Computer Networks

ECE/CS 438

Fall 2020

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Dept. of ECE and CS

ILLINOIS

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Course Logistics

Welcome to ECE/CS 438

- Timing: Tu/Th 3:30 – 4:50pm, UIUC time
- Mode: Online (Zoom)
- Course URL: https://courses.grainger.illinois.edu/cs438/fa2020/

- Instructor: Romit Roy Choudhury

  Faculty ECE and CS

  PhD from UIUC, 2006

  Research: Wireless/Mobile Networking, Sensing

  Webpage: croy.web.engr.illinois.edu

- Office Hours: Tu/Th after class

  Or email croy@illinois.edu for 1:1

Welcome to ECE/CS 438

- Teaching Assistants (TAs) … see URL for email IDs

Wally

Zhijian

Mingjia
(ZJUI TA)

Welcome to ECE/CS 438

- Prerequisite: - Probability
  - Programming

- Further courses:
  - Advanced Computer Networks
  - Advanced Wireless Networking
  - Hot Topics in Mobile Computing
  - Advanced Distributed Systems
  - IoT, Big Data, and CyberPhysical Systems
  - …

Welcome to ECE/CS 438

- Information Dissemination:

URL: https://courses.grainger.illinois.edu/cs438/fa2020/

Most course related information will be posted on the website

When in doubt, check the webpage.

- Some reminder/clarification emails may be sent out

- Piazza:
  - Just search for "ECE CS 438" on Piazza.
  - Piazza meant entirely for students to communicate.
  - Faculty and TAs may respond occasionally.

Welcome to ECE/CS 438

- Grading:
  - Homework (3 or 4): 15%
  - Programming Assignments (3 or 4): 25%
  - 1 mid-term exam: 25%
  - Final exam: 35%

  - Programming assignments may be in groups of 2.
    Each group makes single submission.

  - 4 credit students need to complete a mini-project
    and submit a report at the end of semester (more later)

Finally

- Academic honesty
  1. I believe you won't cheat. If you are anxious, or in great pressure … talk to me. I understand, and some accomodations can be made. But don't take the "wrong pill".

  2. In the long run, GPA does not matter as much as you think it does. Tarnishing a long-term career not worth the 0.05 net GPA points.

  3. I am lenient and easy-going until someone is proven to be cheating.

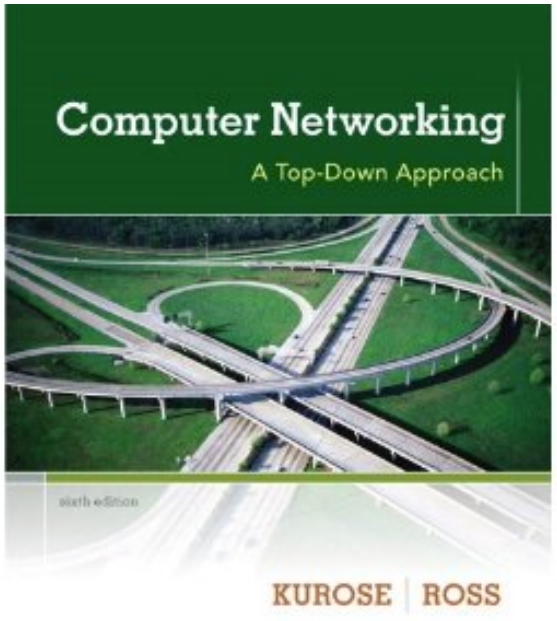
Course Summary
(Very Briefly)

Course information

- Course materials:
  - Text:

    Computer Networking: A Top Down Approach
    J. Kurose & K. Ross,

    Addison Wesley

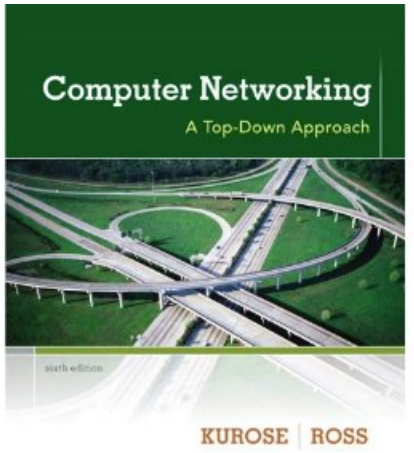


  - Class notes/slides
    - Acknowledgment to Jim Kurose
  - Some supplementary reading material

What is this course about?

- *Introductory* (first) course in computer networking
  - Undergrads, early grad students

- learn principles of computer networking
- learn practice of computer networking
- Internet architecture/protocols as case study
- Real wireless networks as case studies
- Glimpses into the future of networking



Course information

- By the time you are finished …
  - You understand variety of factoids and concepts
  - Propagation delay, transmit time, queueing, …
  - Internet layered architecture, HTTP, DNS, P2P, …
  - Sockets, Ports, …
  - Congestion Control, Flow Control, TCP, …
  - Routing, Basic Graphs, Djikstra's Algorithm, IP, BGP, OSPF, …
  - DSL Vs Cable, Aloha, CSMA, TDMA, Token, …
  - Cellular Network architecture, handoff, roaming, Mobile IP, …
  - Wireless Networks (WiFi)
  - Security, RSA, Digital certificates, MIM attacks, …
  - …

If you understand 75% of these terms, you shouldn't be here

What this Course Does Not Cover

- Does not cover
  - Device drivers, SDNs, cloud computing …
  - Network theory, graph theory, proofs
  - Radio hardware, embedded systems, IoT, scheduling
  - Modulation schemes, transmitter/receiver design
- Not a "communications" course

- This is course on
  - Understanding, analyzing, and (perhaps) designing protocols and algorithms in networking systems (with case studies in wired and wireless networks)

What's the difference between

Communications

And

Networking

Finally

- I cannot / will not / should not be speaking alone in class
  - Questions
  - Comments
  - Disagreements
  - Debates … are highly encouraged
- This course can be real fun
- Whether it will be …
  - Is up to you and me


Hello!
I am ECE/CS 438

Computer Network Architecture

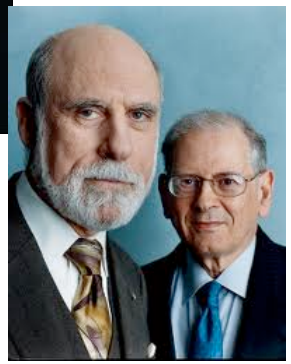
Past, Present, and Future

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



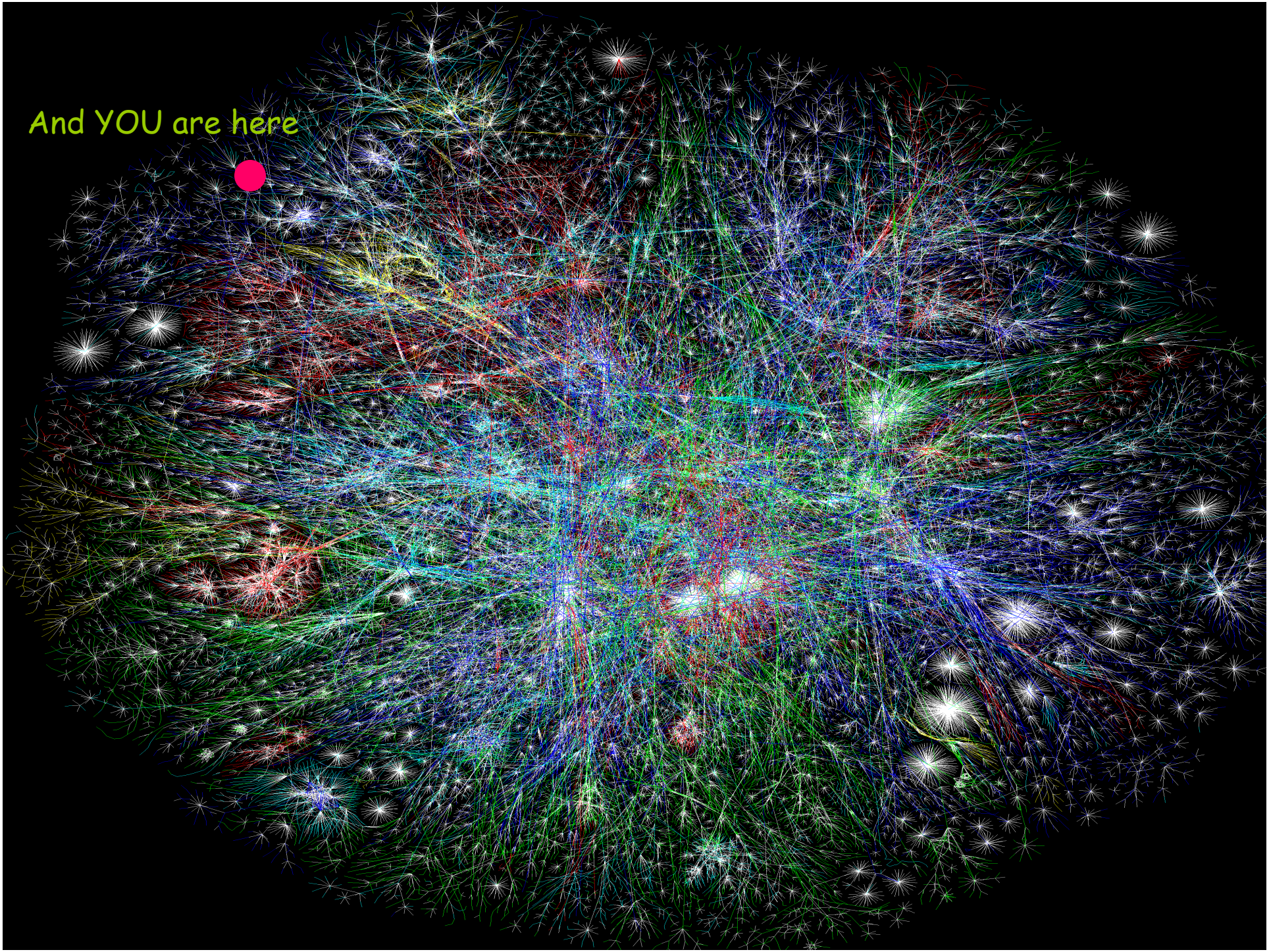




On the Shoulders of Giants …

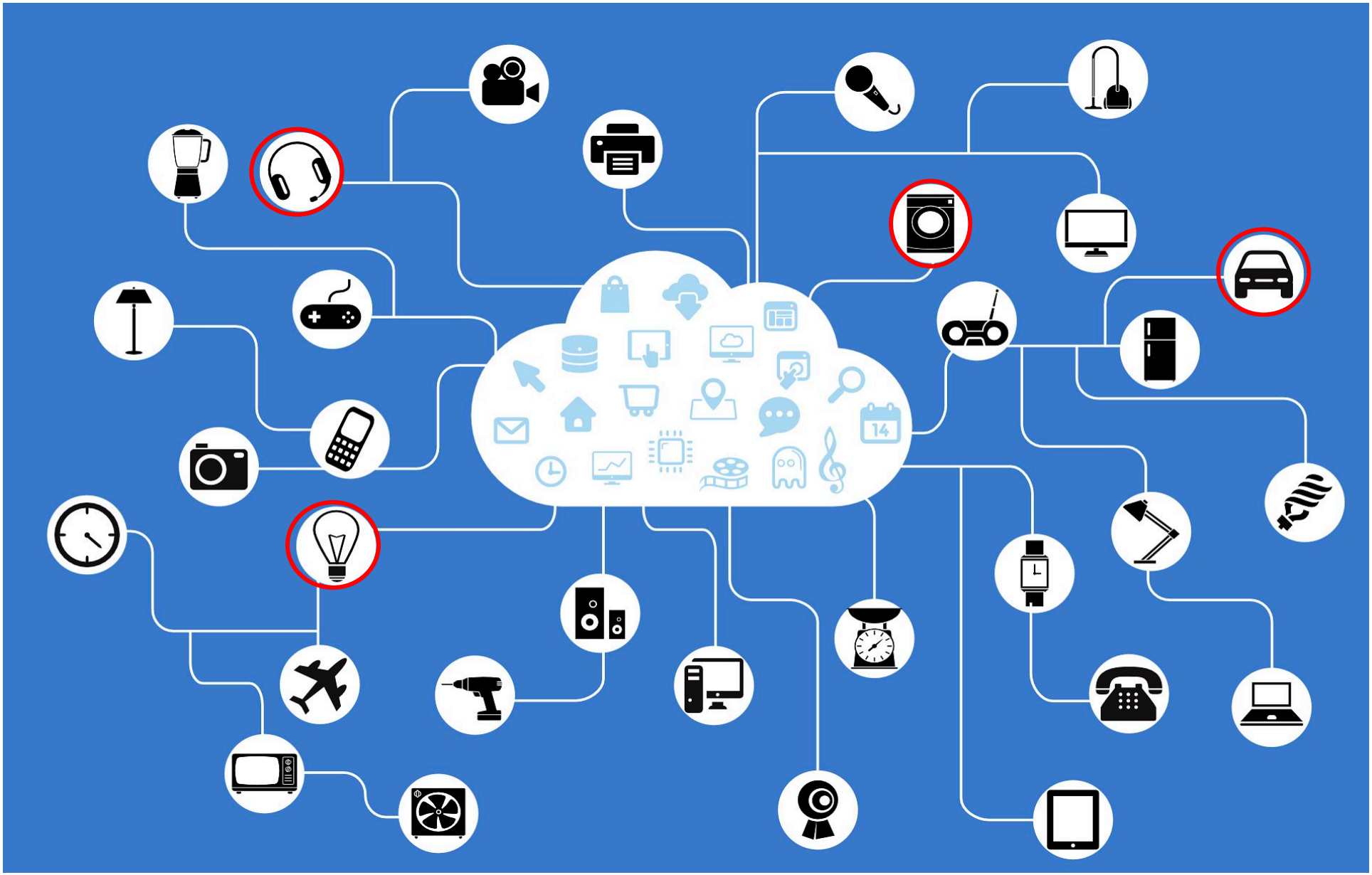
- 1973: David Clark, Bob Metcalfe implemented TCP and designed ethernet at Xerox PARC
- 1975: Paul Mockapetris developed DNS system for host lookup
- 1980: Radia Perlman invented spanning tree algorithm for bridging separate networks
- Things snowballed from there on …

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


And YOU are here

And by "YOU" I mean …

"Cool" internet appliances



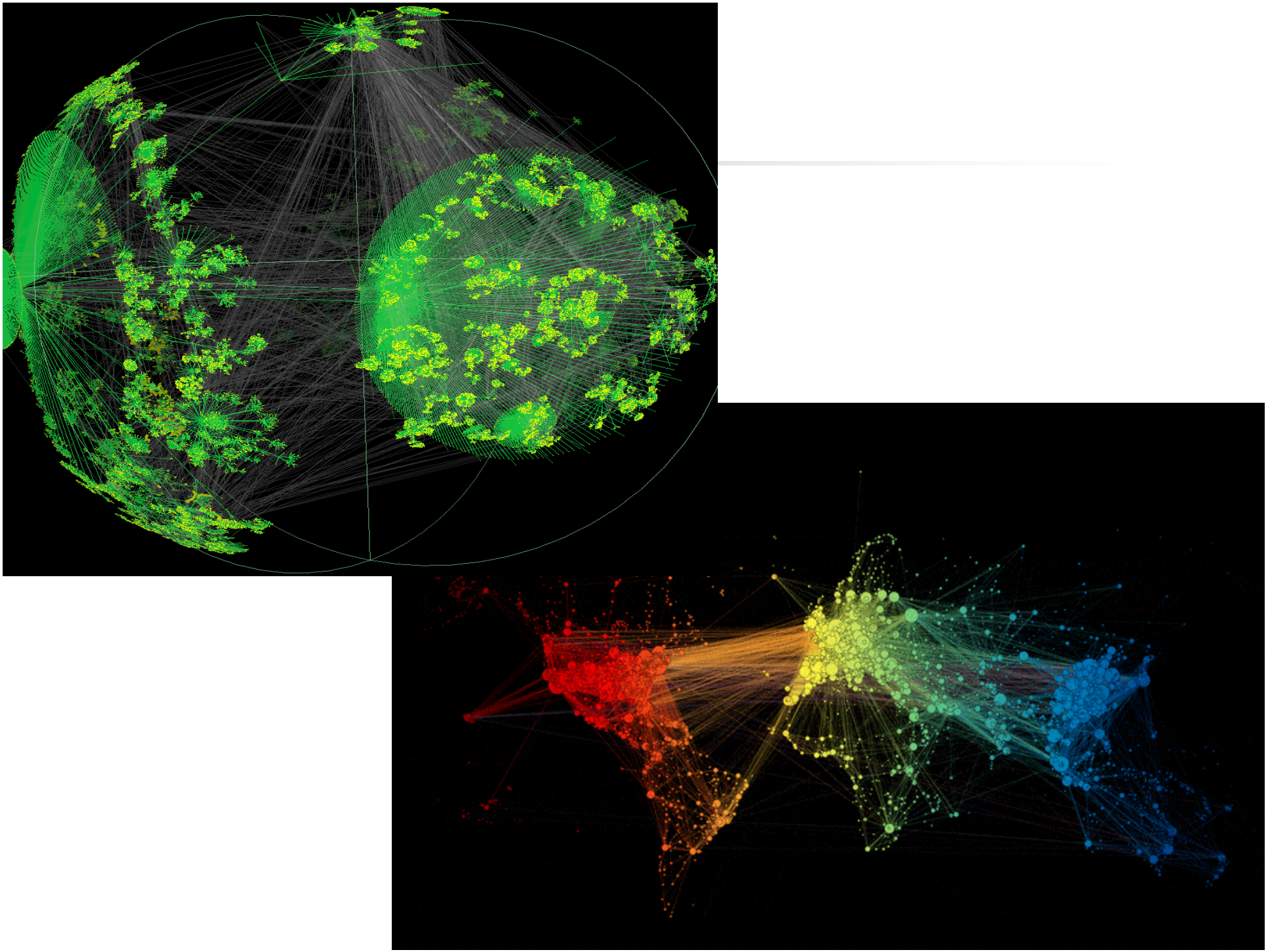
"Cool" internet appliances

Web-enabled toaster +
weather forecaster

And Of Course people …

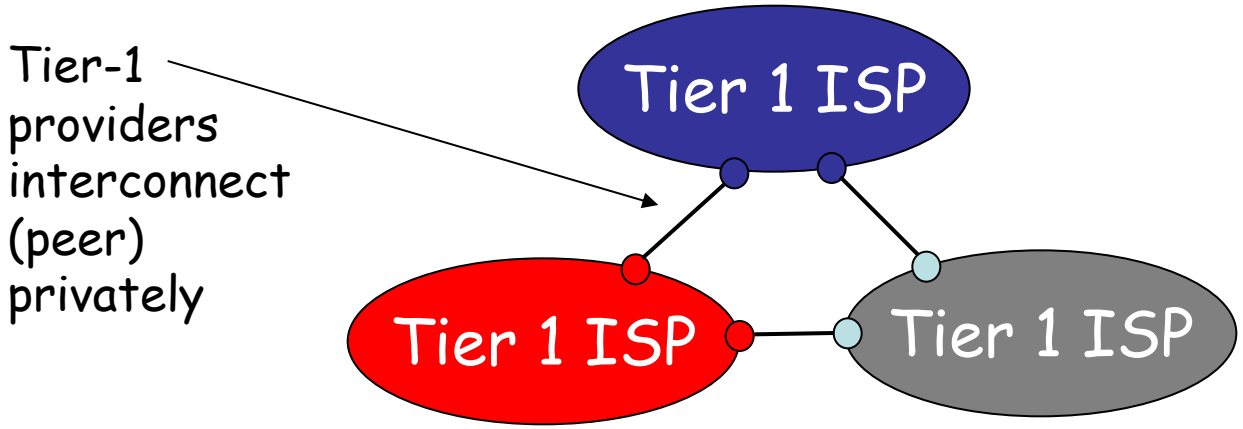
InterNetwork

- 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



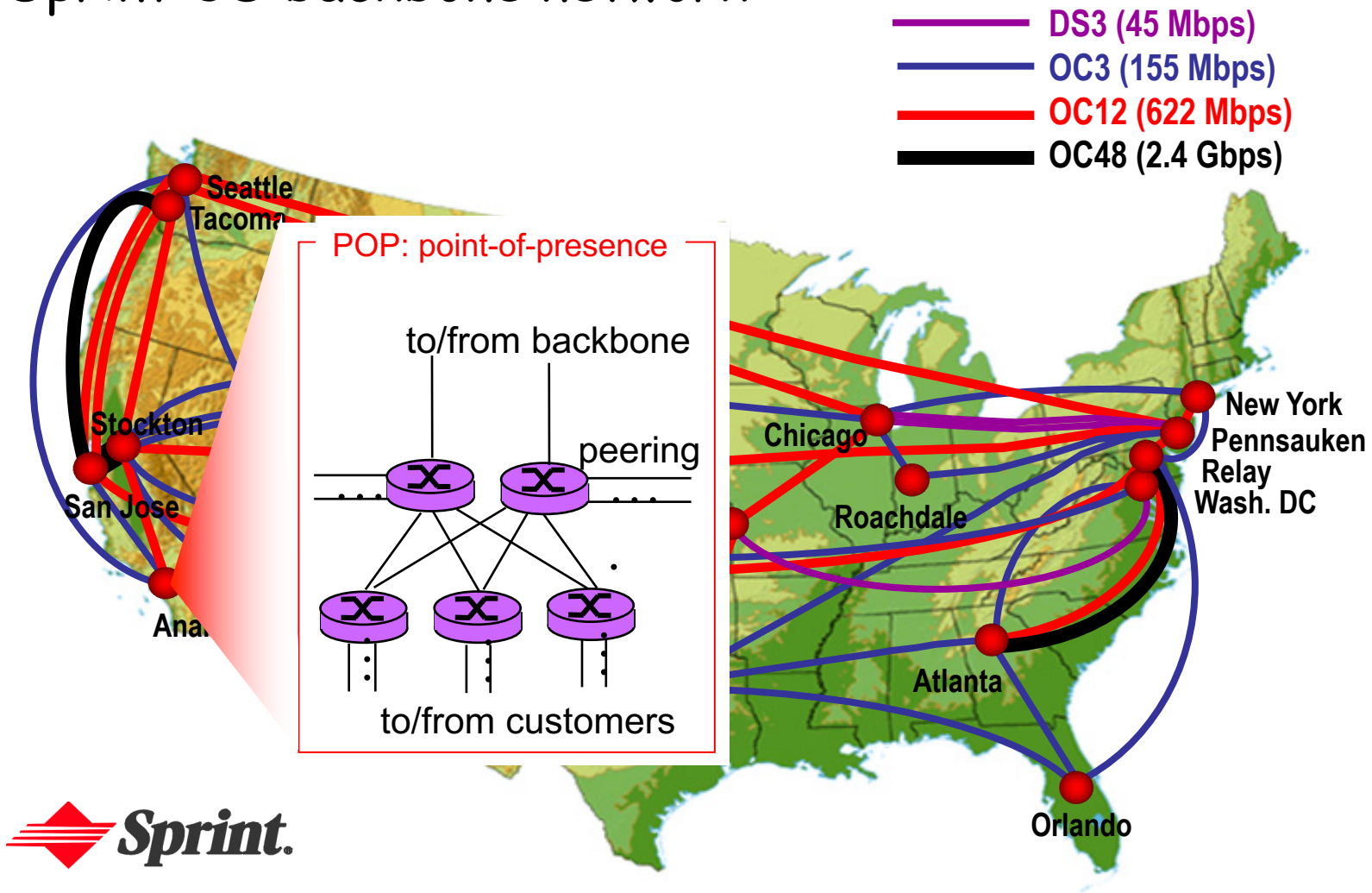
Internet structure: network of networks

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



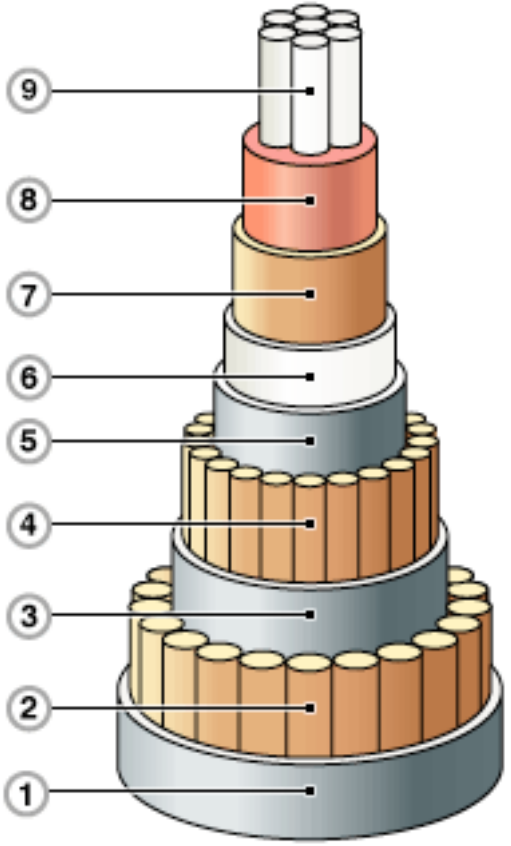
Tier-1 ISP: e.g., Sprint

Sprint US backbone network



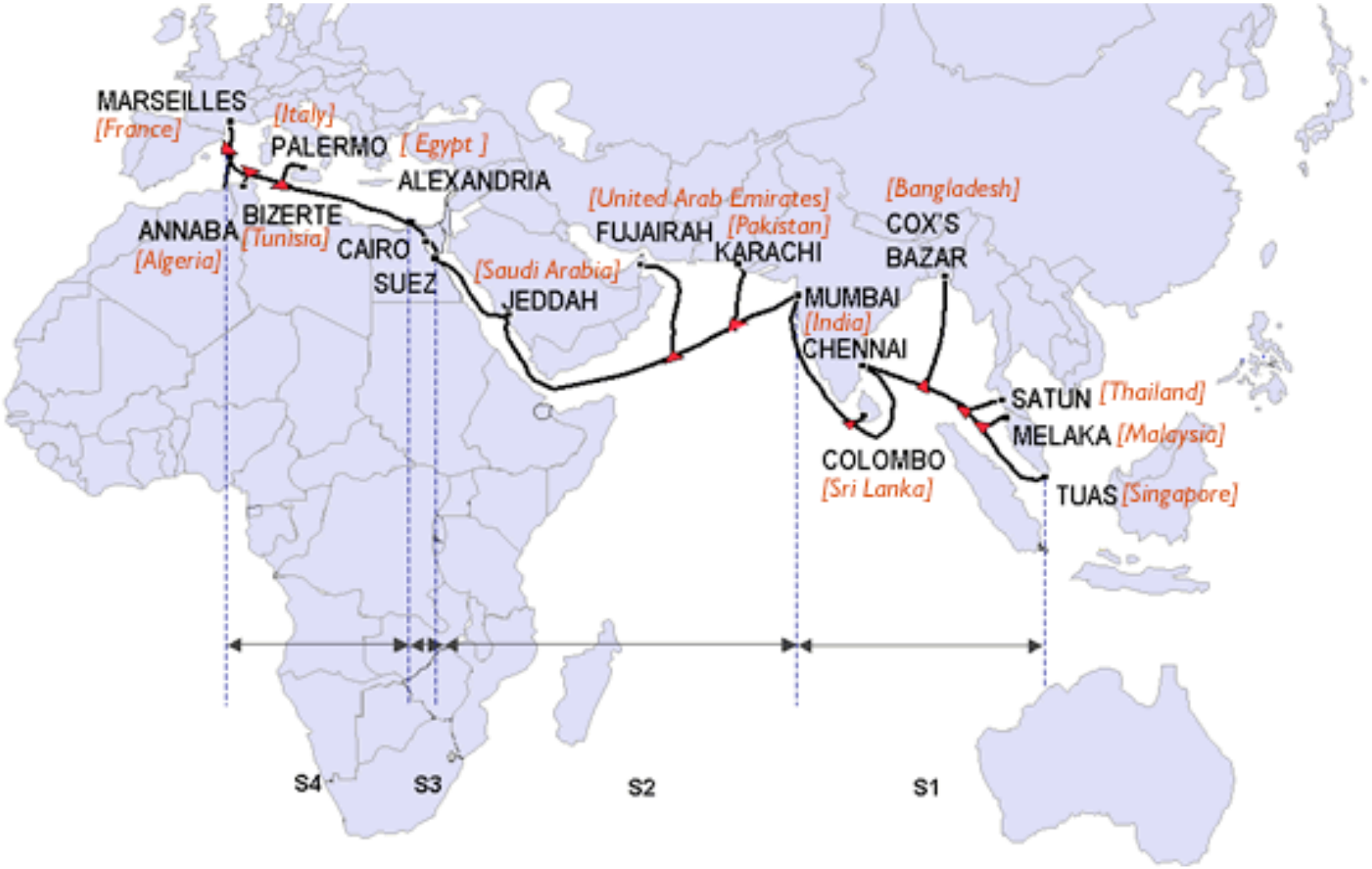
Sprint.

Cables Laid Out in the Oceans



Optical Fiber cross-section

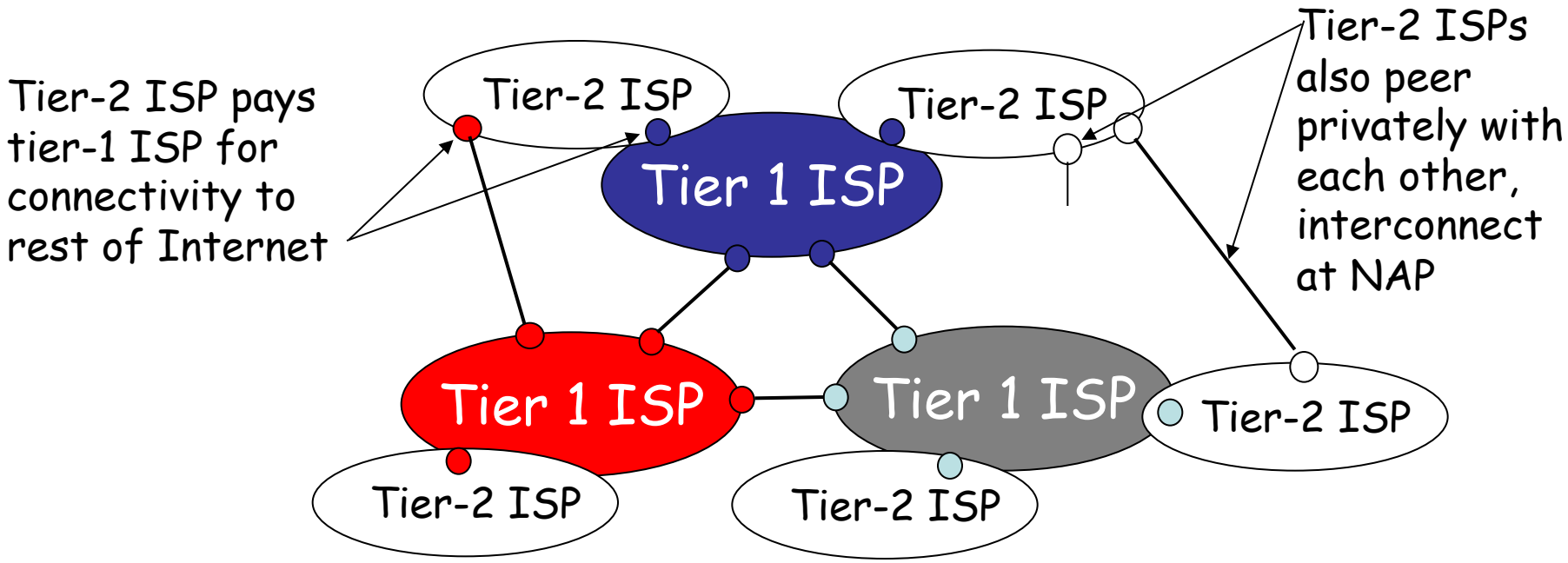
Cable Connections carry 95% traffic (rest?)



Internet structure: network of networks

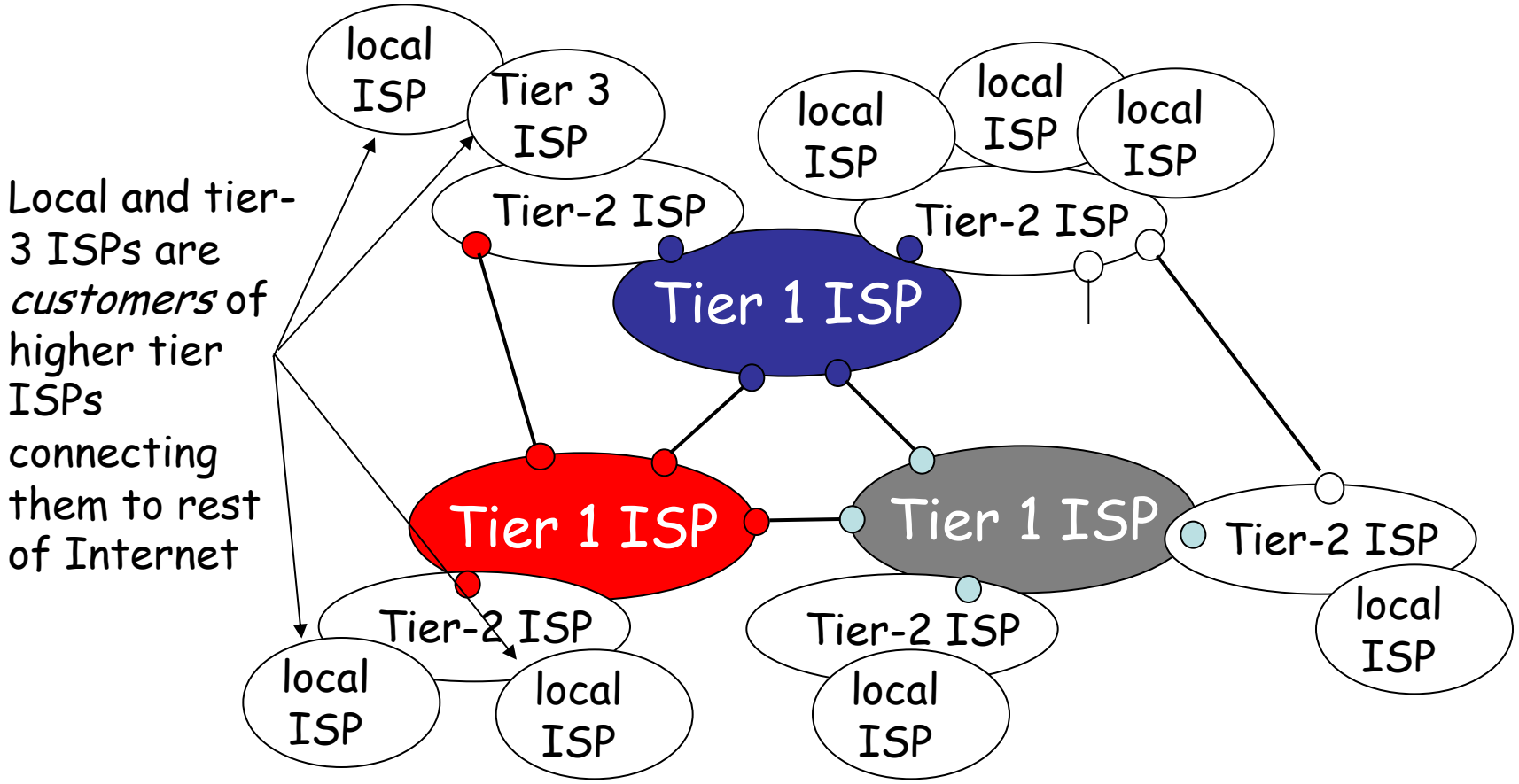
- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs

- France telecome, Tiscali, etc. buys from Sprint

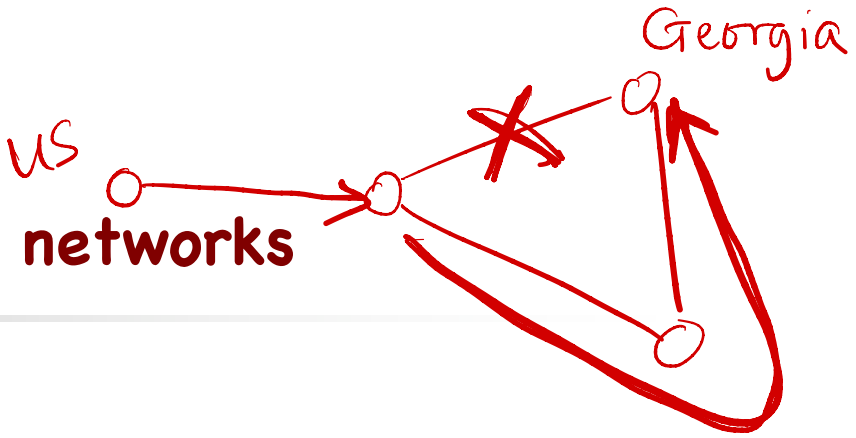


Internet structure: network of networks

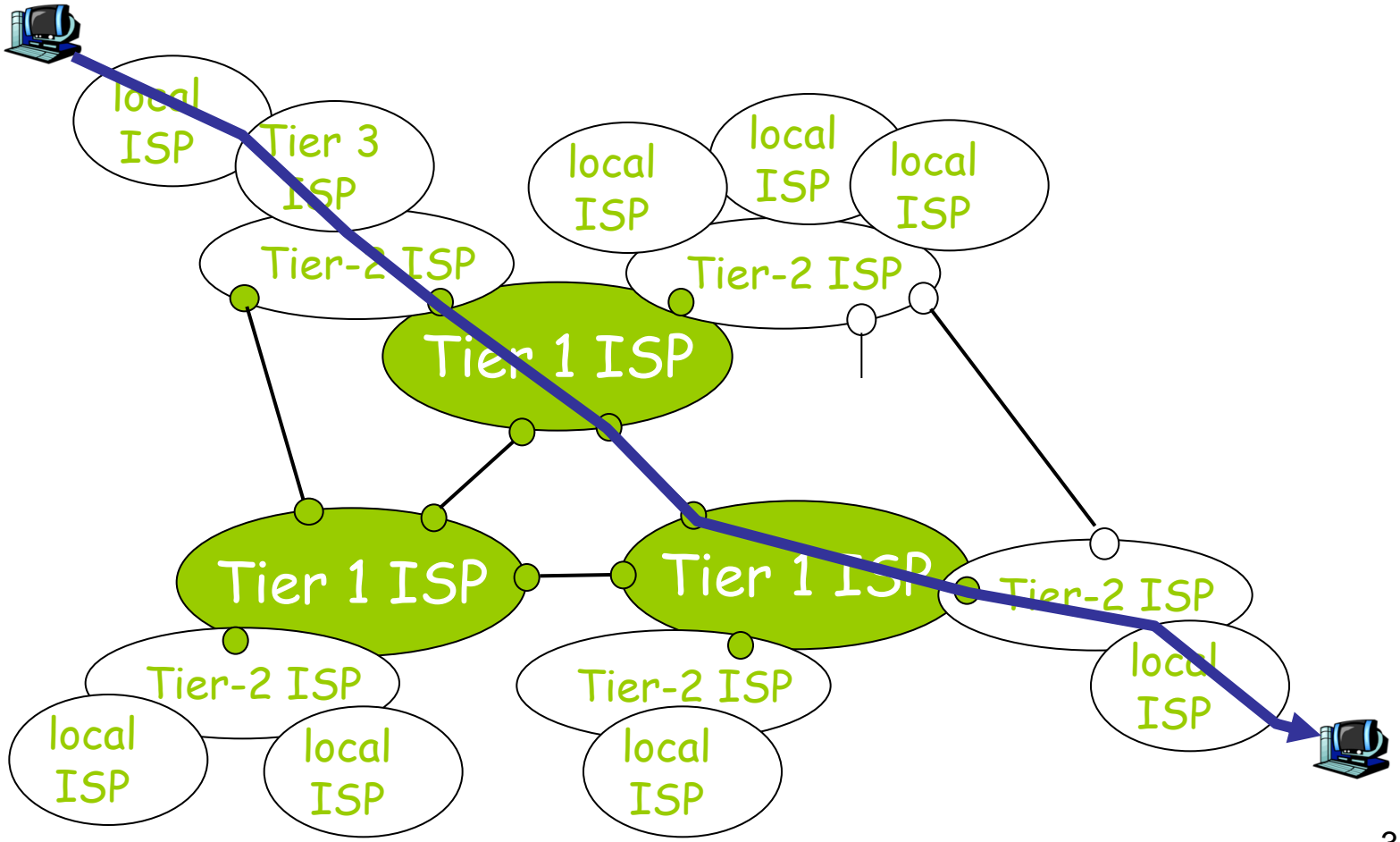
- "Tier-3" ISPs and local ISPs (Time Warner, Earthlink, etc.)
  - last hop ("access") network (closest to end systems)



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!

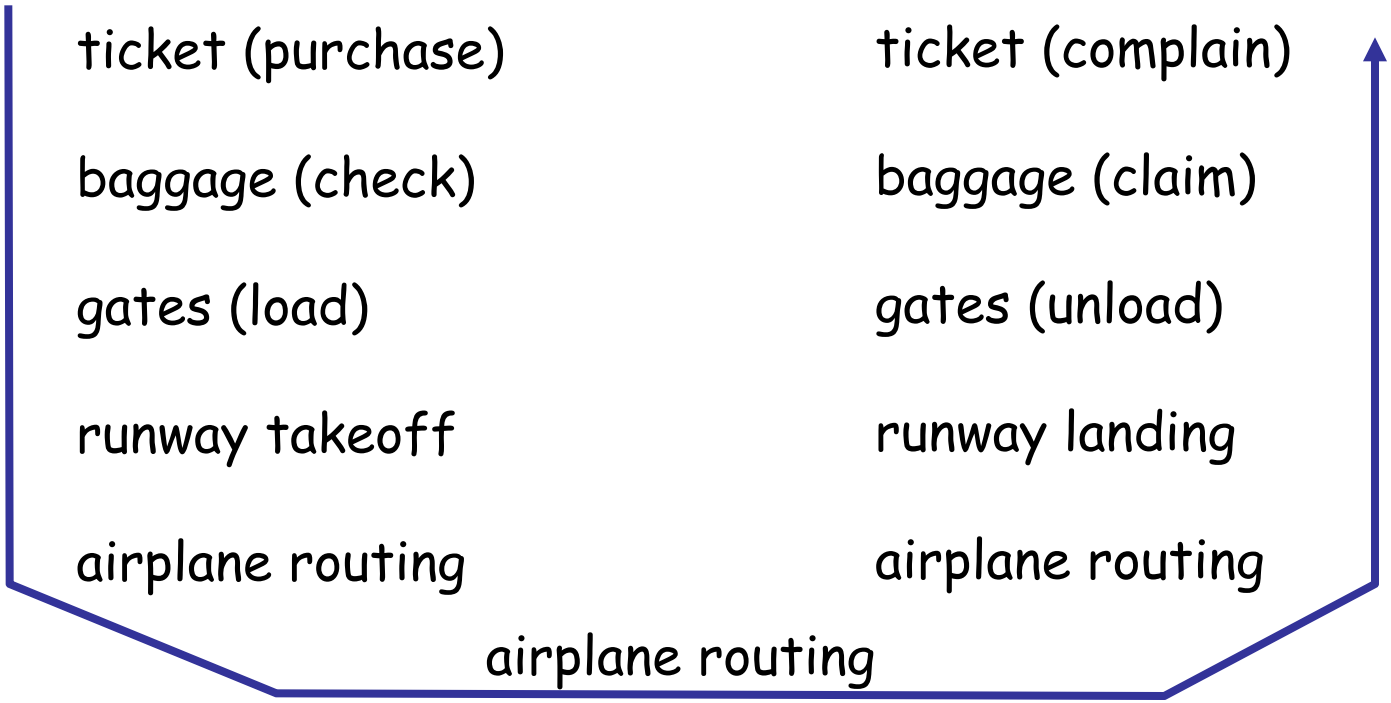
- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:

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

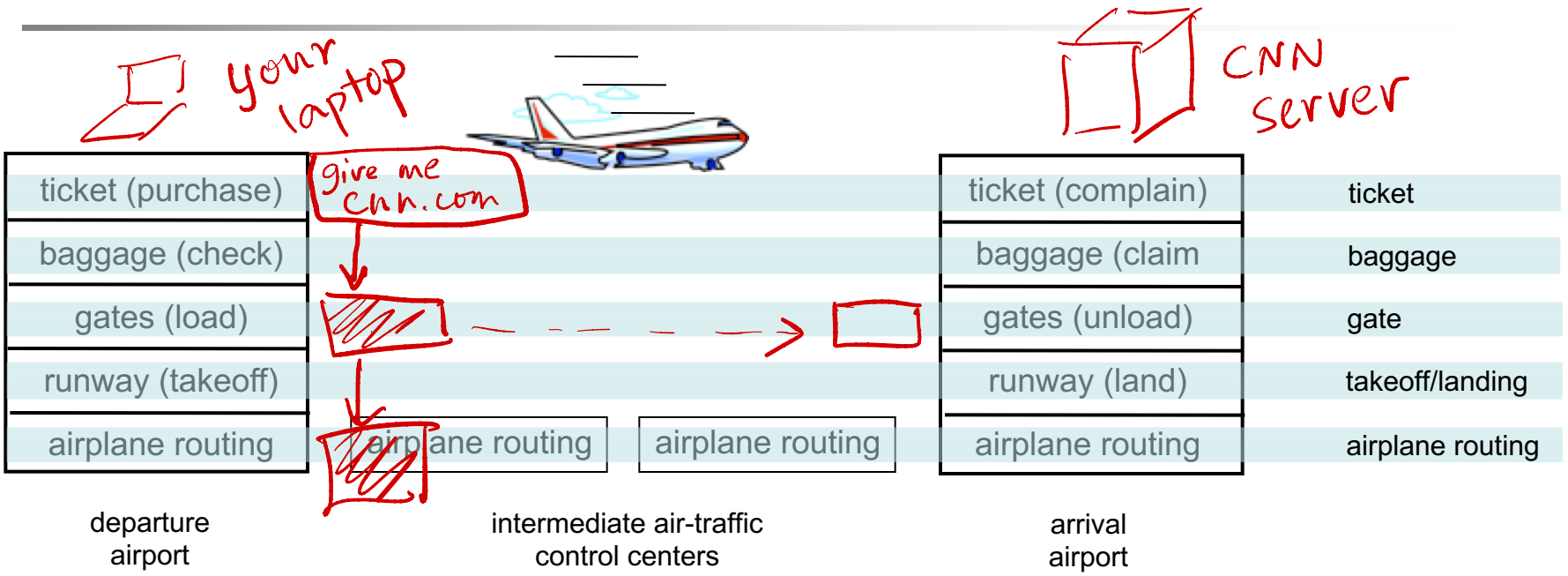
Or at least our discussion of networks?

Turn to analogies in air travel



- 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

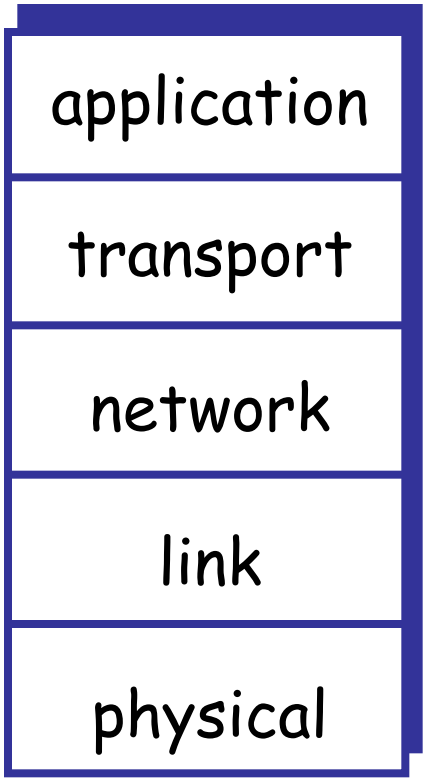
- Universally agreed services called

  PROTOCOLS

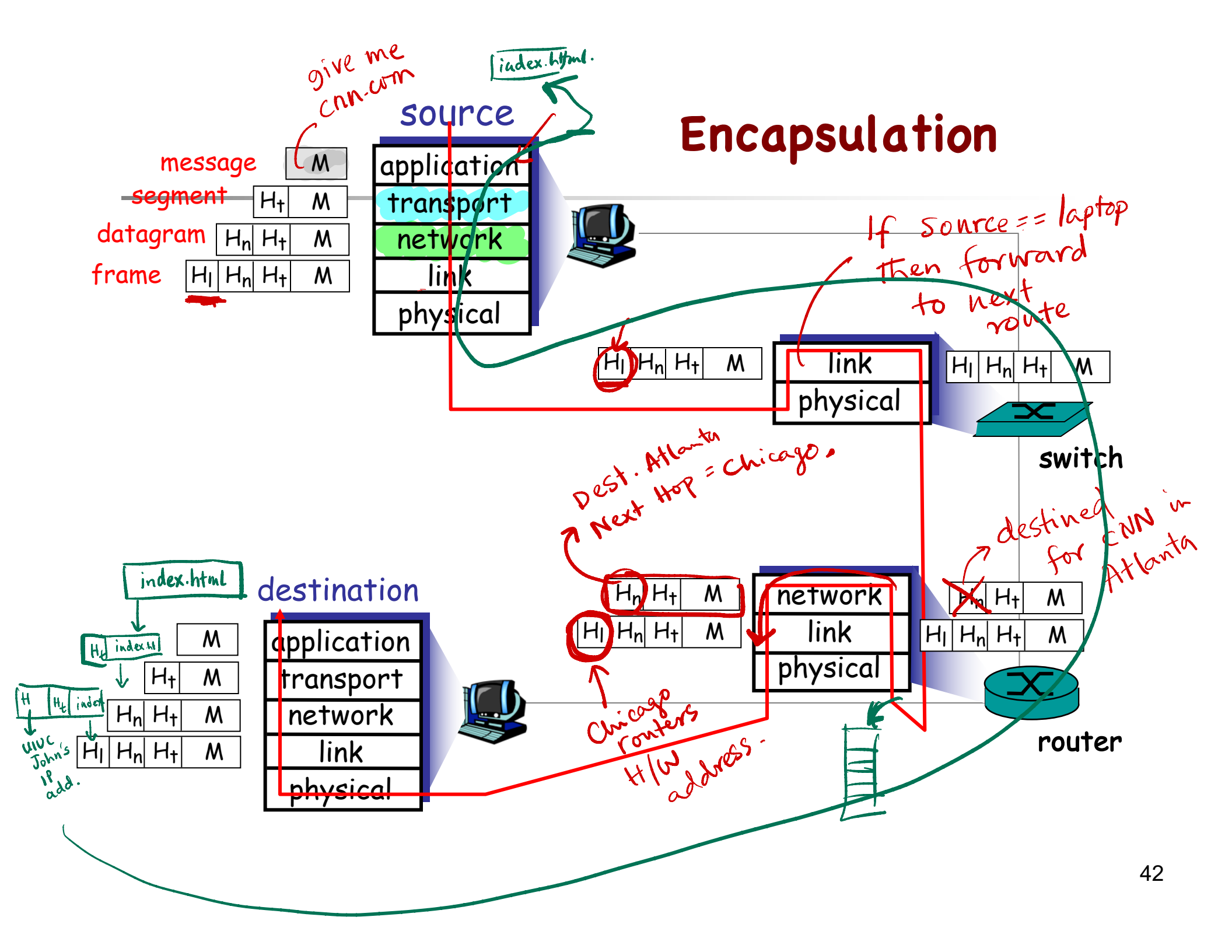
A large part of this course will focus on understanding protocols for networking systems

Internet protocol stack

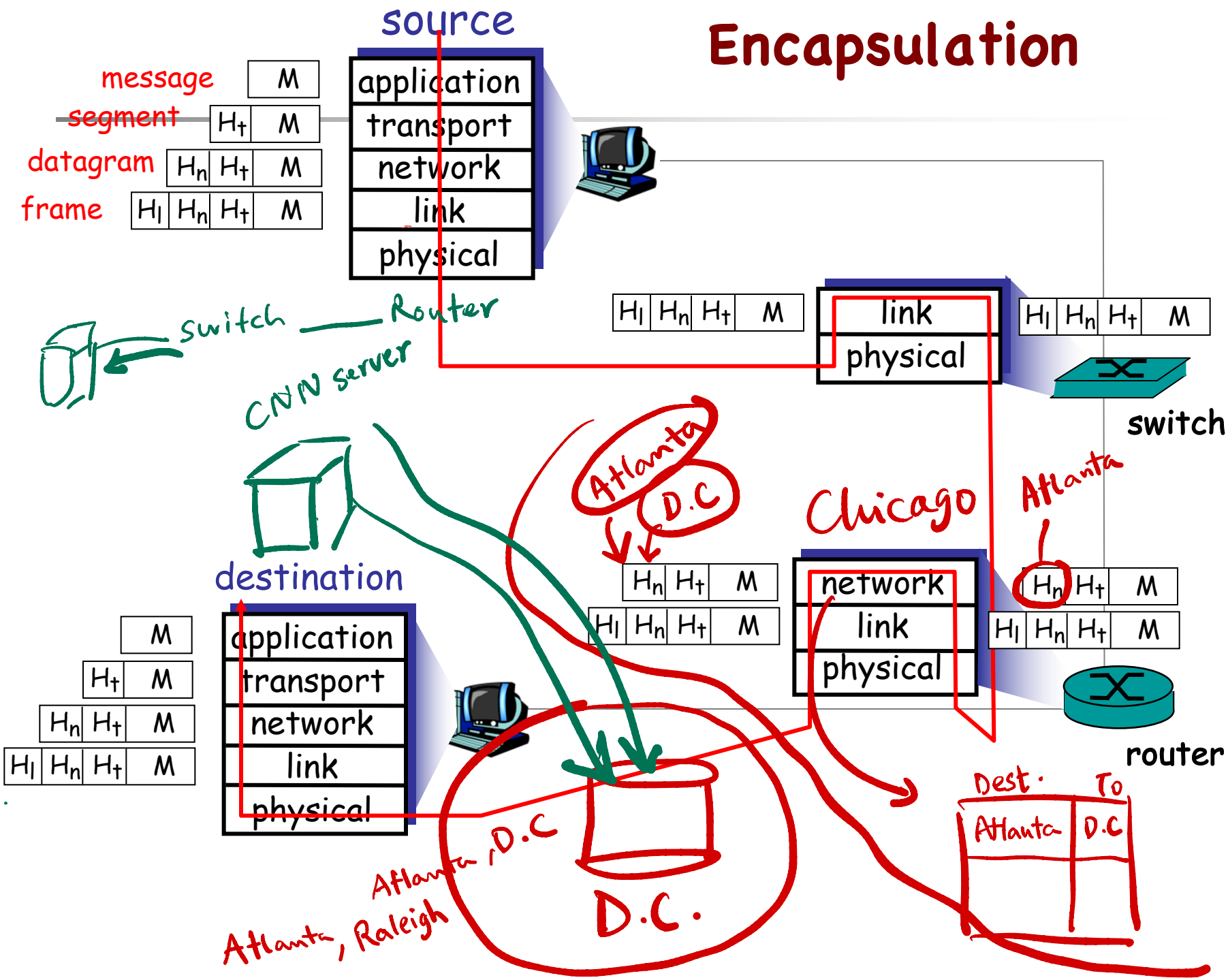
- application: supporting network applications
  - FTP, SMTP, HTTP, DNS …
- transport: host-host data transfer
  - TCP, UDP …
- network: routing of datagrams from source to destination
  - IP, BGP, routing protocols …
- link: data transfer between neighboring network elements
  - PPP, Ethernet, WiFi,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

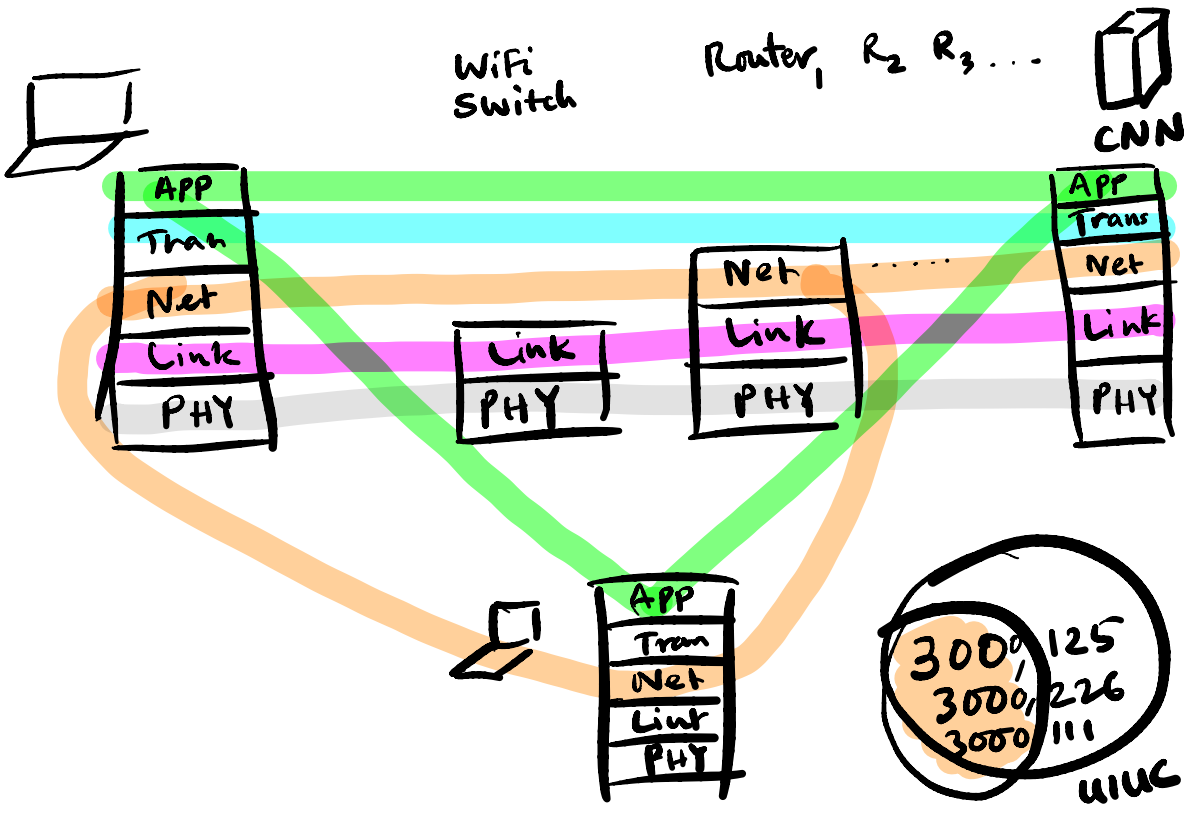


Encapsulation



Encapsulation

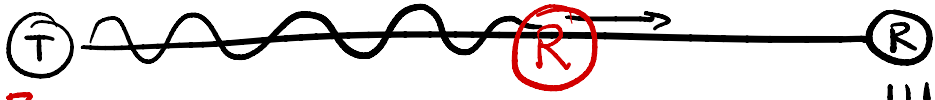



WiFi
Switch
Router, R2 R3 . . .
CNN
App
Tran
Net
Link
PHY
Link
PHY
Net
Link
PHY
App
Trans
Net
Link
PHY
App
Tran
Net
Link
PHY
3000/125
3000/226
3000/111
UIUC

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 ?



1111 0100 1

B

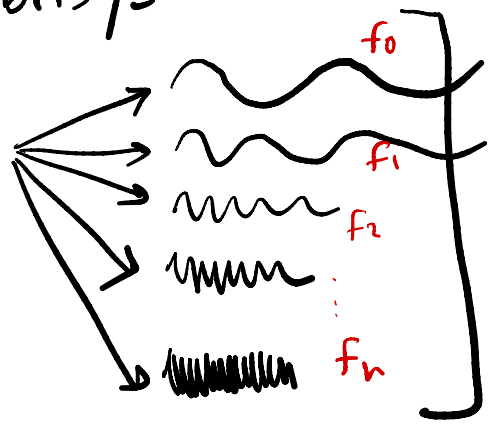
Bandwidth of comm.

Data Rate = bits/s

WiFi — 20 MHz

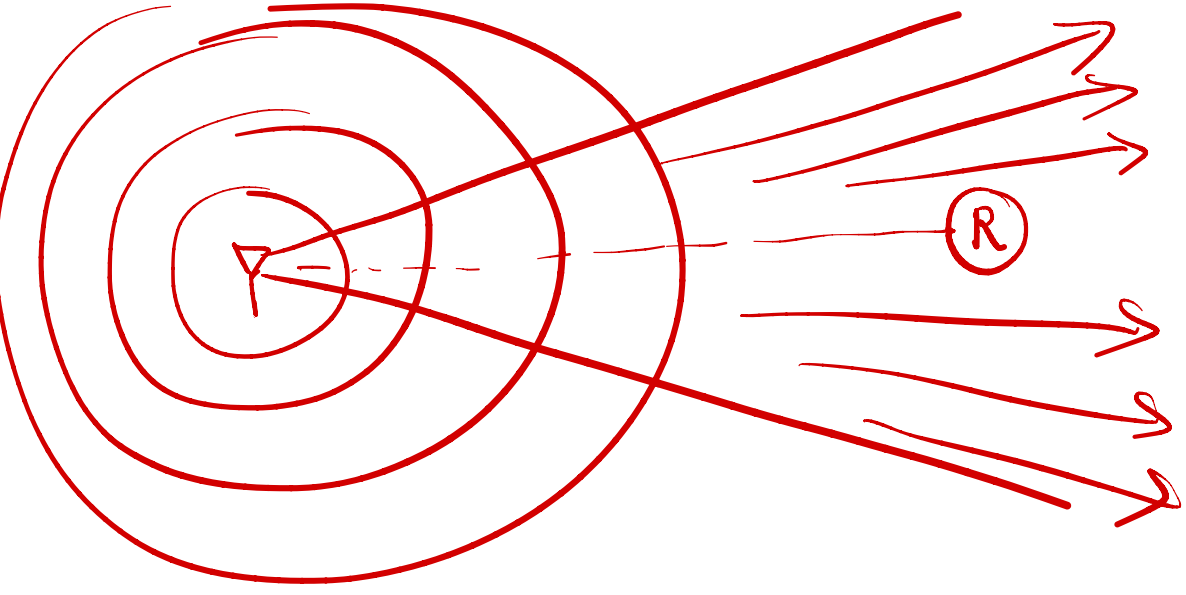
GPS — 2 MHz

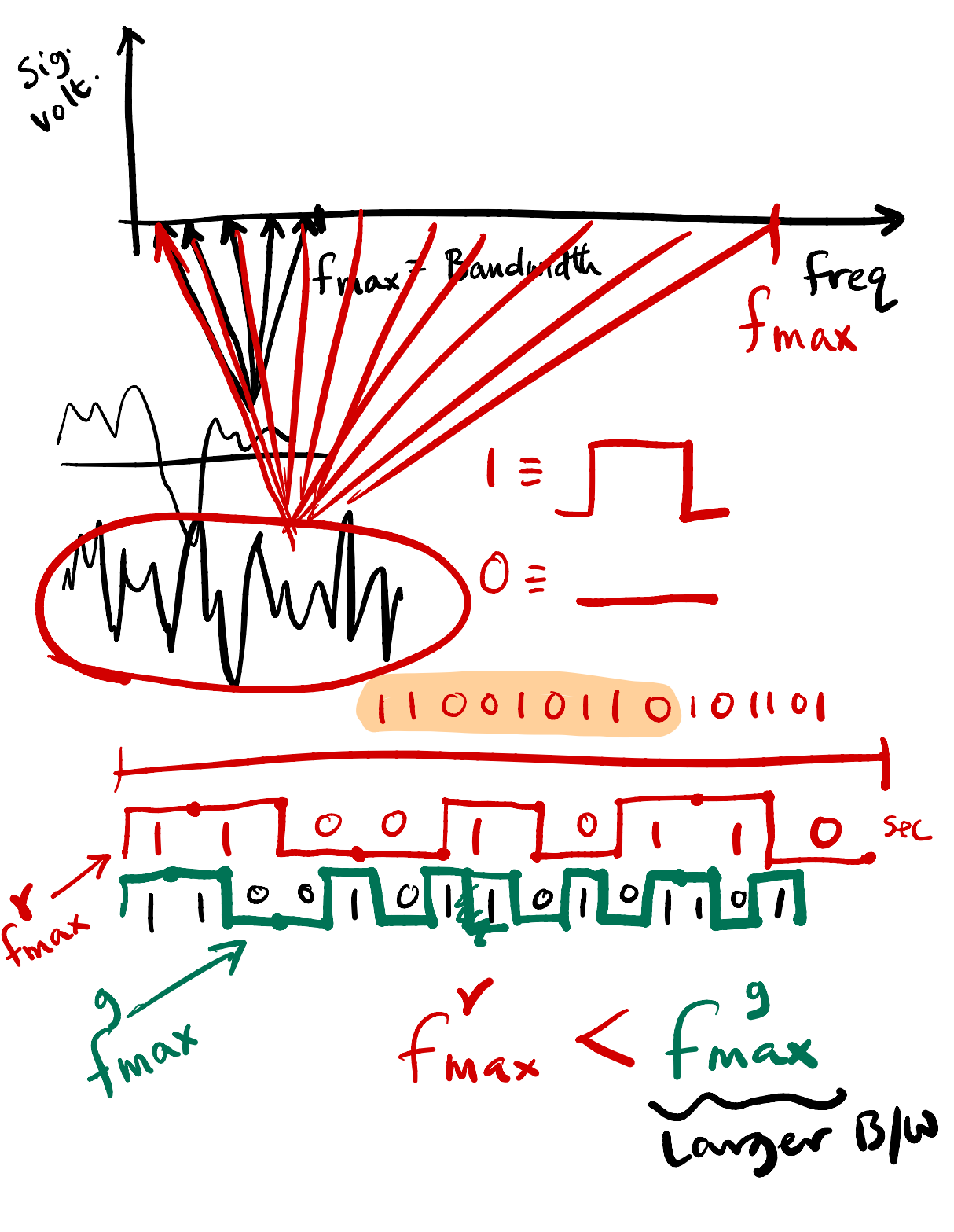
5G — 500 MHz



Speed = B Hz $\log\left(1 + \frac{P_{received}}{Noise}\right)$

Data Rate (bits/s)




Sig. volt.
freq
fmax = Bandwidth
fmax
1 ≡
0 ≡
1 1 0 0 1 0 1 1 0 1 0 1 1 0 1
sec
fmax
fmax
fmax < fmax
Larger B/W

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 …