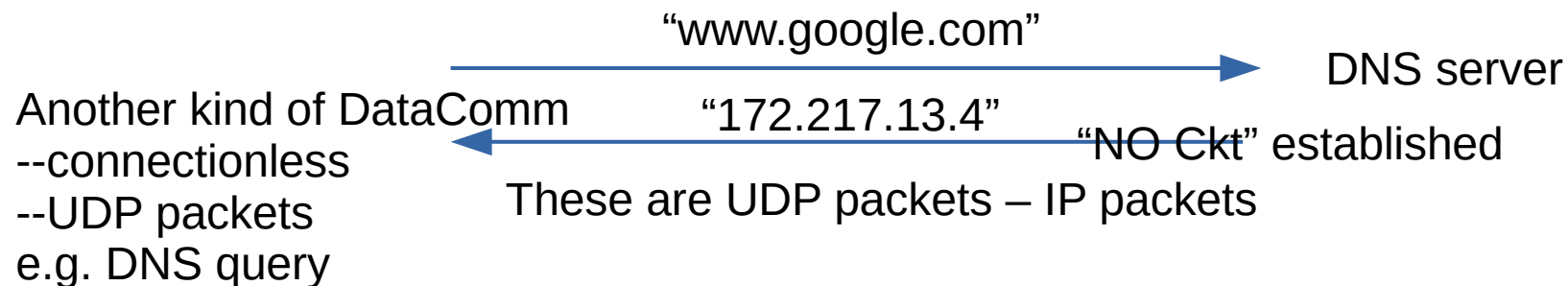
Warning! Still more detail coming

We need to talk about "Data Communications"

Browser Establish TCP session [virtual ckt] -"ckt" to Web Server -3way handshake

←————————————→ "Virtual Ckt" established

Browser client   "Get /"   Web Server
IP address 68.200.57.171 ————————————→ IP address 208.57.30.2
Listen port 64001 e.g.   "index.html"   Listen port 80
                          ←————————————

These are TCP packets – IP packets
--carrying established TCP session talking HTTP protocol
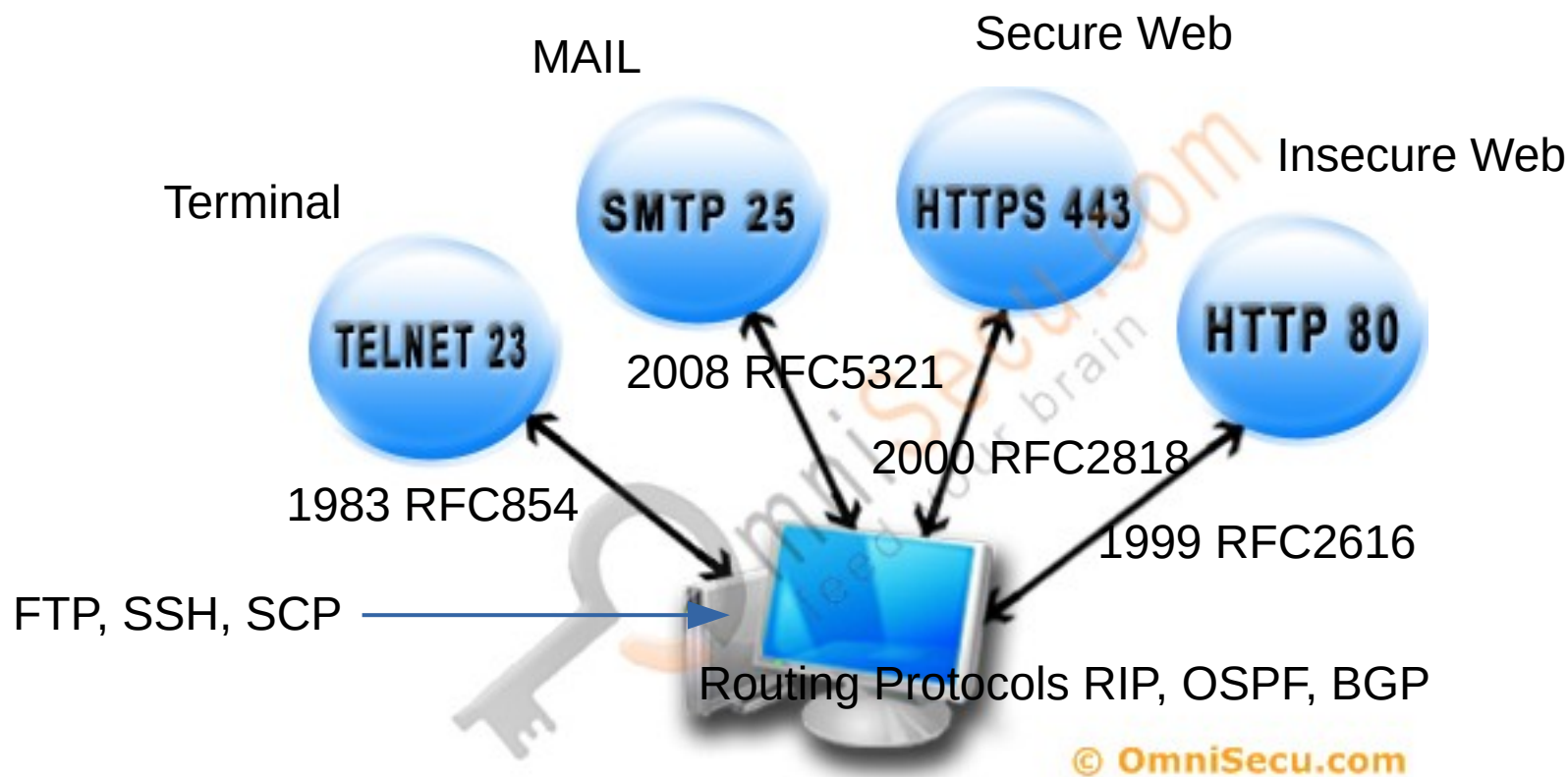--web page may have hundreds more TCP sessions to establish!

                    "www.google.com"
         ————————————————————————→ DNS server
Another kind of DataComm   "172.217.13.4"
--connectionless   ←———————————————— "NO Ckt" established
--UDP packets   These are UDP packets – IP packets
e.g. DNS query

                         TCP/IP
         Client App ——————
                              ——→
In General: Client App ————————→ Server App ←——→ DB
                              ——→ IP, port 80
         Client App ——————

Somebody find their cellphone -wifi- IP address for me OK? -later demo

Warning! Still more detail coming

We need to talk about "Data Communications"

Standard way of talking over network: Protocols – Defined by RFCs

Secure Web

MAIL

Insecure Web

Terminal

SMTP 25

HTTPS 443

HTTP 80

TELNET 23

2008 RFC5321

2000 RFC2818

1983 RFC854

1999 RFC2616

FTP, SSH, SCP

Routing Protocols RIP, OSPF, BGP

© OmniSecu.com

Telnet:
SMTP:
HTTP/HTTPS: GET, POST

We need to talk about "Routing"

Ethernet Frames: carry IP packets, wifi, wires, fiber
--terminated at routers which extract IP packets
--also: ATM, MPLS, DDS
--DS1,DS3,OC3c,OC12c,OC48, wdm → 10GBs links
--FRAMES[packets] here, NOT circuits.
IP packet: carries TCP/upper app layers
IP packets are the "coins" of the realm
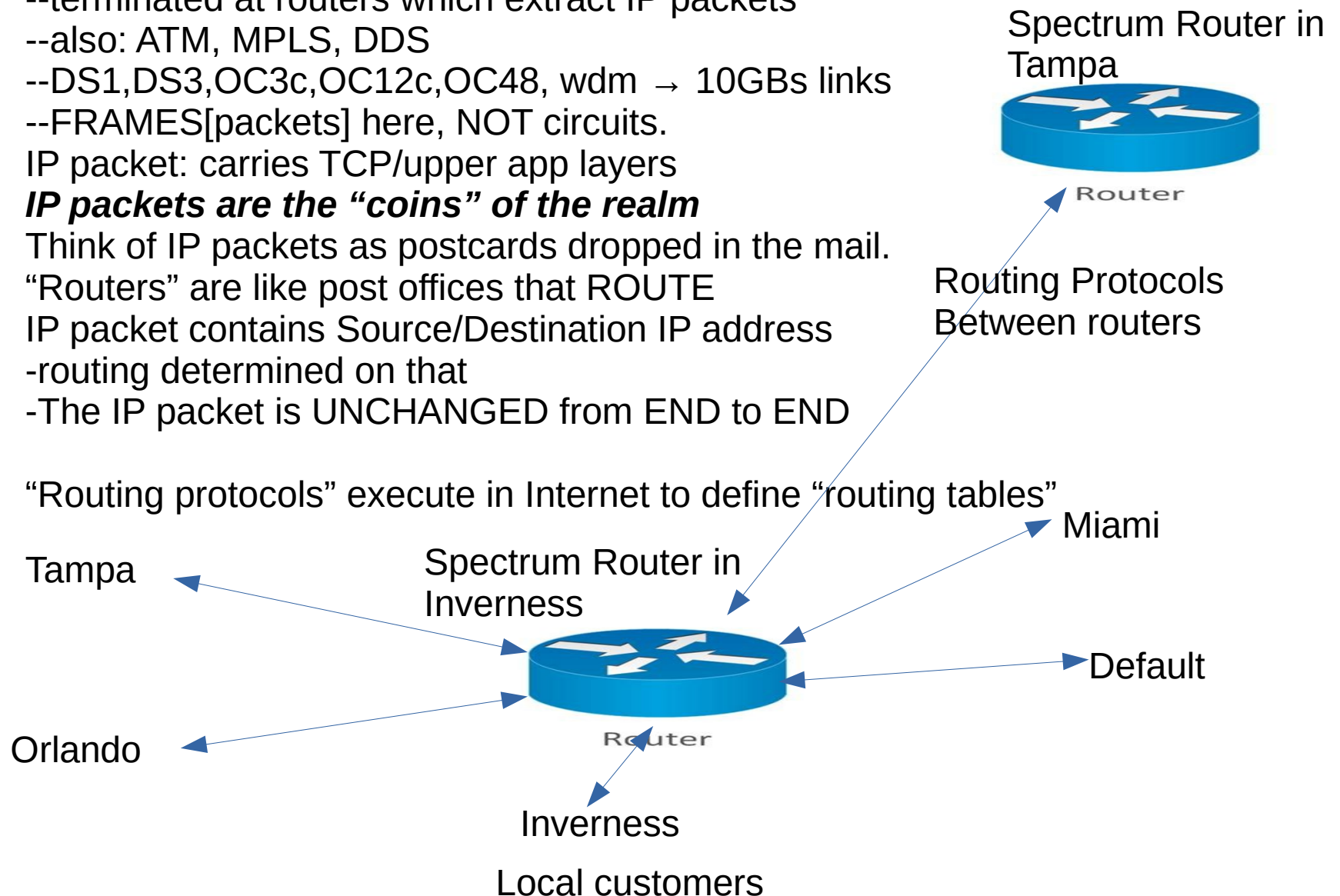Think of IP packets as postcards dropped in the mail.
"Routers" are like post offices that ROUTE
IP packet contains Source/Destination IP address
-routing determined on that
-The IP packet is UNCHANGED from END to END

"Routing protocols" execute in Internet to define "routing tables"

Spectrum Router in Tampa

Router

Routing Protocols
Between routers

Miami

Tampa

Spectrum Router in
Inverness

Default

Orlando

Router

Inverness

Local customers

You can do this experiment yourself!

Example of IP packet route to www.google.com

traceroute www.google.com **(172.217.164.68)**, 30 hops max, 60 byte packets

```
 1  HG6Box (192.168.254.254)  1.886 ms  2.122 ms  2.128 ms  ←HOME ROUTER
 2  10.80.213.29 (10.80.213.29)  11.059 ms  11.298 ms  17.450 ms
 3  71-46-24-189.res.bhn.net (71.46.24.189)  18.192 ms  18.435 ms  18.676 ms
 4  bundle-ether37.tamp20-car1.bhn.net (72.31.7.173)  21.442 ms  21.683 ms  21.683 ms
 5  hun0-0-0-5-tamp20-cbr1.bhn.net (72.31.3.51)  22.628 ms  22.870 ms  22.870 ms
 6  10.bu-ether15.tamsflde20w-bcr00.tbone.rr.com (66.109.6.96)  23.627 ms  21.284 ms  21.488 ms
 7  bu-ether17.hstqtx0209w-bcr00.tbone.rr.com (66.109.1.70)  43.687 ms  43.294 ms  44.226 ms
 8  bu-ether12.dllstx976iw-bcr00.tbone.rr.com (66.109.6.39)  38.660 ms  43.084 ms  39.310 ms
 9  66.109.5.121 (66.109.5.121)  39.870 ms  40.962 ms  41.186 ms
10  ix-ae-52-0.tcore2.dt8-dallas.as6453.net (66.110.57.162)  48.704 ms  49.064 ms  49.333 ms
11  74.125.48.232 (74.125.48.232)  41.405 ms  42.215 ms  42.456 ms
12  108.170.240.210 (108.170.240.210)  42.943 ms  43.181 ms  43.179 ms
13  108.170.228.82 (108.170.228.82)  42.682 ms  42.922 ms  43.393 ms
14  209.85.249.44 (209.85.249.44)  39.498 ms  42.872 ms  39.211 ms
15  108.170.236.129 (108.170.236.129)  42.796 ms  42.867 ms  43.248 ms
16  108.170.249.65 (108.170.249.65)  44.292 ms  45.724 ms  45.966 ms
17  209.85.241.155 (209.85.241.155)  44.522 ms  44.521 ms  44.760 ms
18  atl26s18-in-f4.1e100.net (172.217.164.68)  45.456 ms  45.698 ms  45.697 ms
```

Each line is a "Router"
In a different location

```
[jdloop@localhost ~]$ nslookup
> www.google.com
Server:         192.168.254.254
Address:        192.168.254.254#53

Non-authoritative answer:
Name:  www.google.com
Address: 64.233.177.105
Name:  www.google.com
Address: 64.233.177.106
Name:  www.google.com
Address: 64.233.177.103
Name:  www.google.com
Address: 64.233.177.147
Name:  www.google.com
Address: 64.233.177.99
Name:  www.google.com
Address: 64.233.177.104
```

```
[jdloop@localhost ~]$ ifconfig enp30s0
enp30s0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.254.149  netmask 255.255.255.0  broadcast 192.168.254.255
        inet6 fe80::1109:7d35:3ce7:81d6  prefixlen 64  scopeid 0x20<link>
        ether 70:85:c2:cb:97:a9  txqueuelen 1000  (Ethernet)
        RX packets 416893  bytes 506032334 (482.5 MiB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 241234  bytes 30975756 (29.5 MiB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
        device memory 0xfcc00000-fcc1ffff
```

I'm assuming you
Know what a
"msec" is??

```
[jdloop@localhost ~]$ netstat -nr
Kernel IP routing table
Destination    Gateway         Genmask        Flags  MSS Window  irtt Iface
0.0.0.0        192.168.254.254 0.0.0.0        UG      0 0        0 enp30s0
192.168.122.0  0.0.0.0         255.255.255.0  U       0 0        0 virbr0
192.168.254.0  0.0.0.0         255.255.255.0  U       0 0        0 enp30s0
```

Figure this one out!

Internet Routing/Content Servers/DNS ---complicated!

I was struck, however, at how complicated it all is. There were at least **9 different IPs listed for "Macys.com"** as I was pinging, and I did a traceroute to a few, and at least one was in Hong Kong. So the times are crazy, from a few msec!! to 100 maybe. I supppose it is like this for quite a few sites. These are all "akamai" content server addresses which I presume large sites hire to "distribute" their web content. Akamai, according to wikipedia, has 265,000 servers around the world. Server 15-30% of the Internet traffic. I presume there is a backend, private network that Akamai uses to populate its own servers, invisible to the rest of us, where they check the traffic and modify DNS to distribute load... or something like that!

So our TCP testing -to "big" Internet sites that hire Akamai like the top 100 web- is actually testing the path to the content servers which are ...normally... placed close to you. I suspect one must sit practically NEXT DOOR to Lou, IPwise anyway!!!!   I cannot find an ICMP ping site for Lou that does not seem to be already in the Content Server "cloud."   His router is literally one hop away from.

----I need to get a list of sites NOT on a content server! to check country wide!

root@pi27:~# **traceroute -I 104.71.48.233 (add given for macys.com – 1 of NINE that rotate based on load)**

traceroute to 104.71.48.233 (104.71.48.233), 30 hops max, 60 byte packets

 1 hhanet-north (192.168.1.1) 0.587 ms 0.748 ms 0.692 ms Lou's two routers

 2 192.168.0.1 (192.168.0.1) 1.168 ms 1.128 ms 1.088 ms

 3 * * *   <- this has to be Lou's Internet side of his router - he has ICMP turned off, all it does is decrement rtt

 4 v106.core1.den1.he.net (216.66.78.105) 4.085 ms 4.153 ms 4.200 ms <- the next IP is his ISP - Hurricane Electric [Longmont must use them?] https://he.net/ip_transit.html

 5 100ge16-1.core1.sea1.he.net (184.104.193.186) 34.260 ms 34.310 ms 34.290 ms <- and the next IP hop is Seattle!

 6 100ge11-2.core1.tyo1.he.net (184.105.213.118) 115.505 ms 115.054 ms 114.631 ms Tokyo

 7 100ge10-2.core1.hkg1.he.net (184.105.64.129) 163.560 ms 163.638 ms 163.616 ms **Hong Kong**

 8 akamai6-lacp-100g.hkix.net (123.255.90.184) 289.237 ms 289.206 ms 289.165 ms <-interconnection of Hurricane Electric to Hong Kong peer point? ix?

 9 a104-71-48-233.deploy.static.akamaitechnologies.com (104.71.48.233) 165.797 ms 166.033 ms 166.018 ms <- macys.com in Hong Kong

We need to talk about DNS Domain Name System

---remember, computers(routers)only know BITs
DNS is an overlay system
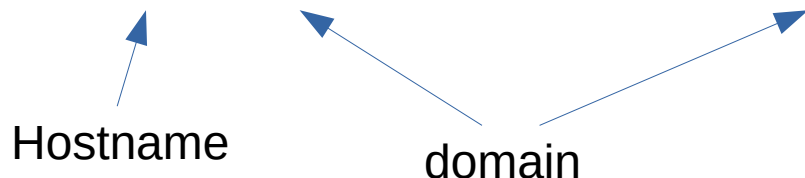Internet can "operate" without it
FQDN: svcdev.test.dlife.att.com [not case sensitive]
Nslookup on site
Nmap on site – port 443, port 25
Ping? Mail?

Svcdev.test.dlife.att.com   like www.google.com

Hostname   domain

DNS server spec'd by IP address
Handed out via DHCP ---BUT---
You may specify your own!
1.1.1.1, 8.8.8.8, 9.9.9.9, 208.67.222.222
You can specify it in the router or on your PC

DNS queries are IN THE CLEAR - !!
Use Ffox to send them over https to cloudflare

"DNS hijacking" especially malicious!

How do we determine what "services"
Run at this host?
--we can scan, or KNOW

If we make it this far, I need to flood you with Detail

We need to talk about PKI -public key infrastructure/encryption

Internet TRANSPORT simply routes IP packets
Security/encryption is imposed/extracted at the endpoints.
Generate rsa pair on linux, create cert
Public-Private key pair -work together to encrypt   Do a Demo
--Private key NEVER leaves host   Https web page
--Public key distributed [via certificate usually]   And look at
Digital Signature – doc signed with private key   Certificate etc
--verified by using public key of signer
Digital envelope – letter signed by public key of recipient
--only recipient can open it with private key
Hash -fingerprint of some doc -can be used INSTEAD of doc

Certificates
Public key SIGNED by "really trustworthy person"
-Ffox about: privacy&security; certificates
When you go to "https" you get certificate of web site, and then
You go and verify it using the public key.
--you get the site's public key from the "really trustworthy person"
--you verify that it has not been revoked/timed out
This allows the session to be encrypted, cannot be seen IN TRANSIT
(viewable at the endpoints of course)
DNS queries are still visible – sold by ISPs?

This a topic for another day

We need to say the Internet is a dangerous place!

Malicious email links
--use gmail? Yahoo? -junk filtering
--ISP mail pretty much junk
--local mail clients a pain these days, use webmail with https
Compromised web sites
--https anywhere
--use adblocker
--new FFox, DOH
Tracking
--stay off BAD websites
Unrestrained file sharing
--ugh Windows, wifi open
Unrestrained money handling
--keep off mobile
--keep to single PC[linux?]
Wifi -esp public is problematic!
--NO money handling in public?
Internet of things (mostly wifi)
--KNOW what you are getting into
--cameras
--audio
--They ALL have links to cloud
Passwords
--You know the drill!!!!!

Example Internet Session

-go to Amazon.com
-get IP from ipconfig
-wireshark SAVED file
-conversations
-look for port 80 -ocsp
-find conversation, follow
-Ethernet
-IP
-TCP
-OCSP

-Wifi in this aud does not reqire passwd. I can
See everything unless you are doing https!!

http://173.184.37.67
https://johnloop.com

IPtoHEX

In Summary

Billions of lines of computer code
Trillions of transistors
Trillions of photons and electrons
SIMULTANEOUSLY in the air/wires/fibers
Millions of bugs???

-Just to get a web page on your phone

Server Farm:
Networked Enterprise
(expensive) computers

There are at least a billion transistors in a smartphone

IT's ALL BECOME

MAGIC

AGAIN!

With quantum computing and quantum teleportation to come!!
Quantum Teleportation

Course Outline?

Bits/addresses/DNS/install wireshark
Ethernet Frames/Access technologies
IP packets/routing
TCP packets/Services
Computers/OS's/Data comm
DNS,Web,email,apps
Dangerous Internet/safe computing