Computer Network Architecture

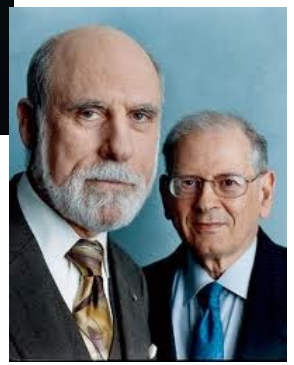
Past, Present, and Future

On the Shoulders of Giants

- 1961: Leonard Kleinrock published a work on packet switching
- 1962: J. Licklider described a worldwide network of computers called Galactic Network
- 1965: Larry Roberts designed the ARPANET that communicated over long distance links
- 1971: Ray Tomilson invents email at BBN
- 1972: Bob Kahn and Vint Cerf invented TCP for reliable packet transport







On the Shoulders of Giants …

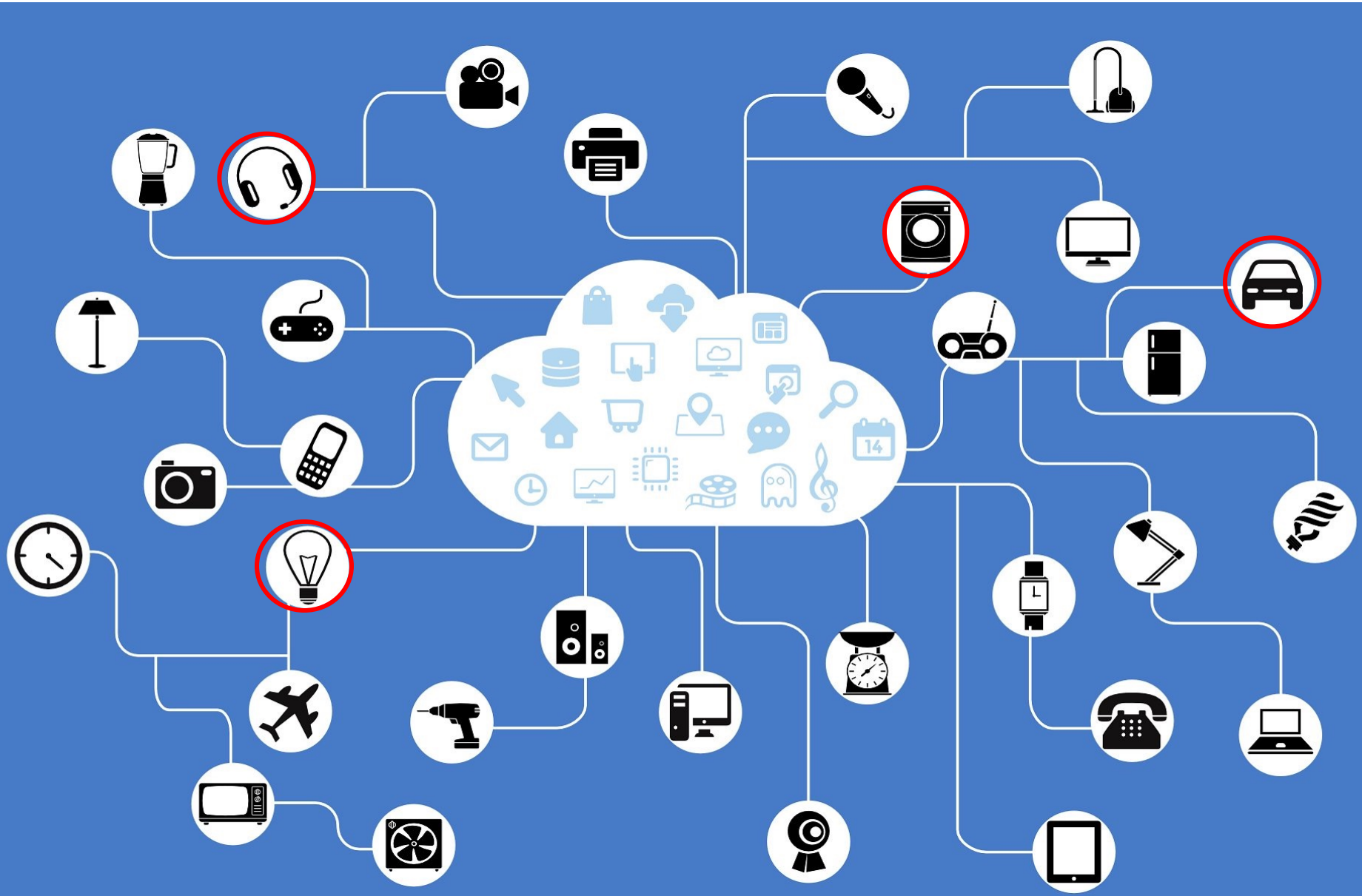
- 1973: David Clark, Bob Metcalfe implemented TCP and designed ethernet at Xerox PARC
- 1975: Paul Mockapetris developed DNS system for host lookup
- 1980: Radia Perlman invented spanning tree algorithm for bridging separate networks
- Things snowballed from there on …

What we have today is beyond any of the inventors' imagination ...


And YOU are here

And by "YOU" I mean …

"Cool" internet appliances



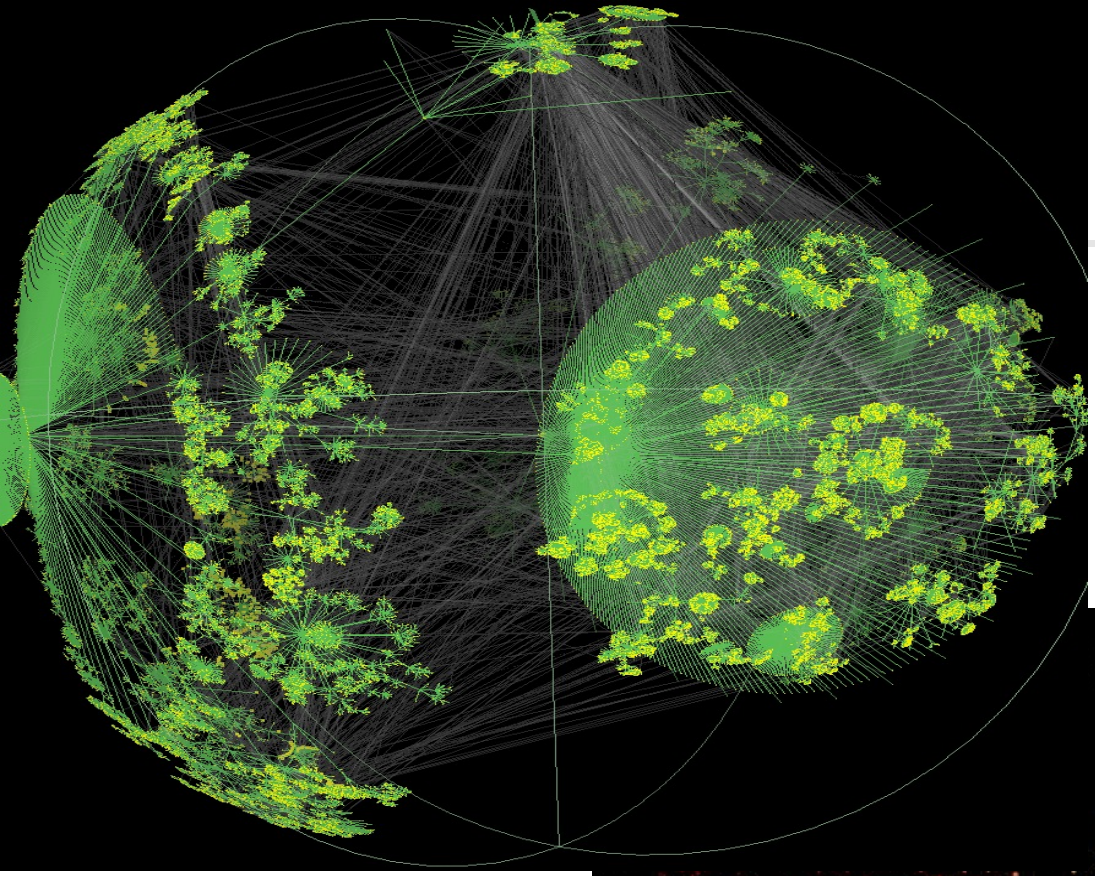
"Cool" internet appliances

Web-enabled toaster +
weather forecaster

And Of Course people …

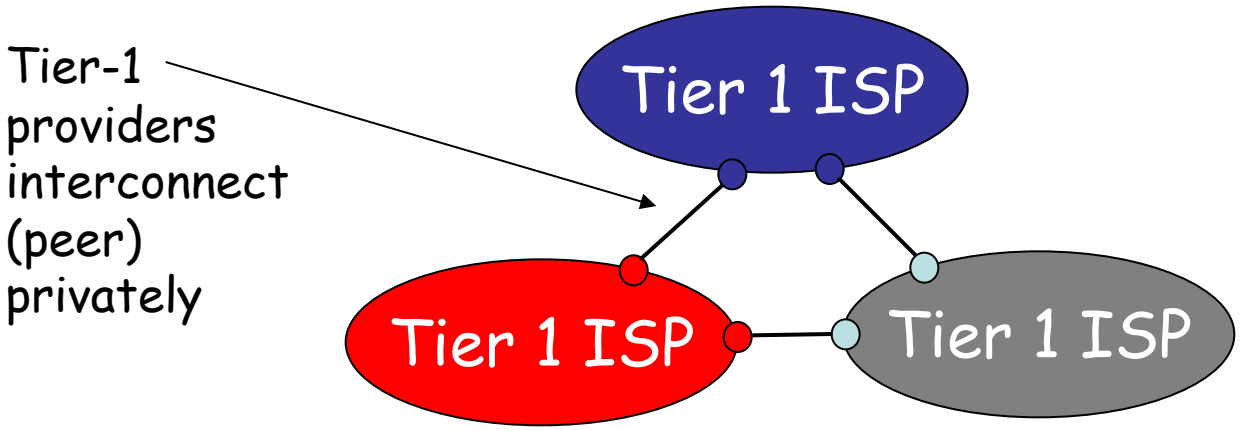
InterNetwork

- Millions of end points (you, me, and toasters) are connected over a network
  - Many end points can be addressed by numbers
  - Many others lie behind a virtual end point
- Many networks form a bigger network
- The overall strcture called the Internet
  - With a capital I
  - Defined as the network of networks



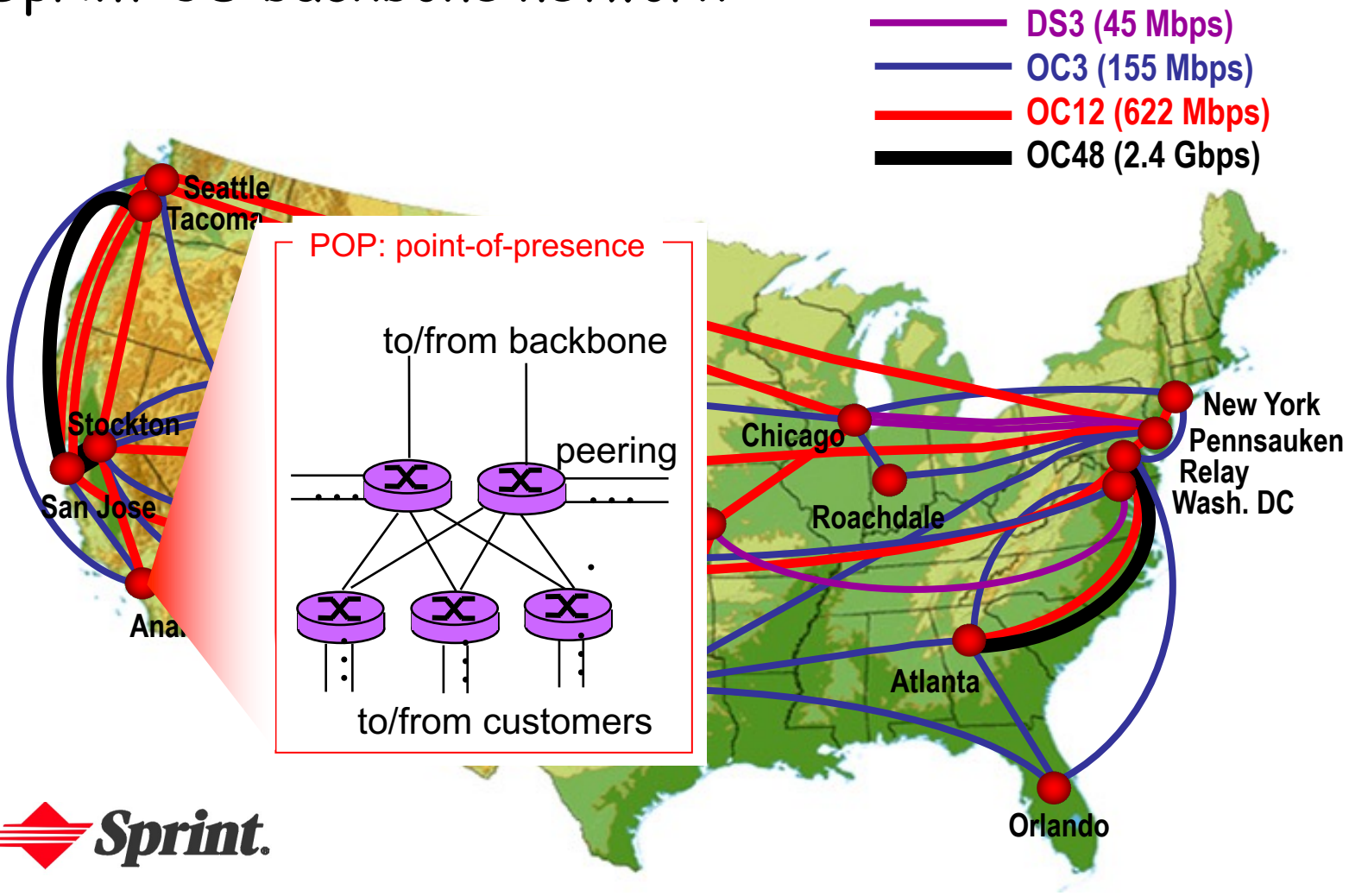
Internet structure: network of networks

- roughly hierarchical
- at center: "tier-1" ISPs (e.g., MCI, Sprint, AT&T, Cable and Wireless), national/international coverage
  - treat each other as equals

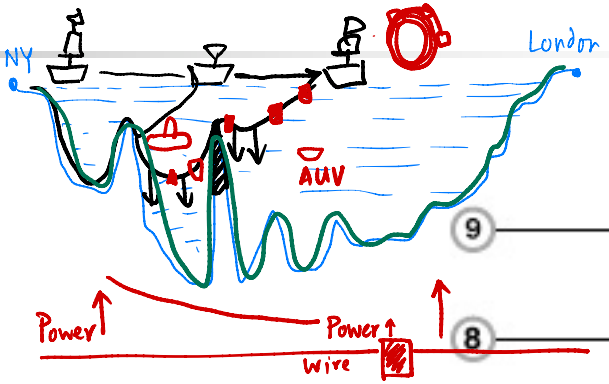


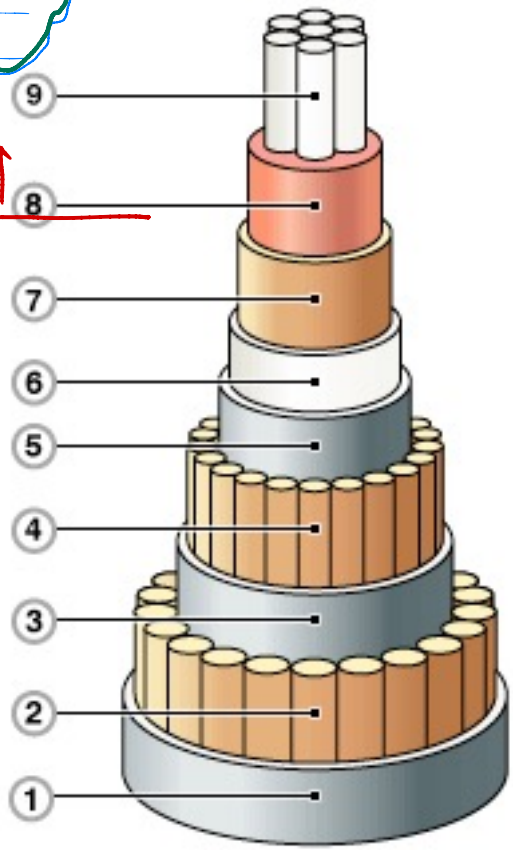
Tier-1 ISP: e.g., Sprint

Sprint US backbone network



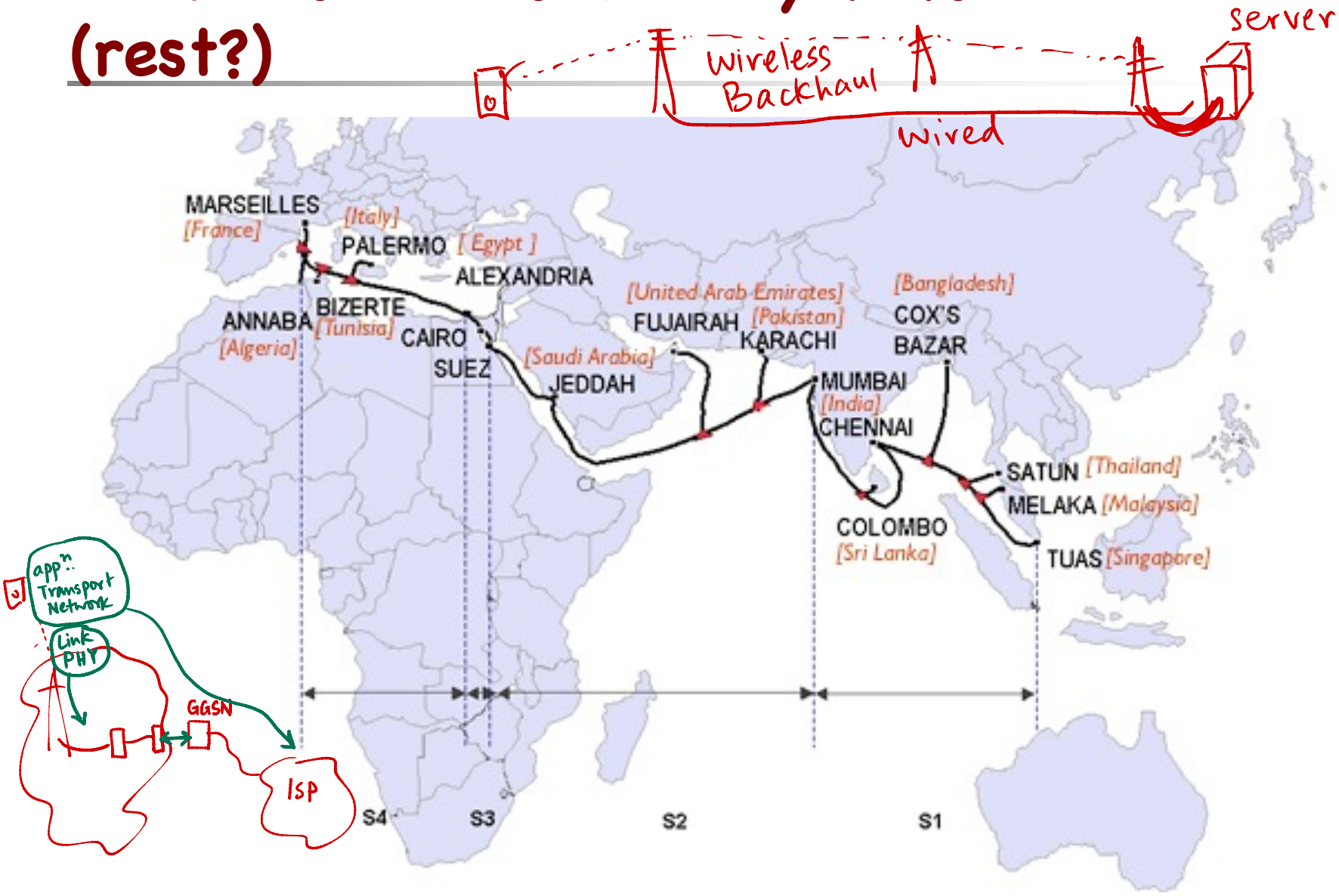
Cables Laid Out in the Oceans





Optical Fiber cross-section

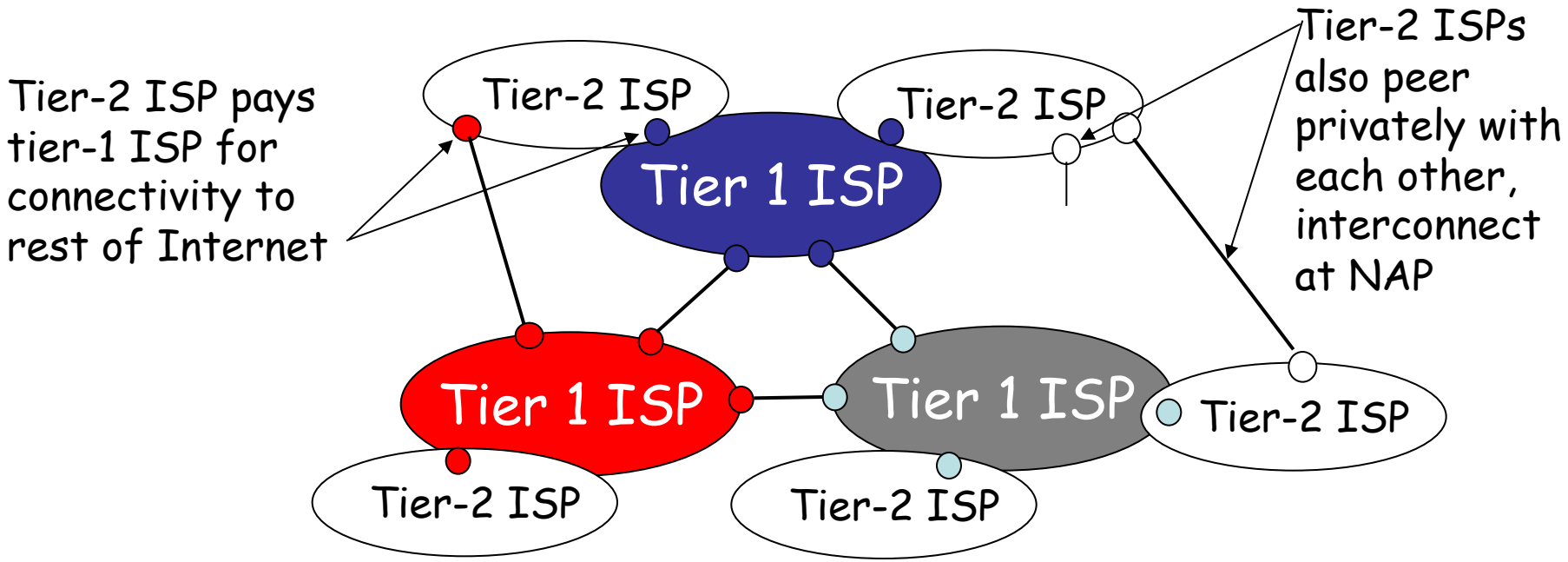
Cable Connections carry 95% traffic (rest?)



Internet structure: network of networks

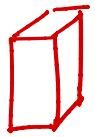
- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs

- France telecome, Tiscali, etc. buys from Sprint



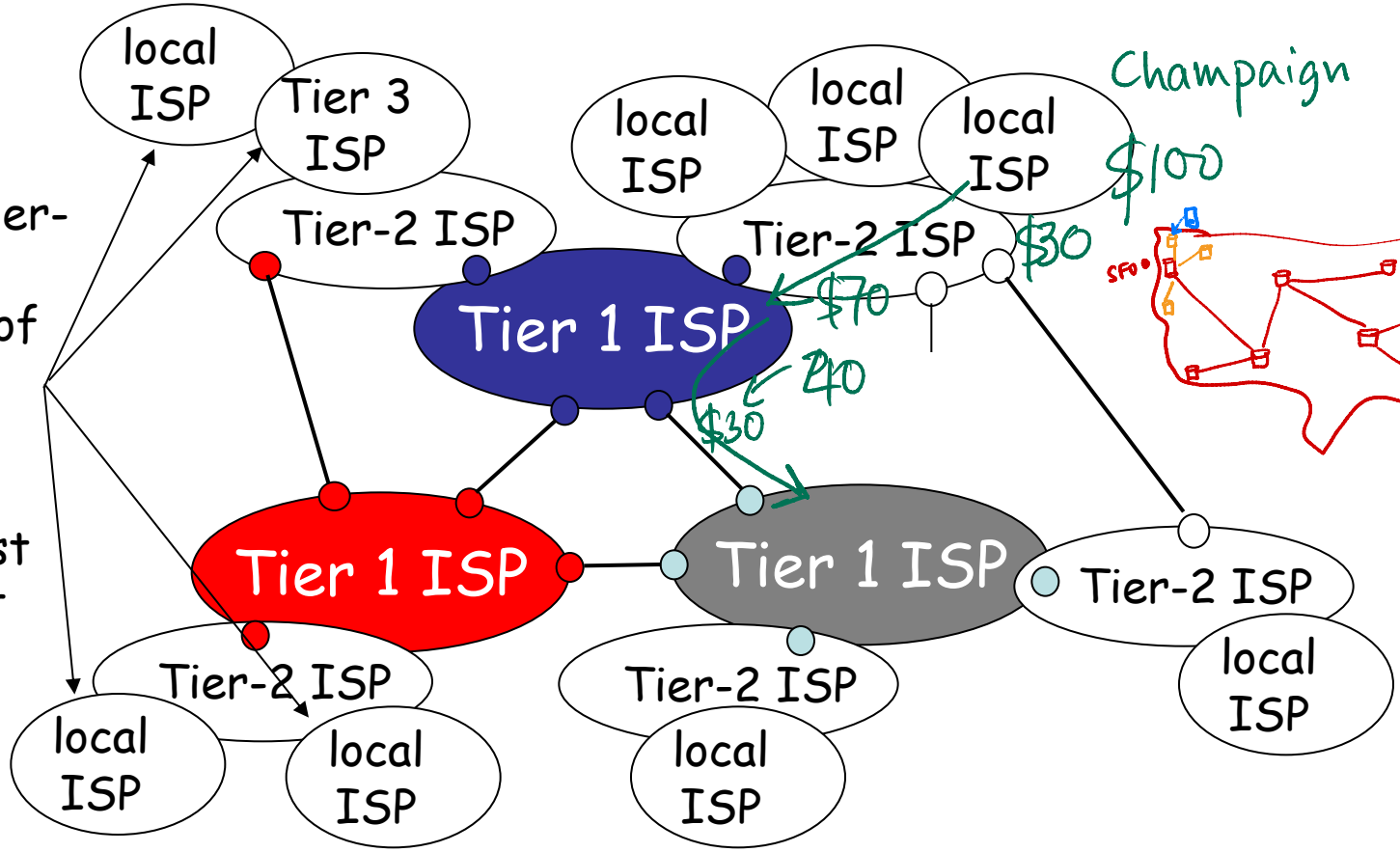
Internet structure: network of networks

- "Tier-3" ISPs and local ISPs (Time Warner, Earthlink, etc.)
  - last hop ("access") network (closest to end systems)



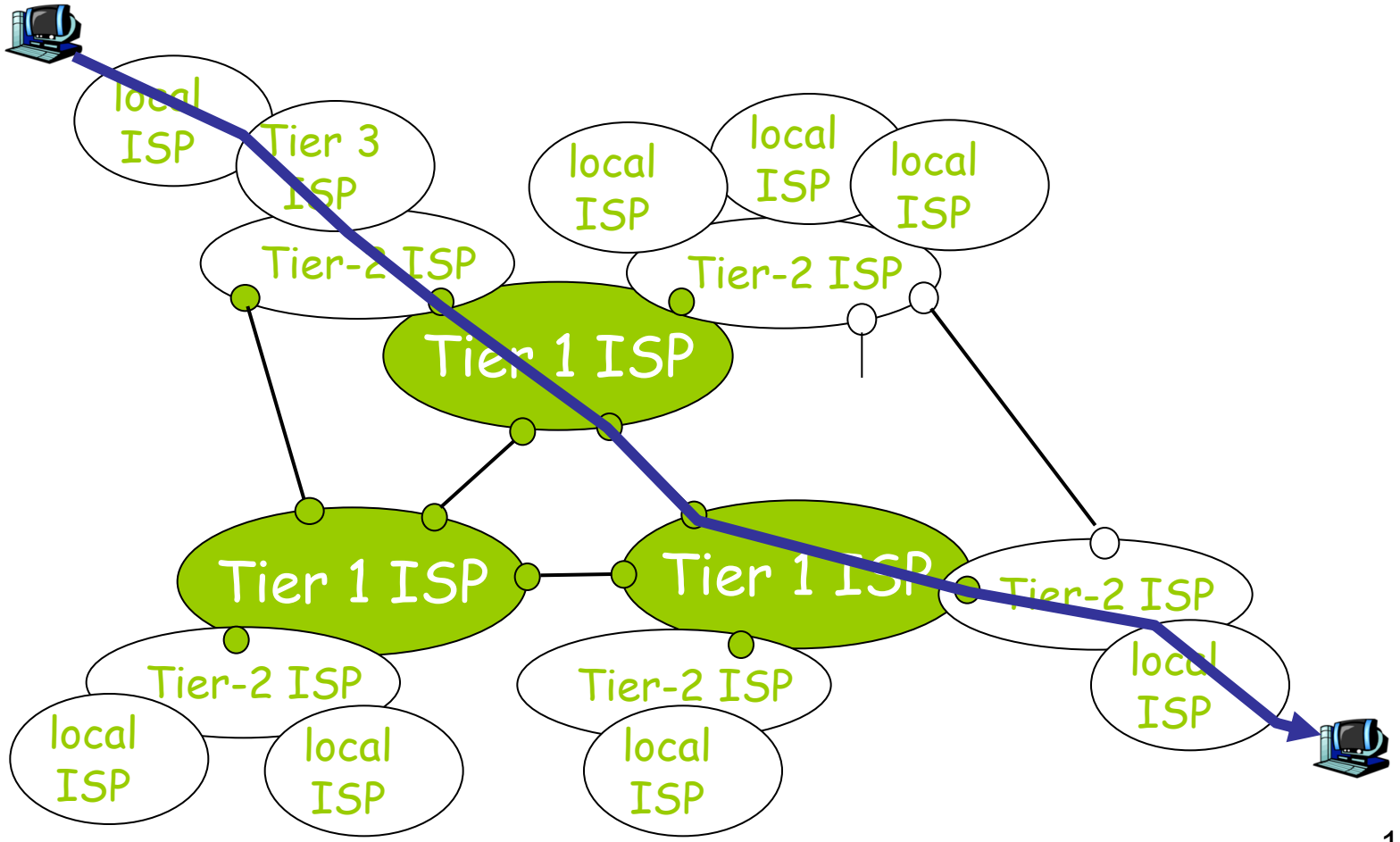
ISP : Internet Service Provider

Local and tier-3 ISPs are *customers* of higher tier ISPs connecting them to rest of Internet



Internet structure: network of networks

- a packet passes through many networks!
  - Local ISP (uber) -> T3 (bus to ORD) -> T2 (flight to NYC) -> T1 (flight to Tokyo)



Organizing the giant structure

Networks are complex!

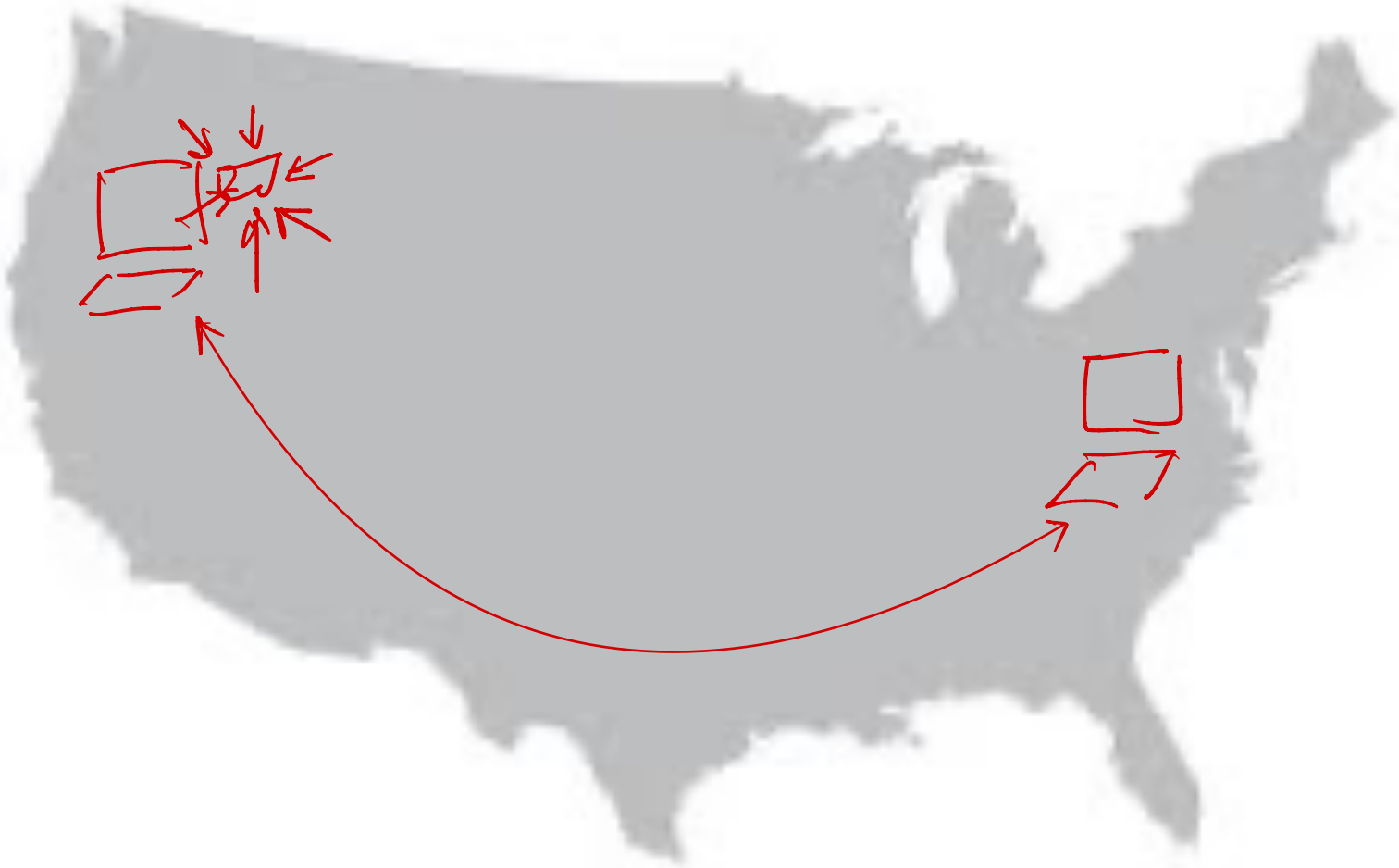
- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:

Is there any hope of *organizing* structure of network?

Or at least our discussion of networks?

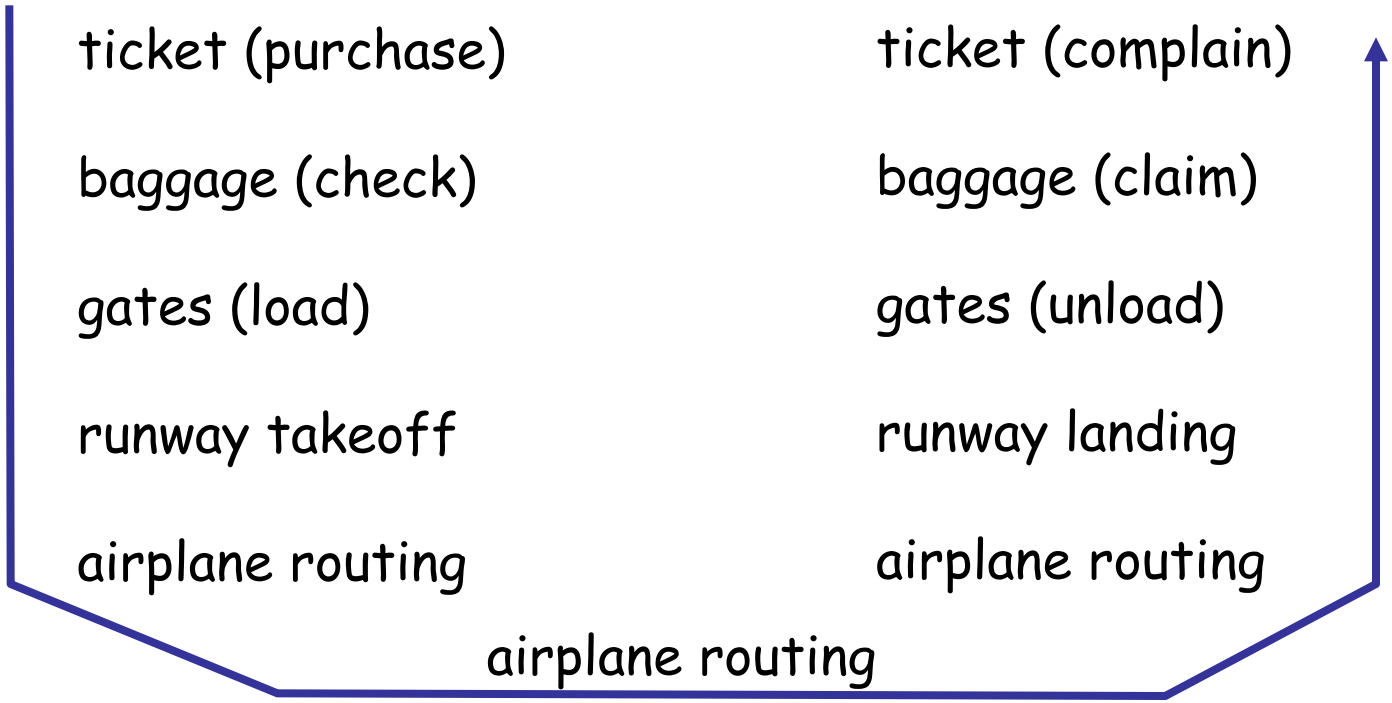
Your job in 1975: Design the Internet across the whole country



Your job in 2021: Design the human colony in Mars

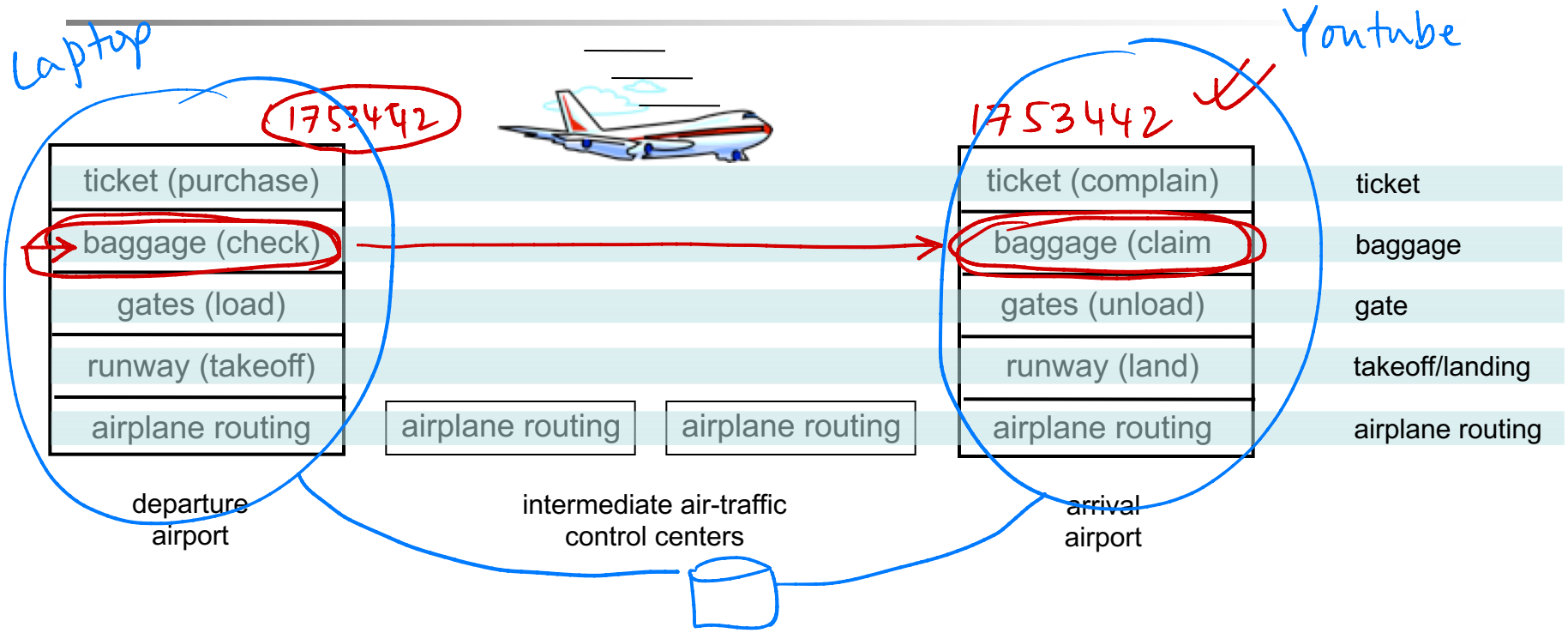
Turn to analogies in air travel

voxel = 3D pixel



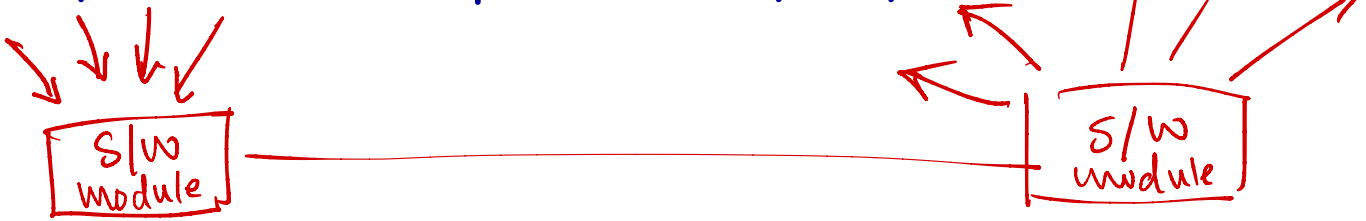
- a series of steps

Layering of airline functionality



Layers: each layer implements a service

- layers communicate with peer layers
- rely on services provided by layer below



Why layering?

- Explicit structure allows identification, relationship of complex system's pieces

- Modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., runway delay (wheels up time) depends on clearance of destination runway … doesn't change the baggage tagging systems … or flight to gate assignment

Protocol "Layers"

- Service of each layer encapsulated

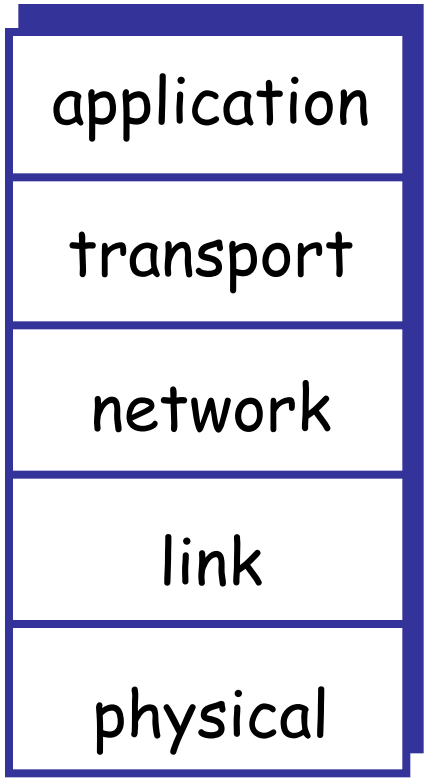
- Universally agreed services called

  PROTOCOLS

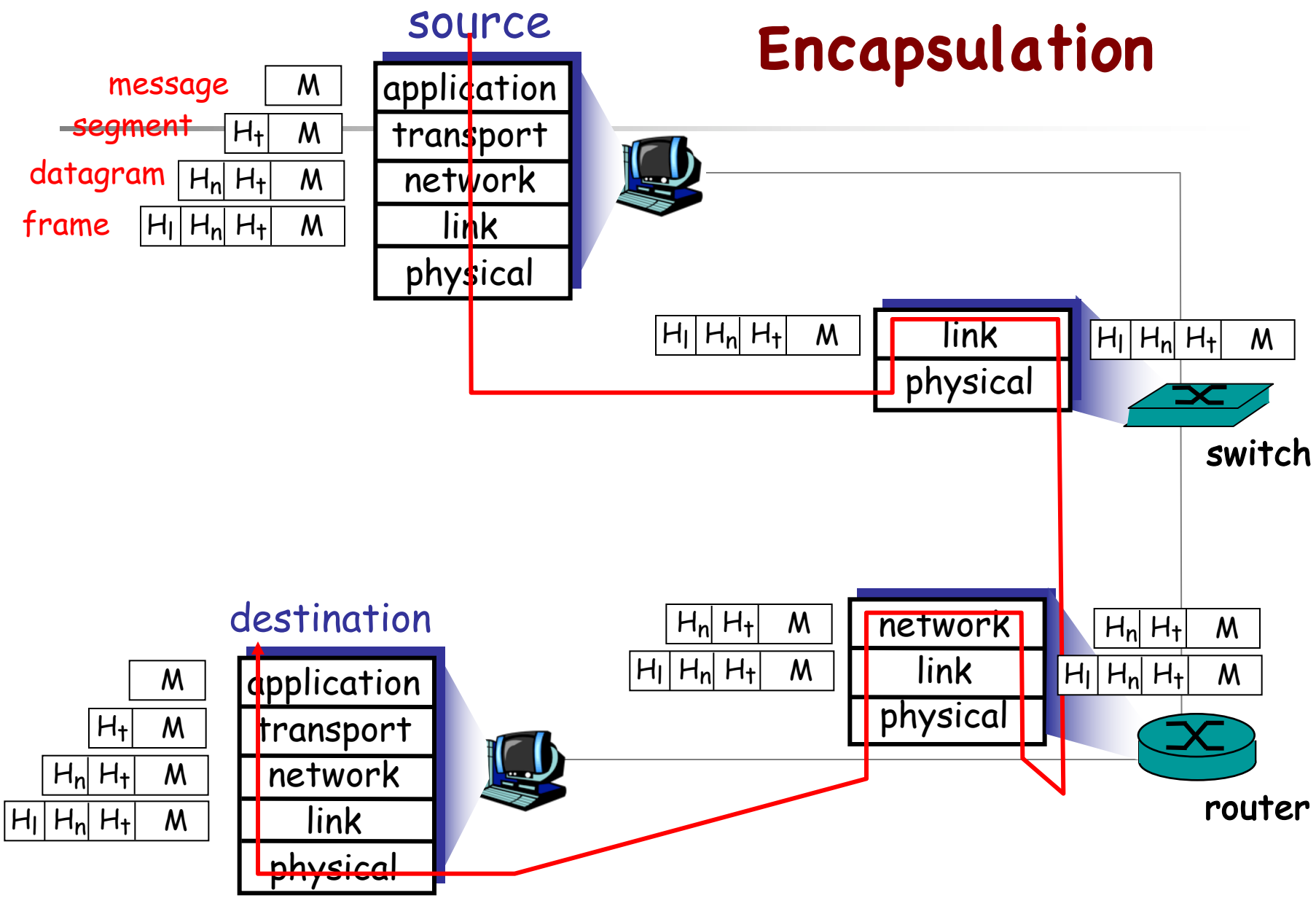
A large part of this course will focus on understanding protocols for networking systems

Internet protocol stack

- application: supporting network applications
  - FTP, SMTP, HTTP, DNS …
- transport: host-host data transfer
  - TCP, UDP …
- network: routing of datagrams from source to destination
  - IP, BGP, routing protocols …
- link: data transfer between neighboring network elements
  - PPP, Ethernet, WiFi, Bluetooth …
- physical: bits "on the wire"
  - OFDM, DSSS, CDMA, Coding …



Encapsulation



Success of Layering

- Protocol stack successful in Internet
- Internet uses wired physical layer links
  - Very reliable
  - Bit Error Rate (BER) = 10^{-8}
- What about wireless networks
  - Very unreliable due to channel fluctuations
  - Due to co-channel interference
  - Due to external noise
- Does horizontal layering still hold ?

Questions ?

Assignment # -1

Watch "City in the Sky" documentary on Netflix

You will appreciate both airline systems and
The Internet much more than you do now …