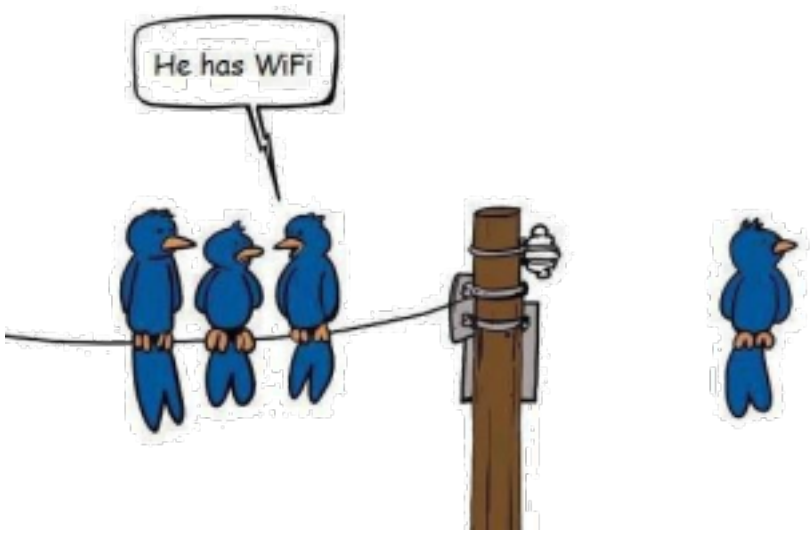
6.829: Computer Networks and Mobile Systems

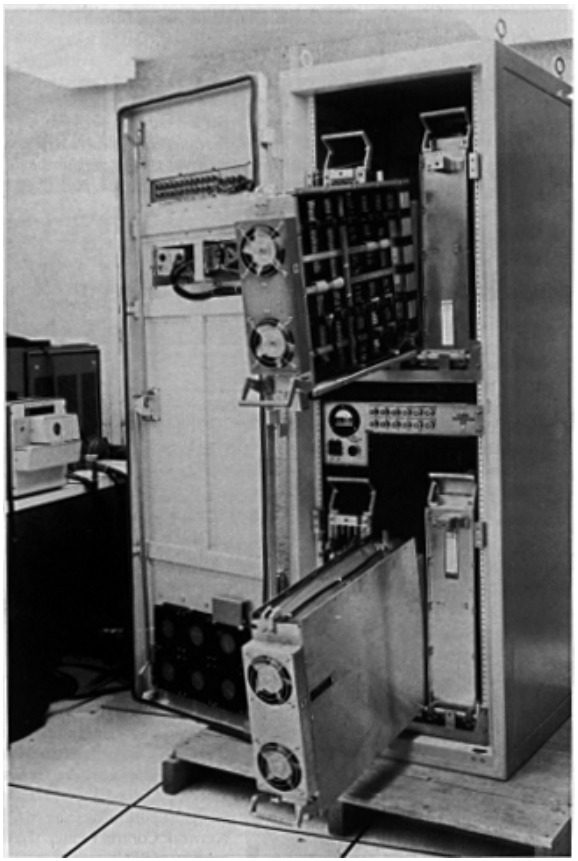
Lecture 1: Introduction



✧ Includes material from lectures by Haitham Hassanieh (UIUC , Nick McKeown (Stanford), Jennifer Rexford (Princeton)

Internet History & Modern Networking

Computer Comms & Packet Switching



- ARPA: 1957, in response to Sputnik (the first satellite by the Soviet Union)
- Donald Davies, early 1960s
  - Coins the term “packet”
- Len Kleinrock (MIT thesis): “Information flow in large communication nets”, 1961
- J. Licklider & W. Clark (MIT), On-line Man Computer Communication
- L. Roberts (MIT), first ARPANET plan for time-sharing remote computers, SOSP ‘67 paper

Project Funded → ARPANET

BBN team that implemented the interface message processor

- ARPANet
  - 1967: Connect computers at key research sites across the US using point-to-point telephone lines
  - Interface Message Processors (IMP) ARPA contract to BBN
  - Senator Ted Kennedy sent a telegram to BBN to congratulate them on winning contract to develop an "interfaith message processor".

ARPANET Topology in 1969

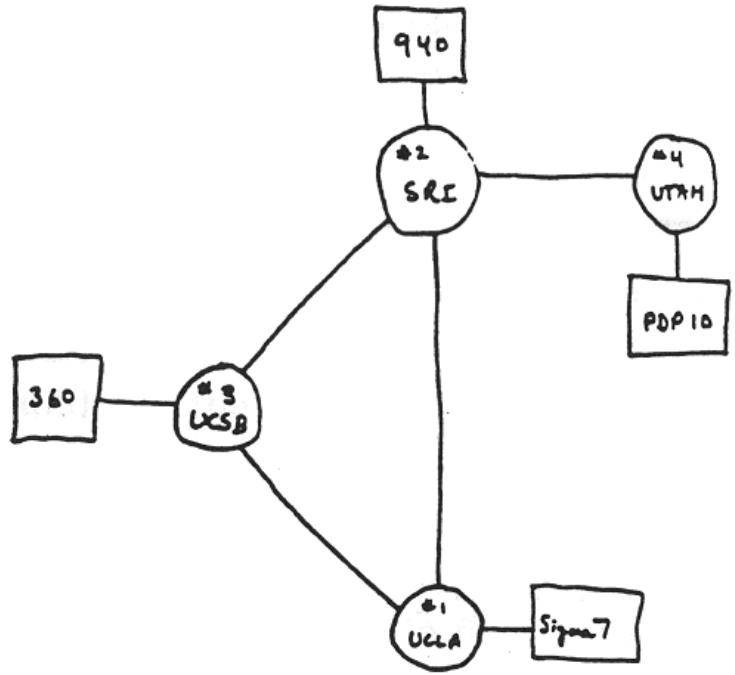


FIGURE 6.2 Drawing of 4 Node Network (Courtesy of Alex McKenzie)

First inter-site demo, 1969.
First crash very soon after!

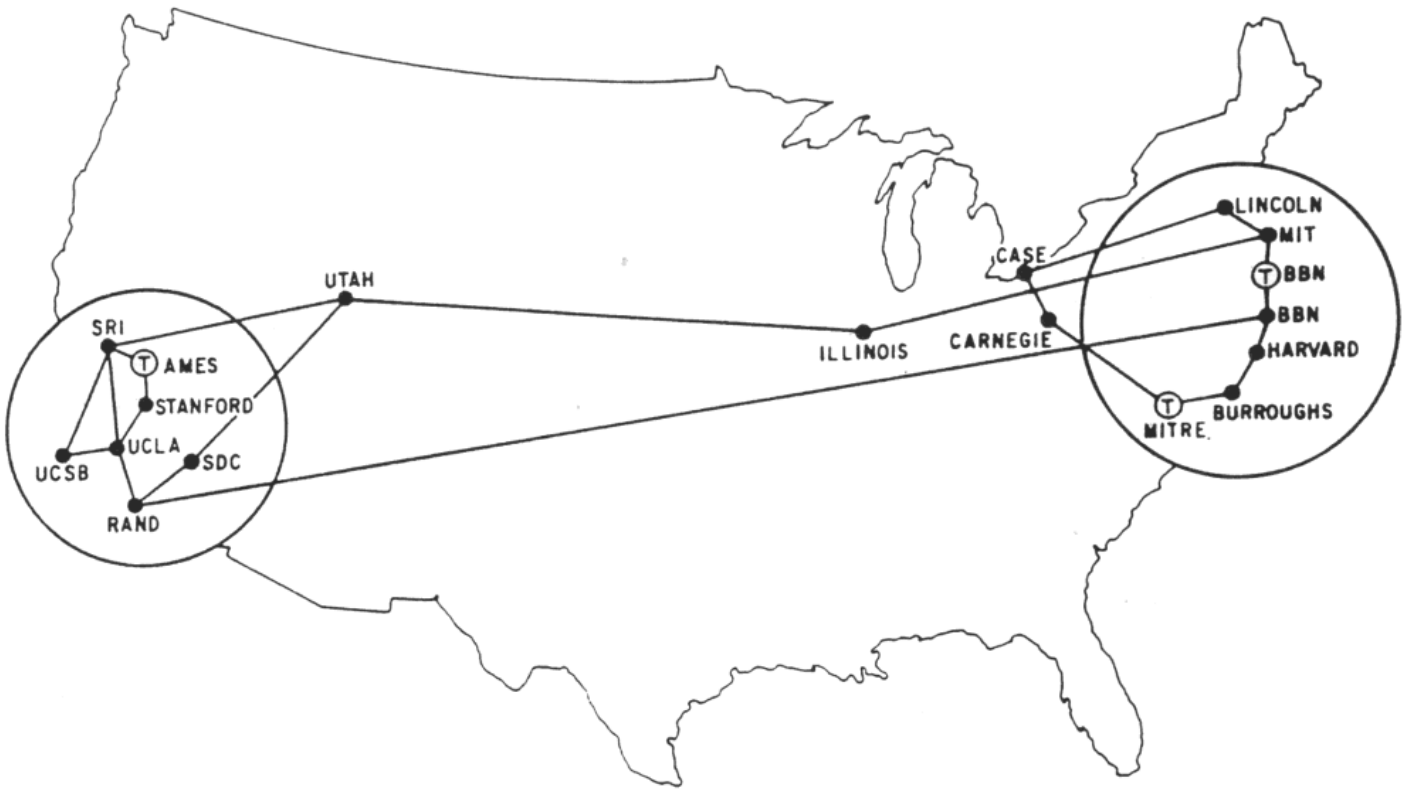
1967-1971: So what do we do with it?

- 1967-1972 – Vint Cerf, graduate student in Kleinrock's lab, works on application level protocols for the ARPANET (file transfer and Telnet protocols)

- 1971 - Ray Tomlinson of BBN writes email application; derived from two existing: an intra-machine email program (SENDMSG) and an experimental file transfer program (CPYNET)

1971-1973: Network Growing

- 1970 - First 2 cross-country link, UCLA-BBN and MIT-Utah, installed by AT&T at 56kbps



MAP 4 September 1971

1971-1973: Network Growing

1970 - First 2 cross-country link, UCLA-BBN and MIT-Utah, installed by AT&T at 56kbps.

1973 – Ethernet was designed in 1973 by Bob Metcalfe at Xerox Palo Alto Research Center (PARC)

Other networks: ALOHAnet (microwave network in Hawaii), Telenet (commercial, BBN), Transpac (France)

How do we connect these networks together?

1972-1978: IP/TCP

1972-1974 – Robert Kahn and Vint Cerf develop protocols to connect networks without any knowledge of the topology or specific characteristics of the underlying nets

1977 - First three-network TCP/IP based interconnection demonstrated linking SATNET, PRNET and ARPANET

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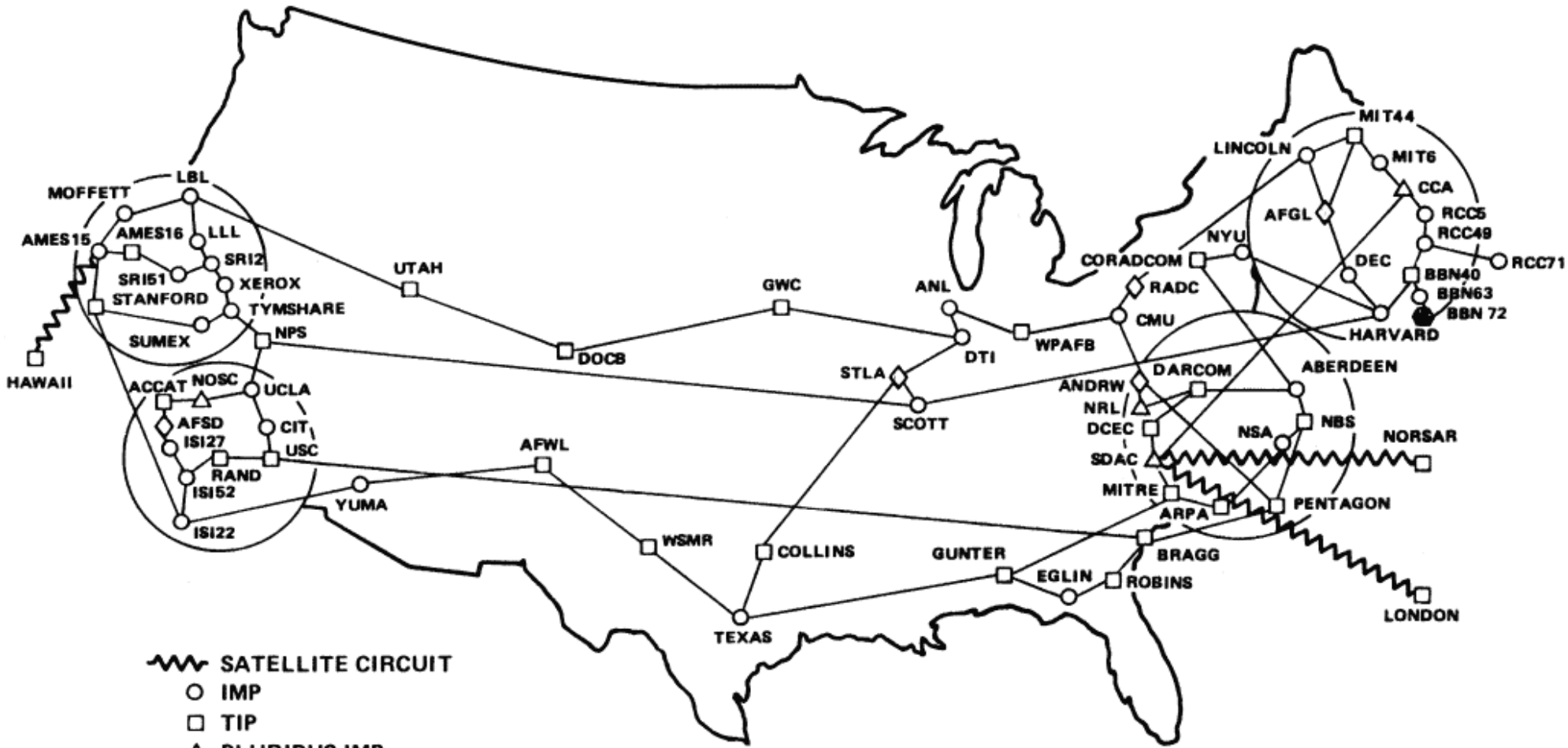
ARPANET GEOGRAPHIC MAP, OCTOBER 1980



(NOTE: THIS MAP DOES NOT SHOW ARPA'S EXPERIMENTAL SATELLITE CONNECTIONS)
NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

1981 –1988: Growth, Excitement & Pain

1981 – Term “Internet” coined to mean collection of interconnected networks

Early 80’s – Move to link state routing protocol to address convergence problem

1982 – Domain Name System introduced (DNS) to replace host.txt and address scale problems

1983-- ARPANET had a Flag-Day in which it transitioned to TCP/IP

1988 --TCP congestion control in response to congestion collapse episodes in 1986

1988 - Nodes on Internet began to double every year

1988 – Internet worm affecting about 10% of the 60000 computers on the Internet (the Morris Worm)

1989 – BGP to introduce policy based routing

1990s: WWW & Commercialization

1990 – ARPANET ceases to exist

1990 – First ISP world.std.com

1990 – Tim Berners-Lee invents the Web and develops HTML and HTTP

1991 – NSFNET lifted restrictions on use of NSFNET for commercial purposes

1993 – InterNIC created by NSF to provide Internet services; Private companies transition into roles (AT&T – directory and database services; Network Solutions – registration services; CERFnet – information services)

1993 – Move to CIDR to cope with shortage of IP addresses

Today

One of the most influential inventions

- A research experiment that escaped from the lab
- … to be the global communications infrastructure

Ever wider reach

- Today: nearly 3 billion users
- Tomorrow: more users, computers, sensors, “things”, … 40 to 50 billion devices by 2020

Constant innovation

- Web, P2P, social networks, virtual worlds, online markets, E-commerce, …

The Internet Transformed Everything

The ways we do business

- E-commerce, advertising, cloud computing, ...

The way we have relationships

- E-mail, IM, Facebook, Instagram, virtual worlds

How we think about law

- Interstate commerce? National boundaries? Wikileaks?

The way we govern

- E-voting
- Censorship and wiretapping

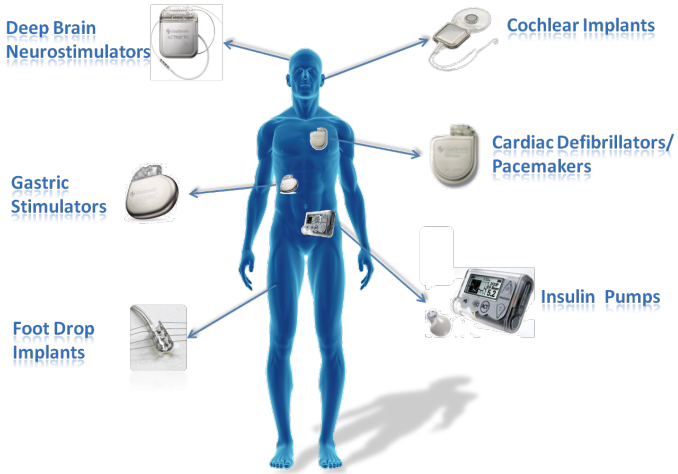
The way we fight

- Cyber-attacks, including nation-state attacks

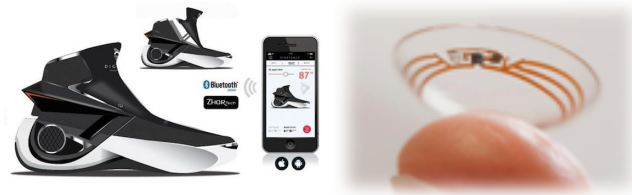
The Wireless and Mobile Revolution

WiFi in everything

Wireless Biomedical Implants



Wireless Wearables



Cellular Networks

Wireless Sensors

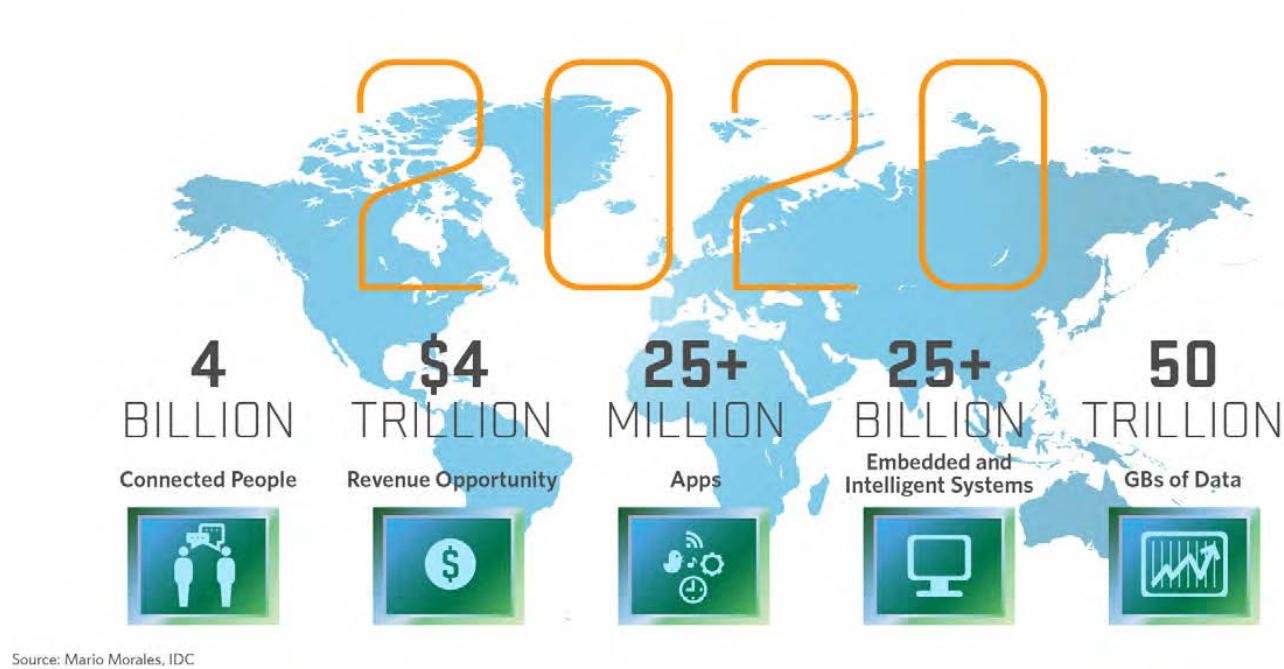
Drones

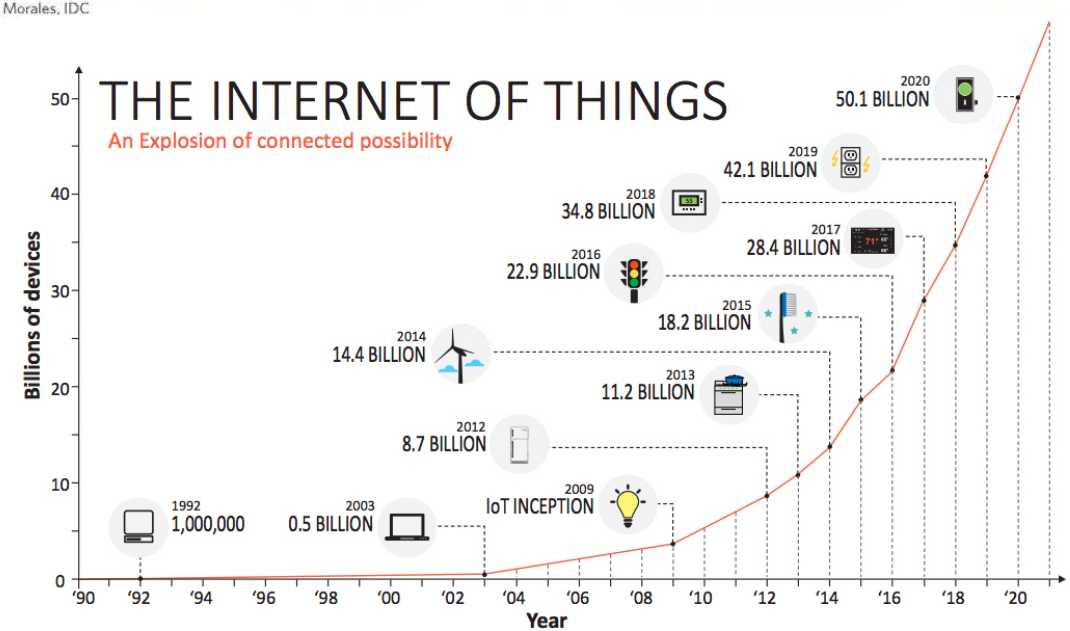
Wireless Data Centers

Connected Vehicles

Increasing Demand for Wireless Connectivity

Increasing Demand for Wireless Connectivity





About this class

Goals

1. To understand how wireless and wired networks work, and how to develop mobile and networked systems

2. To understand how to conduct networking research and develop innovative ideas.

General Information

- Instructors
  - Lecturers: Dina Katabi dk@mit.edu and Fadel Adib fadel@mit.edu
  - Office hours: Thursday after class or by appointment
- TAs
  - Chen-Yu Hsu cyhsu@mit.edu Office Hours: Tue 2:30-3:30pm at 32-268
  - Mingmin Zhao mingmin@mit.edu Office Hours: Thu 4:00-5:00pm at 32-268
- Class Web Page
  - http://web.mit.edu/6.829/www/currentsemester/index.html

Course Structure

- Lectures & Readings
- Problem Sets
- One Quiz
- Final Project

Lecture & Readings

Lecture

- Each class we will discuss 1-2 papers or lecture notes
- You must read the papers before class
- Most of lecture will be spent discussing/debating the papers
- Come prepared to discuss the main ideas!

Questions about readings

- A few questions will be posted on class webpage per lecture
- Submit answers online **by midnight** the night before lecture (see class webpage)

Syllabus Summary

- Wireless Networks
  - How WiFi and cellular networks work
- Sensors and the Internet of Things
  - Smart home sensors
  - Localizing people using the signal from their cell phones
- Wired Networks
  - Internet architecture and protocols
  - Data Centers
- Miscellaneous
  - ML in networking
  - Security
  - Apps, e.g., video

Rest of Today

A sampler of class topics

Indoor Localization with Wireless Signals

GPS has changed how we navigate outdoor space

GPS does not work indoors…

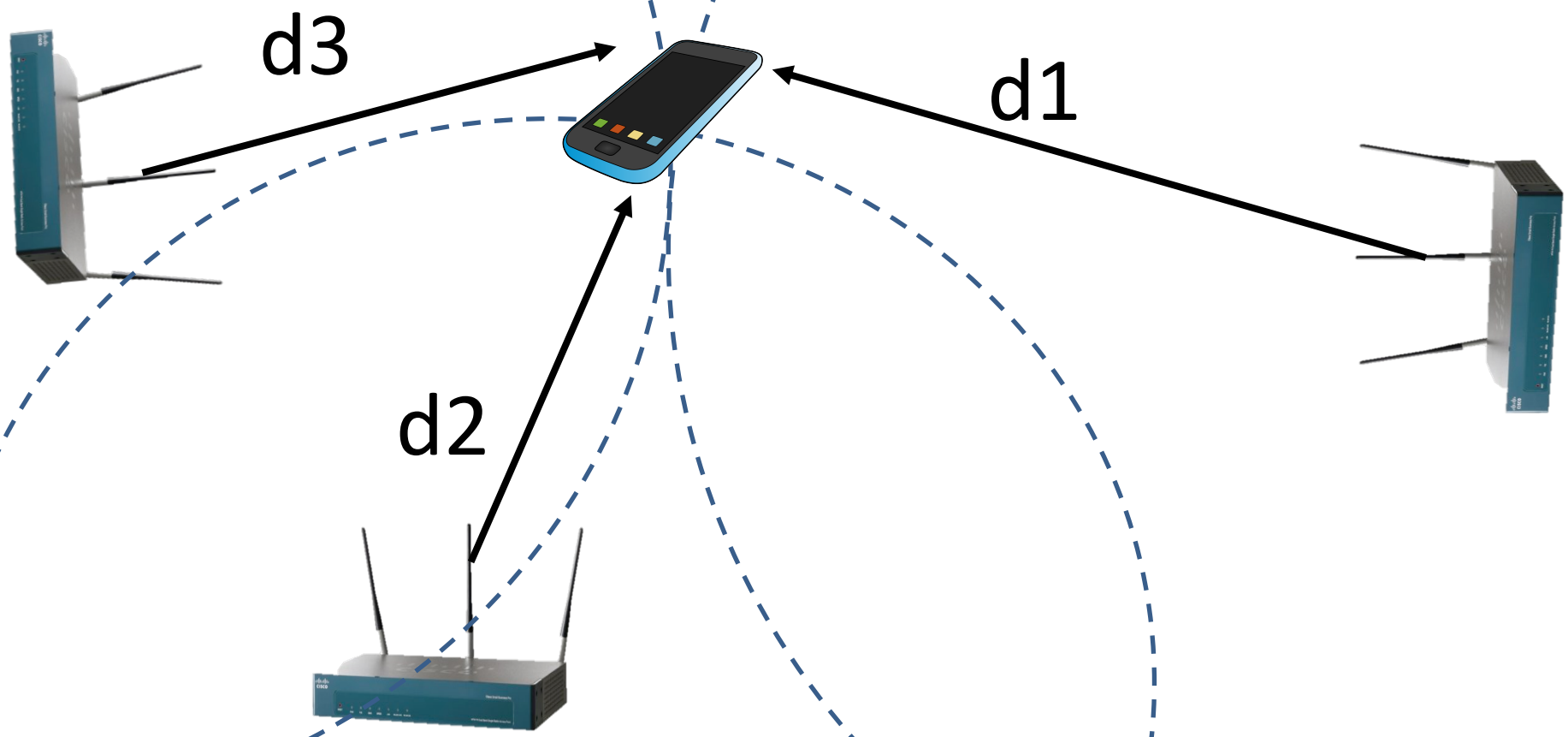
Now, we can use RF for Indoor localization

Navigation

Business Analytics

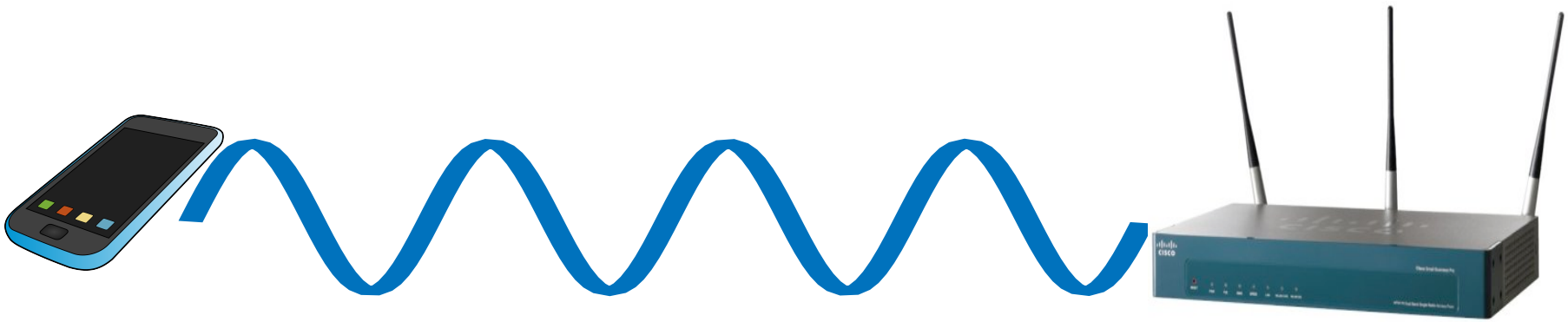
Inventory

How Do We Localize?



Measure distances between phone and access point?

Measuring Distance



Distance = speed of light x propagation delay

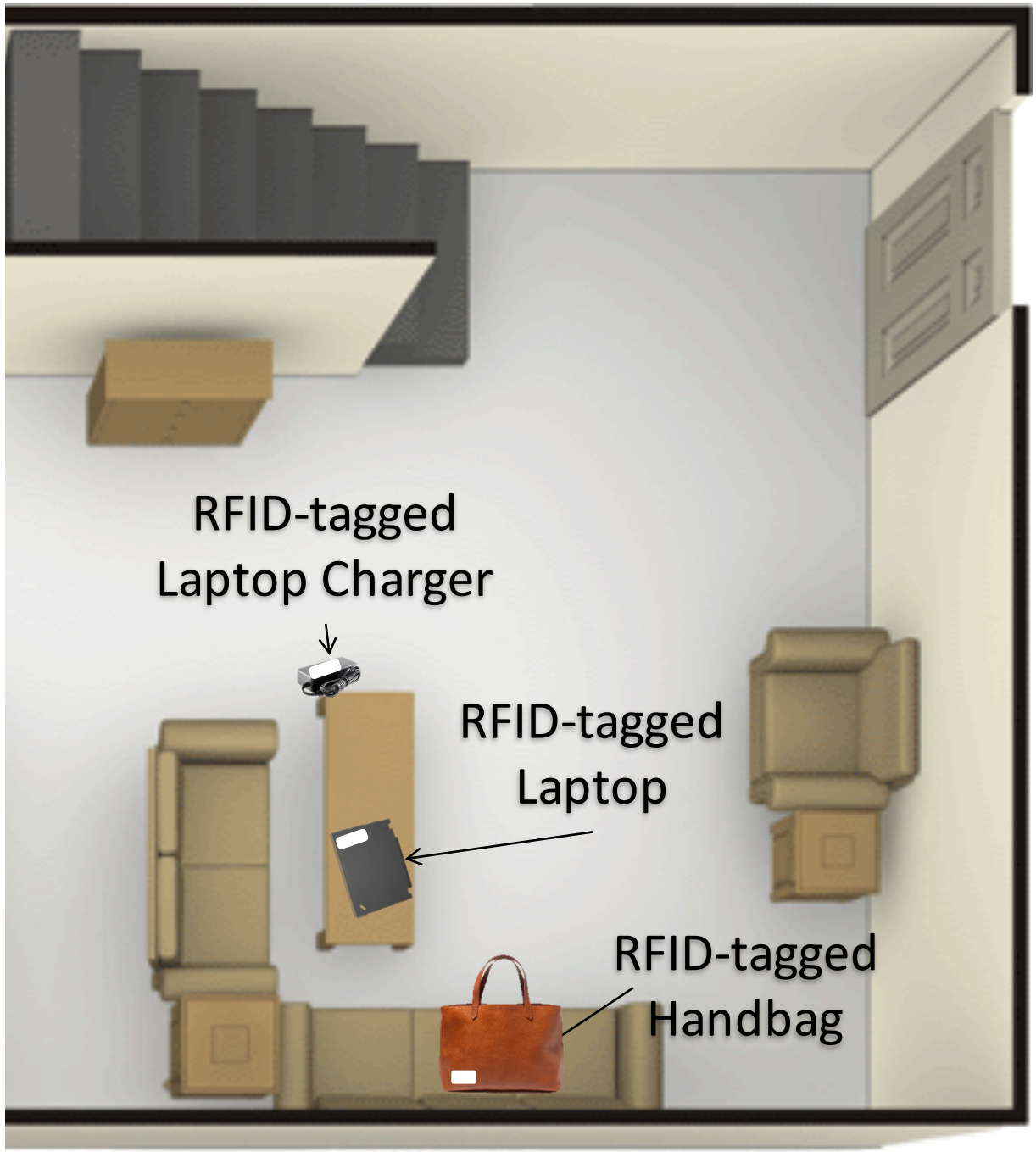
We can use signal property to measure propagation delay

WiFi-Based Indoor GPS

Localization works even with RFIDs

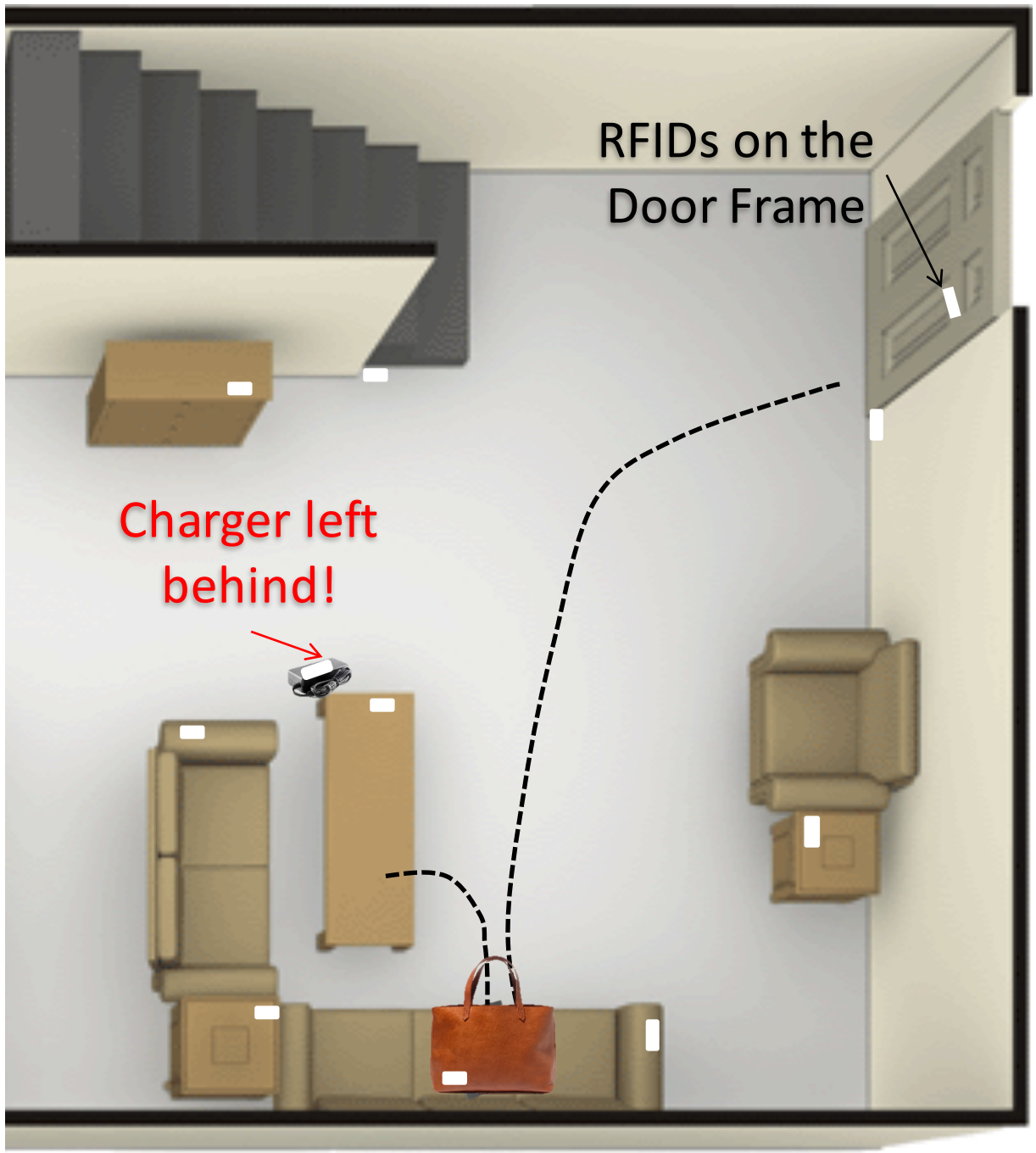
Battery-free stickers to tag any and every object

Smart Homes

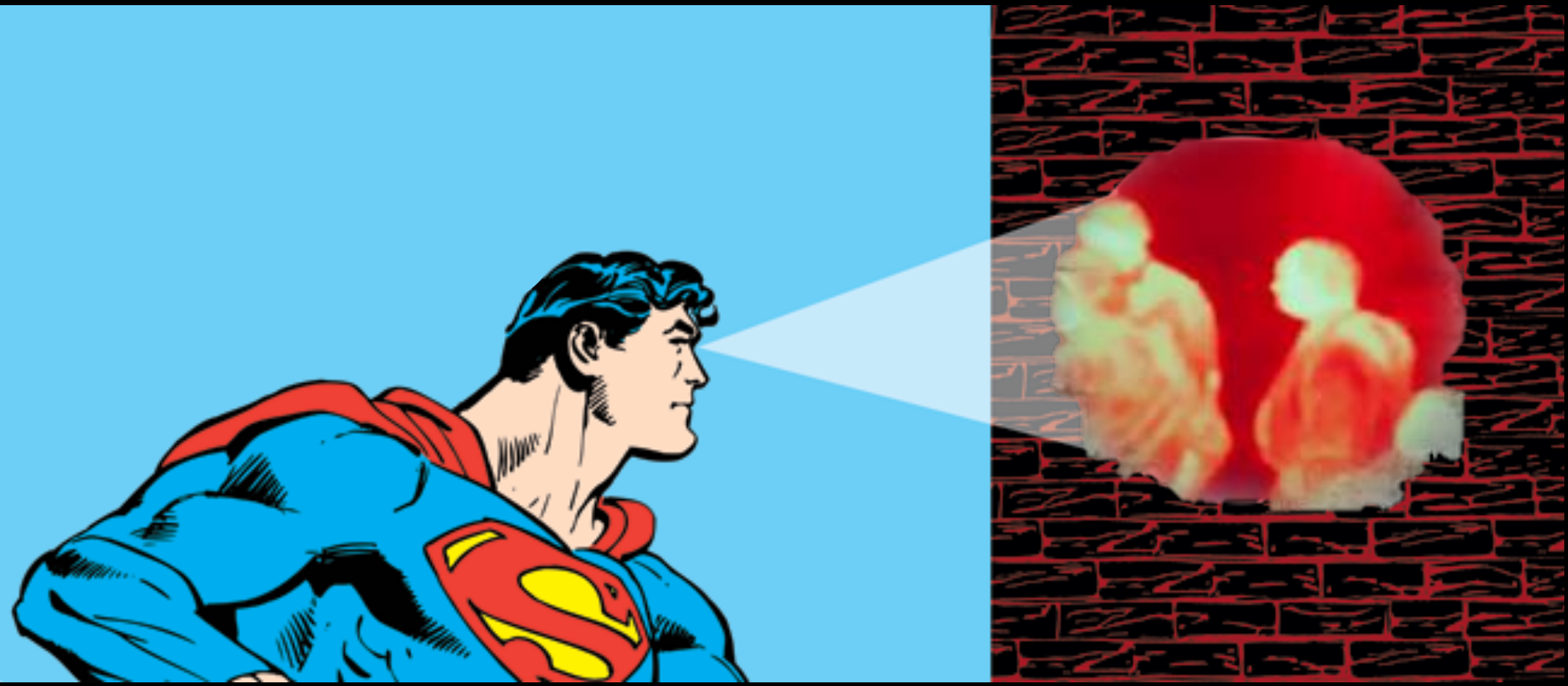

RFID-tagged
Laptop Charger
RFID-tagged
Laptop
RFID-tagged
Handbag

Smart Homes

Smart Homes

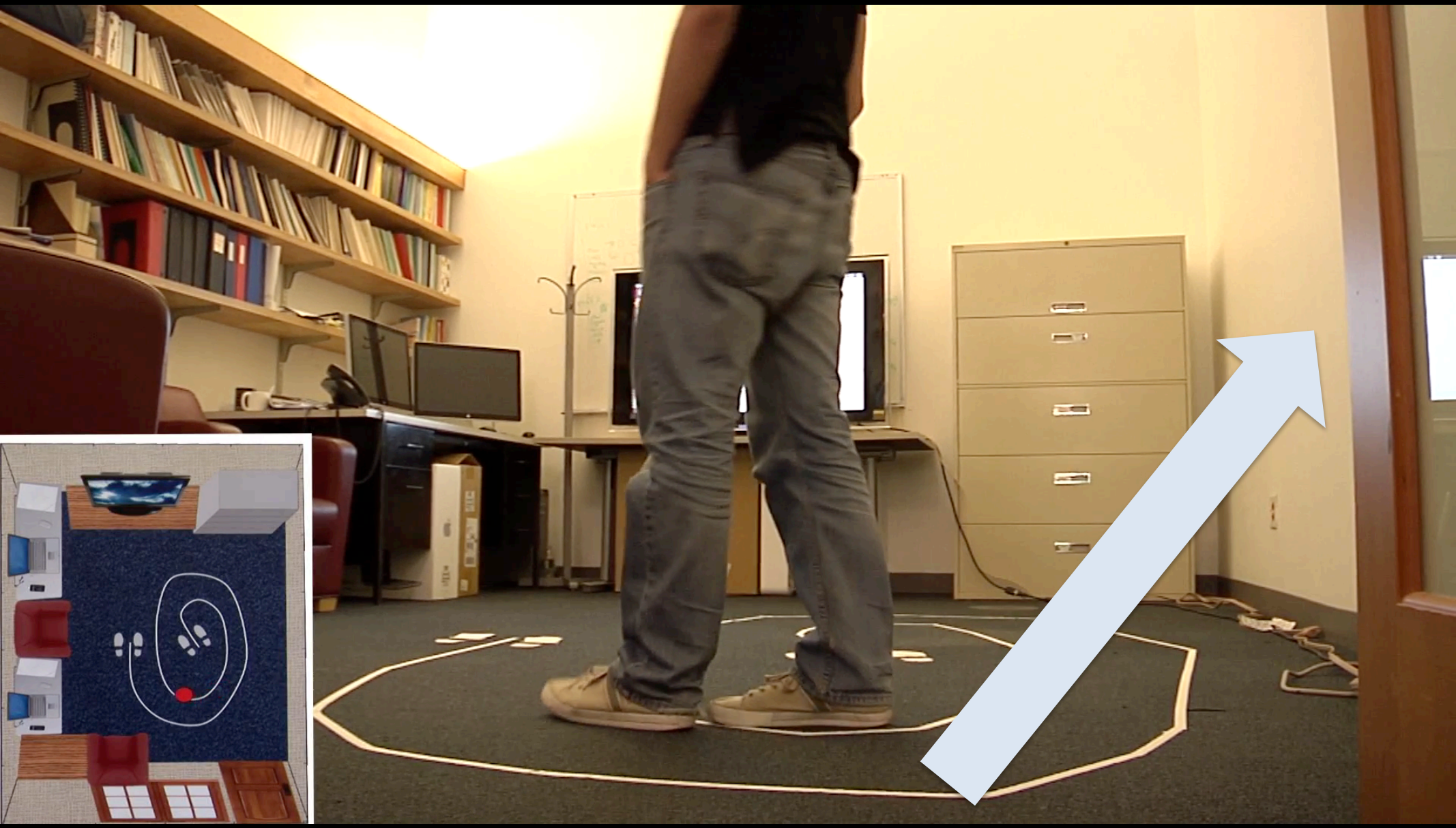


X-Ray Vision



Imagine having X-ray vision!

[Video from NBC News]



Device behind wall

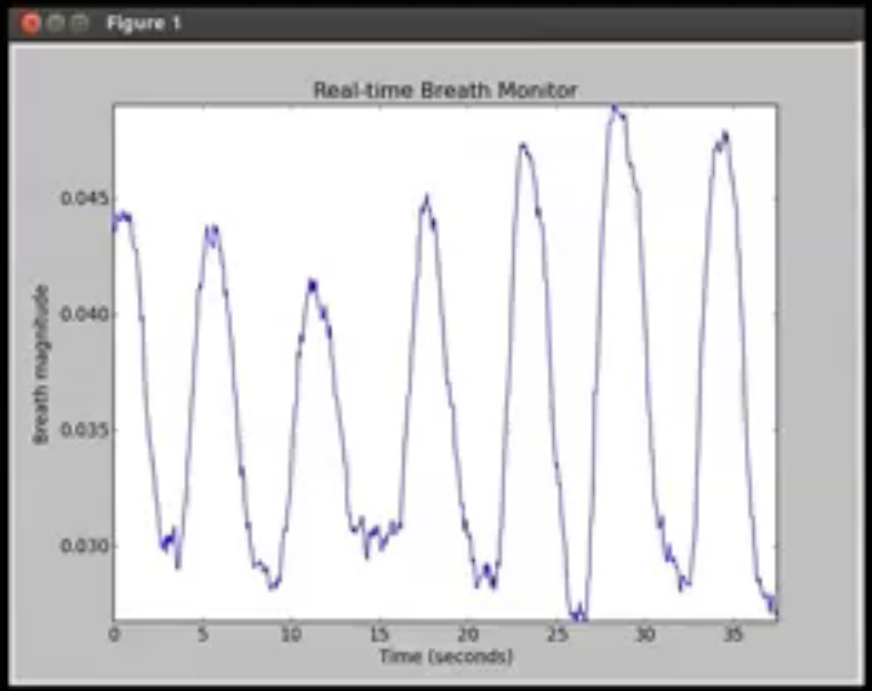
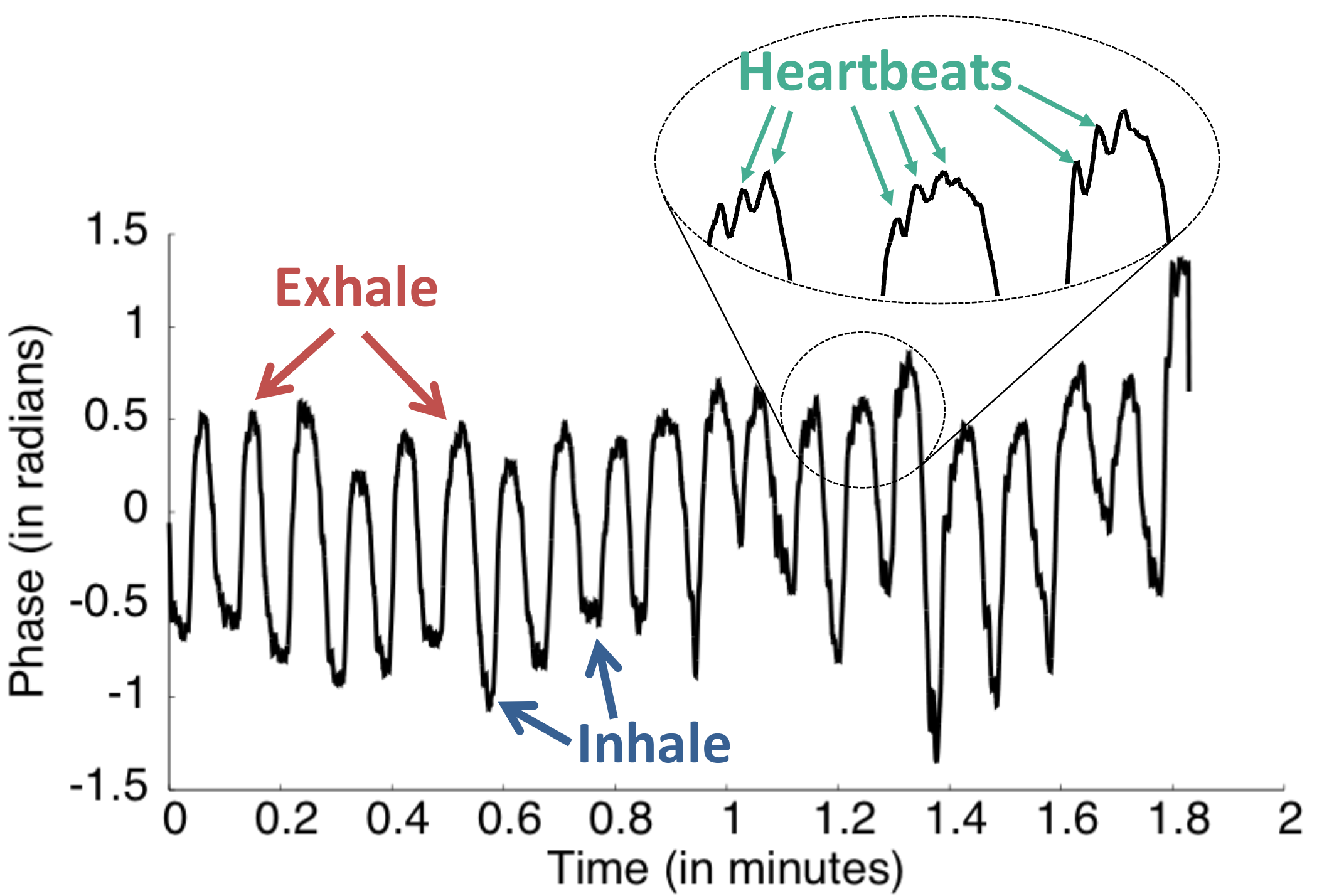


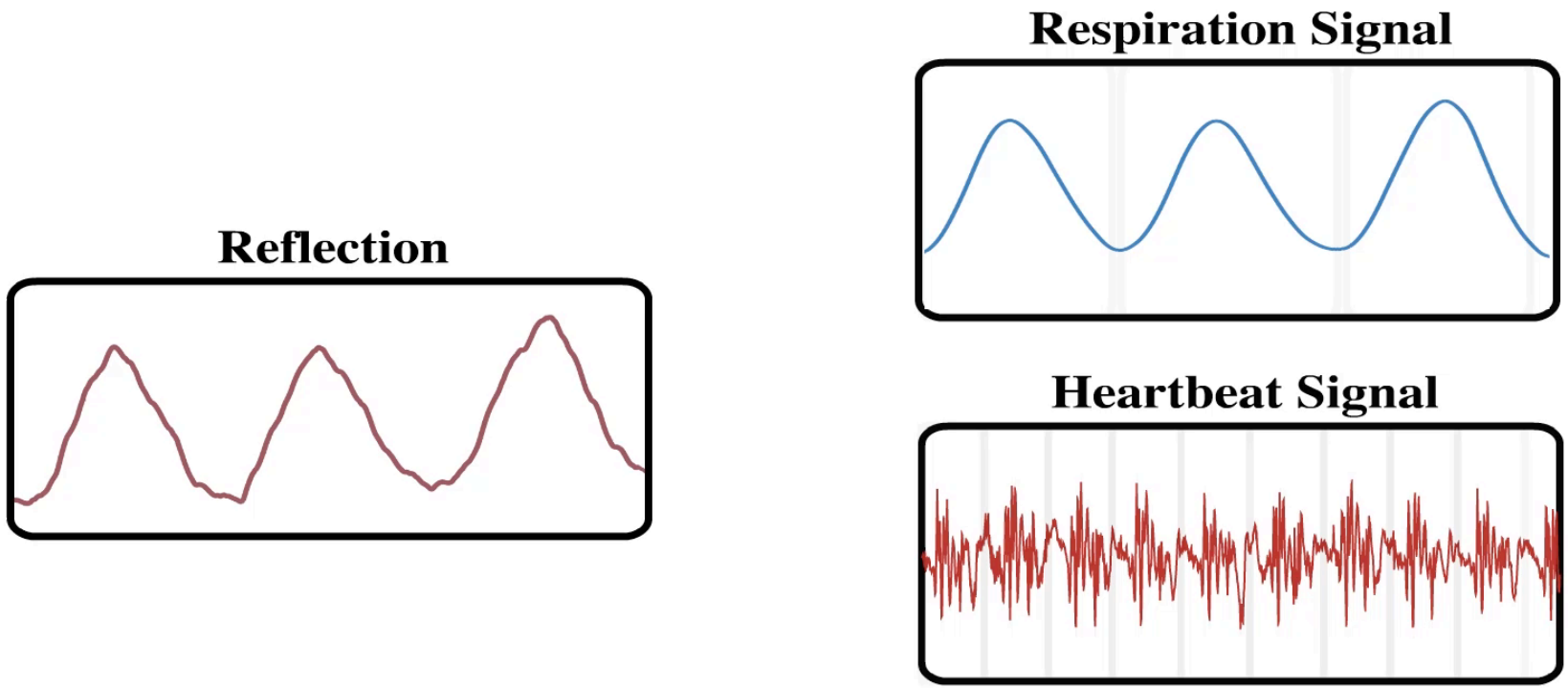
Figure 1
Real-time Breath Monitor
Breath magnitude
0.045
0.040
0.035
0.030
0
5
10
15
20
25
30
35
Time (seconds)


Heartbeats
Exhale
Inhale
1.5
1
0.5
0
-0.5
-1
-1.5
Phase (in radians)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (in minutes)

Emotion Recognition with RF Signals

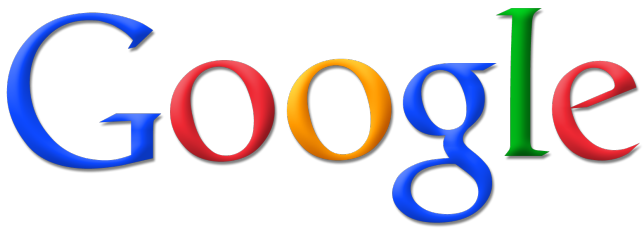

Was there a
moment
in your life
when you looked at
someone's face

EQ-Radio: Emotion recognition using wireless signals



Data Centers

These things are *really* big



10-100K servers

100s of Petabytes of storage

100s of Terabits/s of Bw
(more than core of Internet)

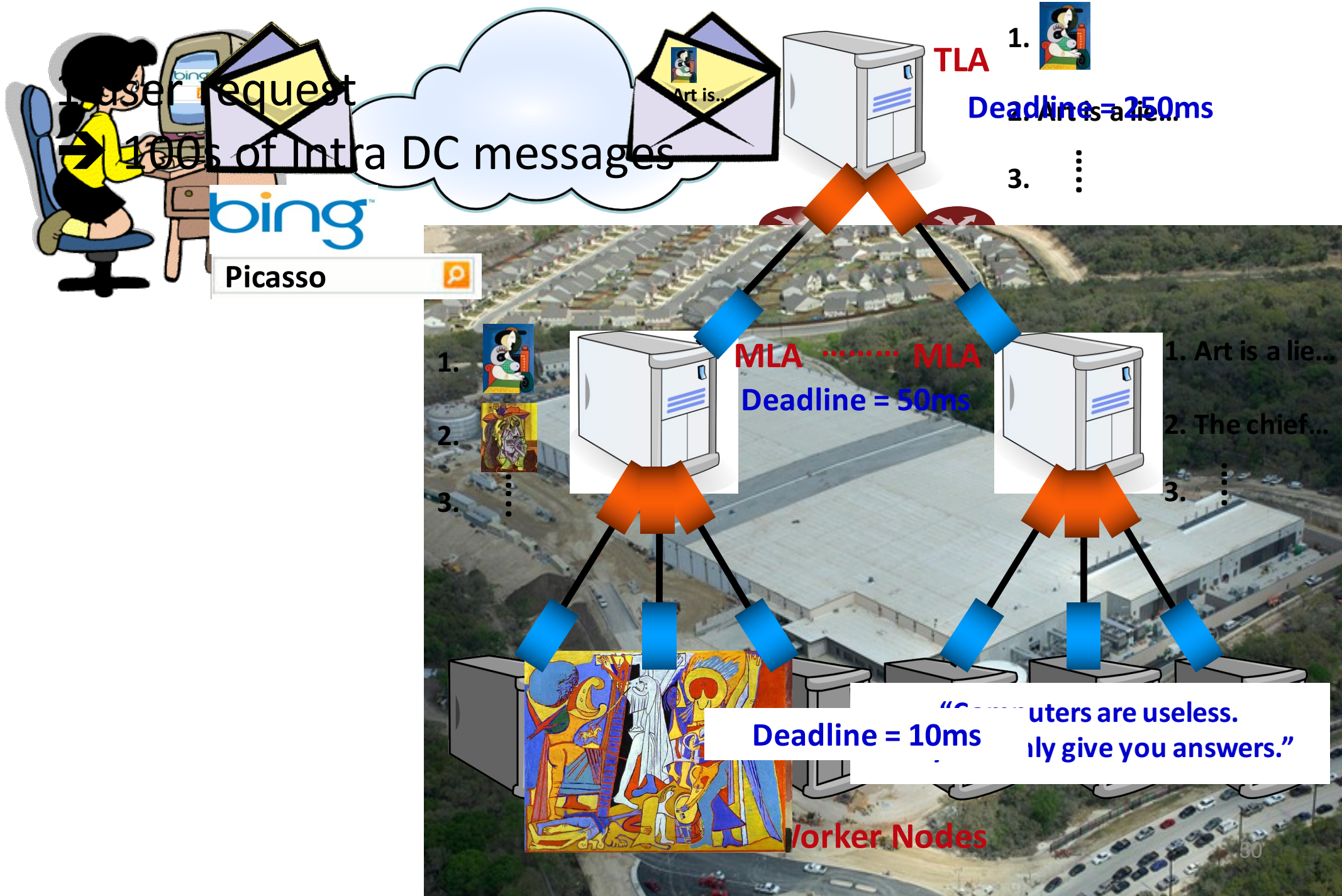
10-100MW of power
(1-2 % of global energy consumption)

100s of millions of dollars

✧ Slide by George Porter (UCSD)


Microsoft

Networking *Inside* Datacenters



Datacenter Networking Challenges

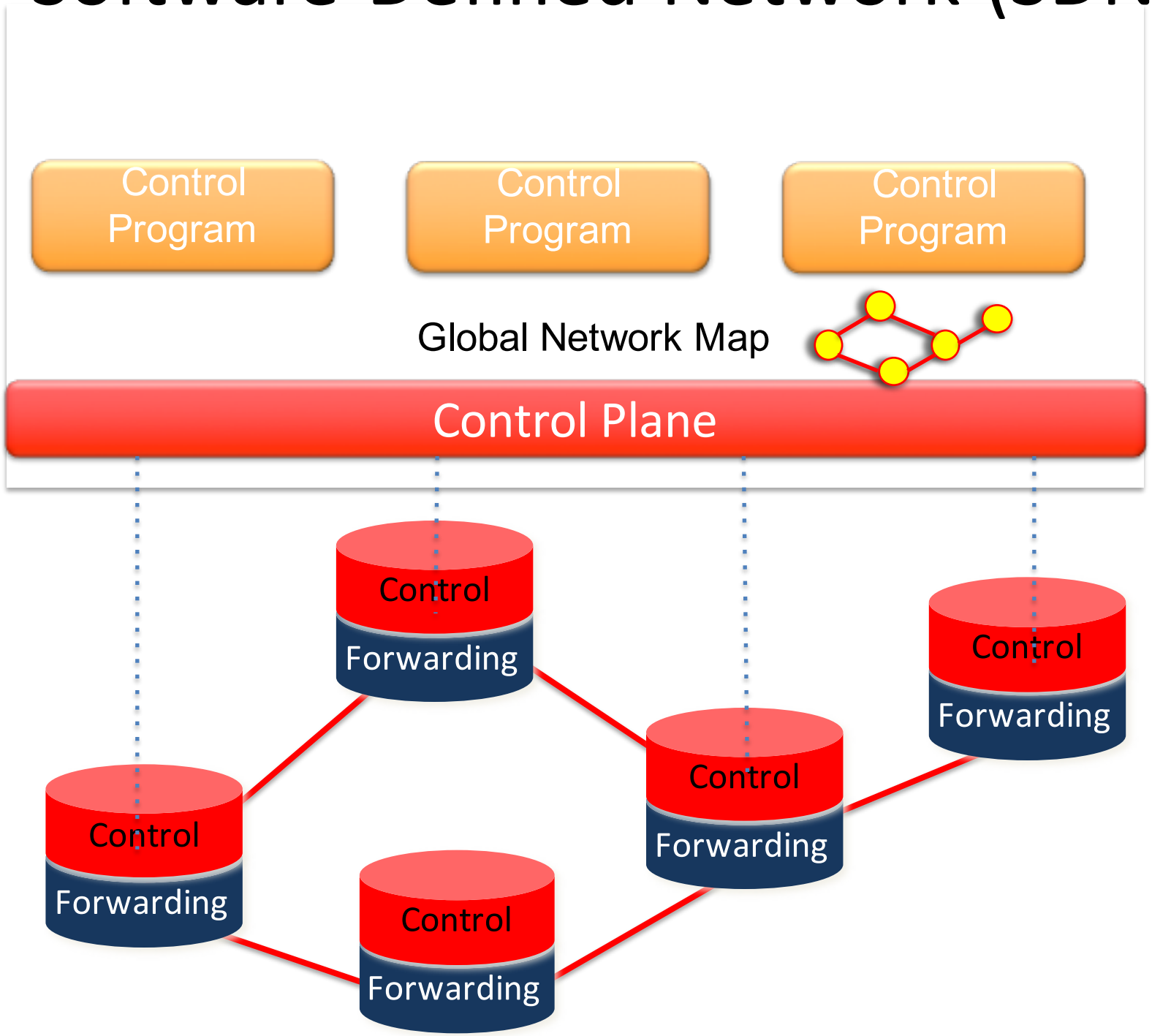
- Very high speeds (10-100Gbps links)
- Tiny round trip times (microseconds)
- Dense, multi-path topologies
- Cheap switches with small buffers
- Message latency is King

On the other hand…

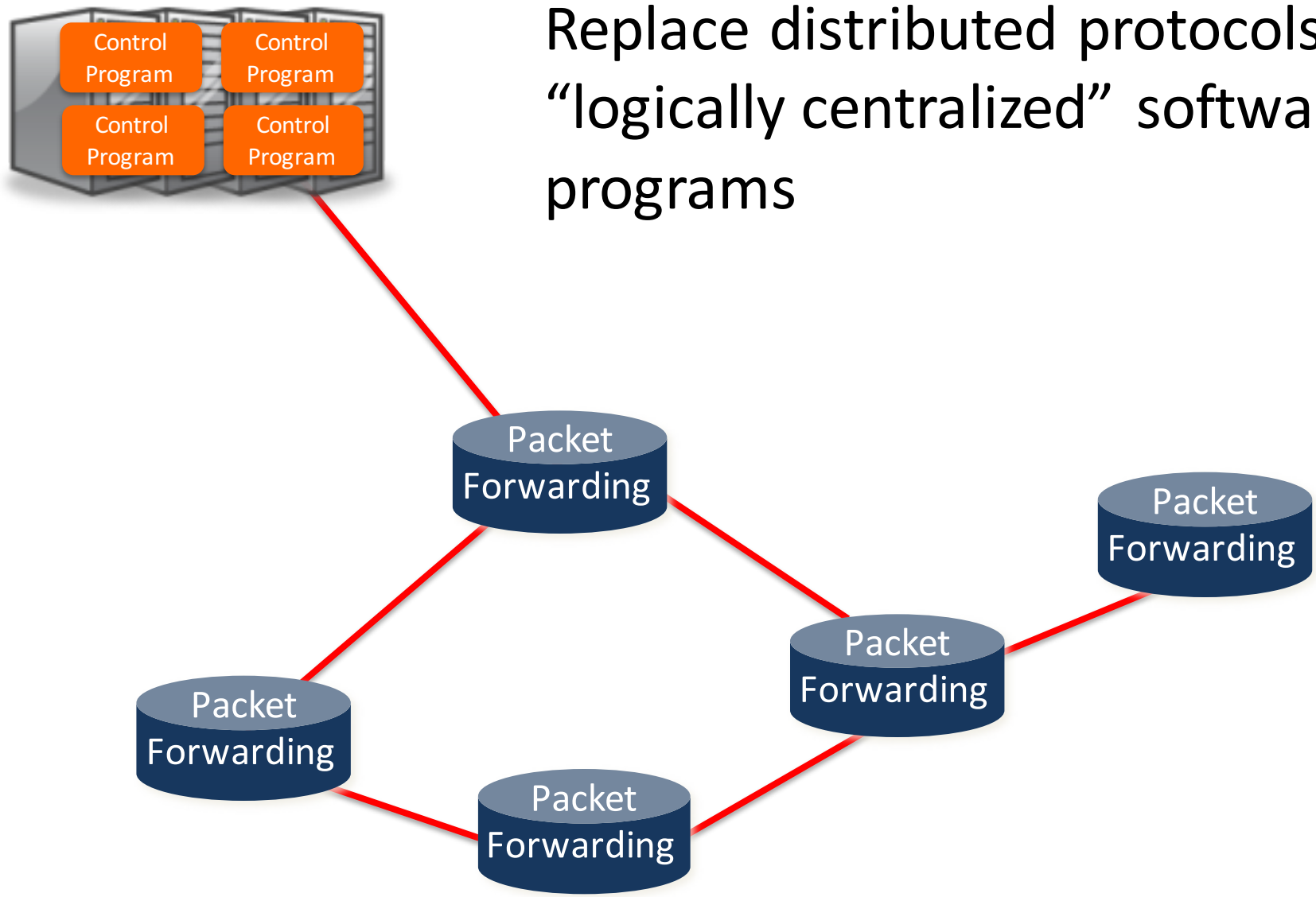
- Single administrative domain
- No need to be compatible with outside world

Network Programmability

Software Defined Network (SDN)



Software Defined Network (SDN)

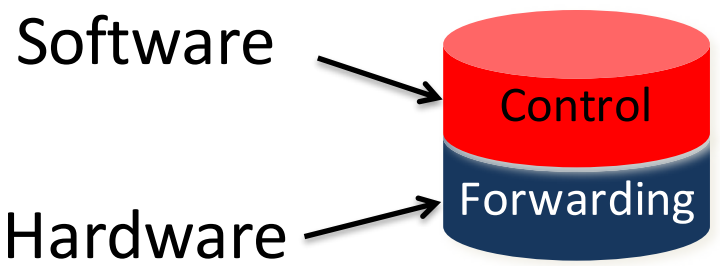


Replace distributed protocols with "logically centralized" software programs

Programmable Data-plane

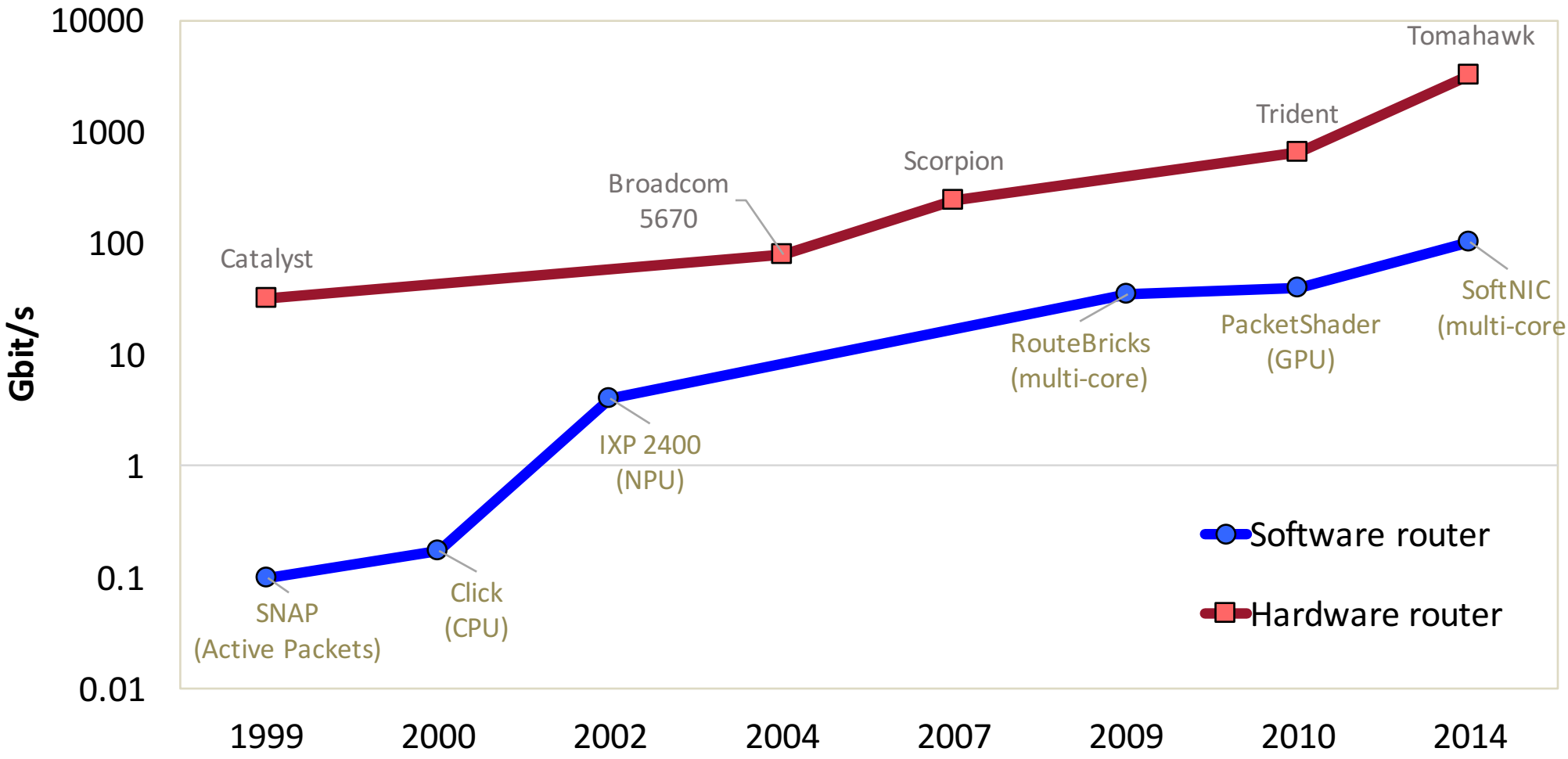
Can we program new data-plane algorithms?

- Congestion control
- Measurement
- Load balancing
- Packet scheduling



Traditionally, these algorithms are hard-coded into router hardware

Software vs. Hardware routers



10–100X gap between hardware and software routers

Programmable router hardware

Same performance as fixed-function chips,
Some programmability