Freie Universität Berlin

Telematics

Chapter 1

Motivation

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INRIA / Freie Universität Berlin

Institute of Computer Science

Computer Systems and Telematics (CST)

Contents

- Evolution of telecommunications
  - Brief prehistoric overview
  - From multiple networks to a single network
  - From wired to wireless
  - Towards IoT and machine-to-machine communications
- Economic & social aspects of telecommunications
- Computer Networks & the Internet
- Why this course?

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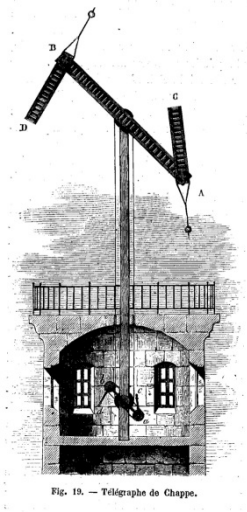
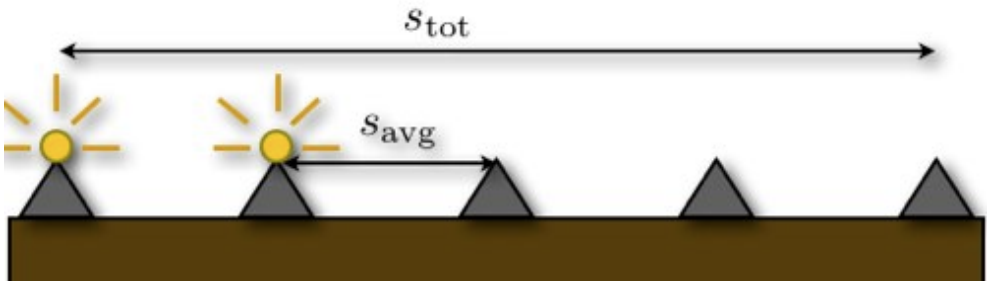
History of telecommunications

Before 1800s: stuck with Antiquity techniques



- biological message carriers
- smoke signals
- light beacons network
- semaphore relay stations network (Claude Chappe, 1792)

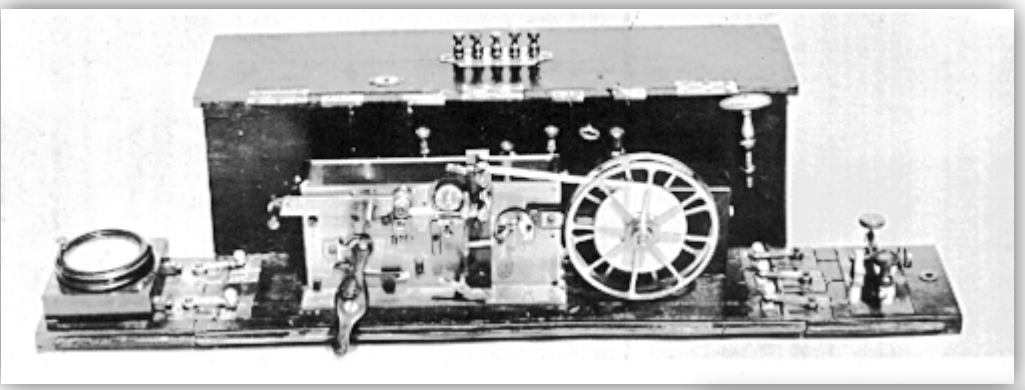


History of telecommunications

Since 1800s: high-paced progress

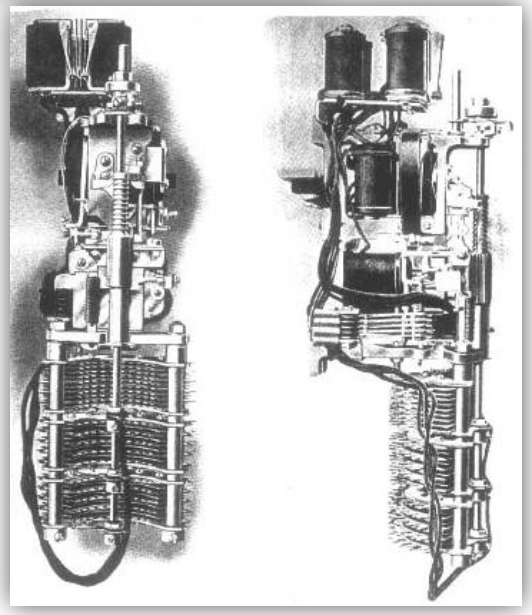
1837:	Samuel Morse develops the telegraph
1858:	first transatlantic telegraph cable
1876:	Alexander G. Bell patents the telephone
1897:	Almon Strowger invents the telephone switch
1900:	Guglielmo Marconi develops wireless telegraphy
1903:	Nevil Maskelyne hacks into Marconi's wireless network
1924:	First demo of bidirectional, mobile, wireless phone (Bell Labs)
1953:	First transatlantic telephone line! (TAT-1 with 36 Channels)
1962:	First communications satellite (Telstar)
1973:	First publicly available mobile (Motorola)
1977:	First digital, optical fiber network (Chicago)
1986:	Birth of the Internet (IETF)
1990:	Tim Berners-Lee invents the world wide web (www)
1995:	Towards massive Internet access/use

Pictures from the 1800s



Early telegraph

Early telephone

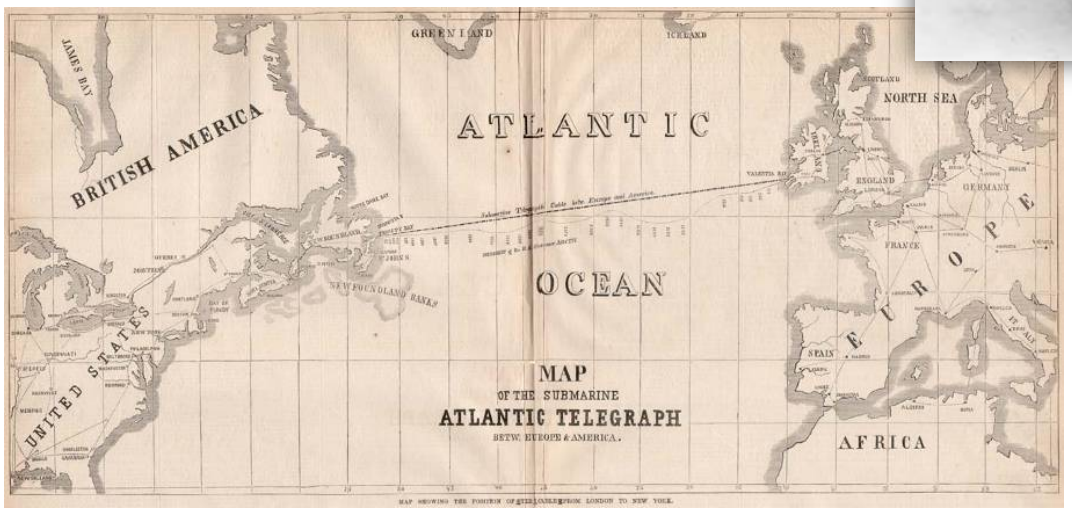


Early telephone switch

Pictures from the Early 1900s

Early phone signal amplifier

Early mobile telephony



First transcontinental cable

Milestones and their Impact

Year	Invention	Result
1840	Morse-Telegraph	Exchange of messages over long distances
1861	Telephone	Voice communication over long distances
1887	Electromagnetic Waves	Radio technology
1897	Strowger switch	Automatic switching
1923	Radio Broadcast	Mass communication
1929	Coax cable	High data rates
1964	Satellites	Basis of global communications
1966	Fiber	Even higher data rates
1986	Internet	From many networks to a single network
1997	Wavelength Division Multiplex	Even higher data rates up to 1Tbps (Tera = 10^{12})
2000	Mobile Internet	Start of bitrate race for wireless Internet access

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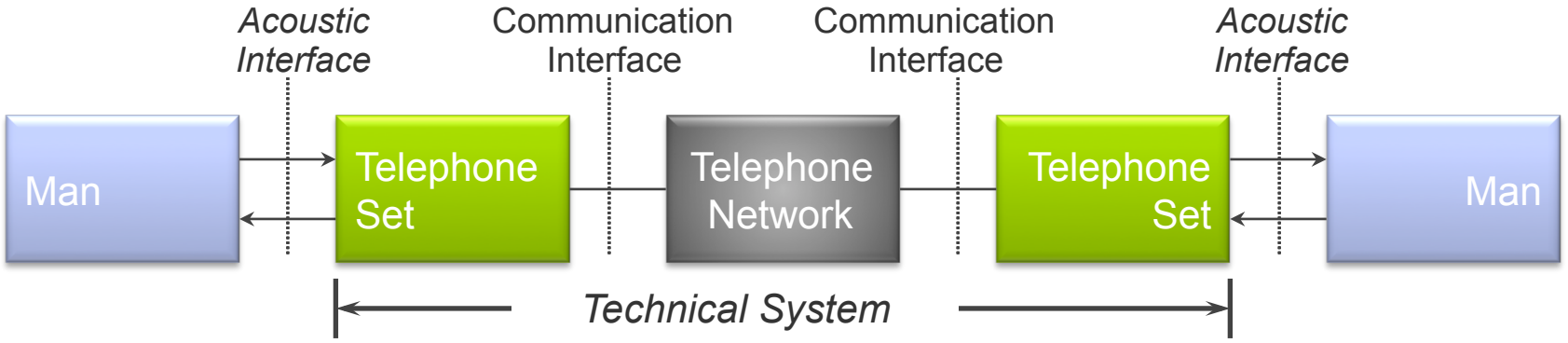
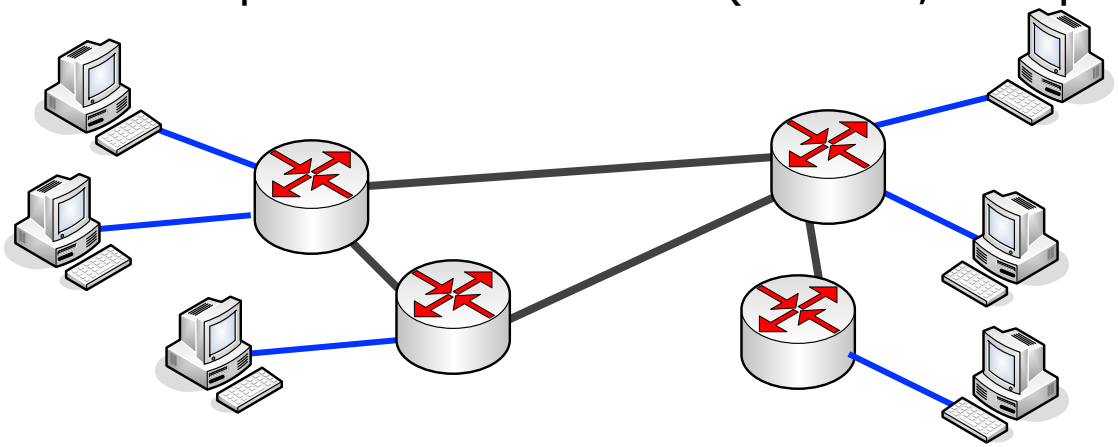
In the Past: Multiple Types of Networks

1. Initially: **Voice communication networks** between humans
   - ➡Stringent **Quality of Service** (QoS) requirements

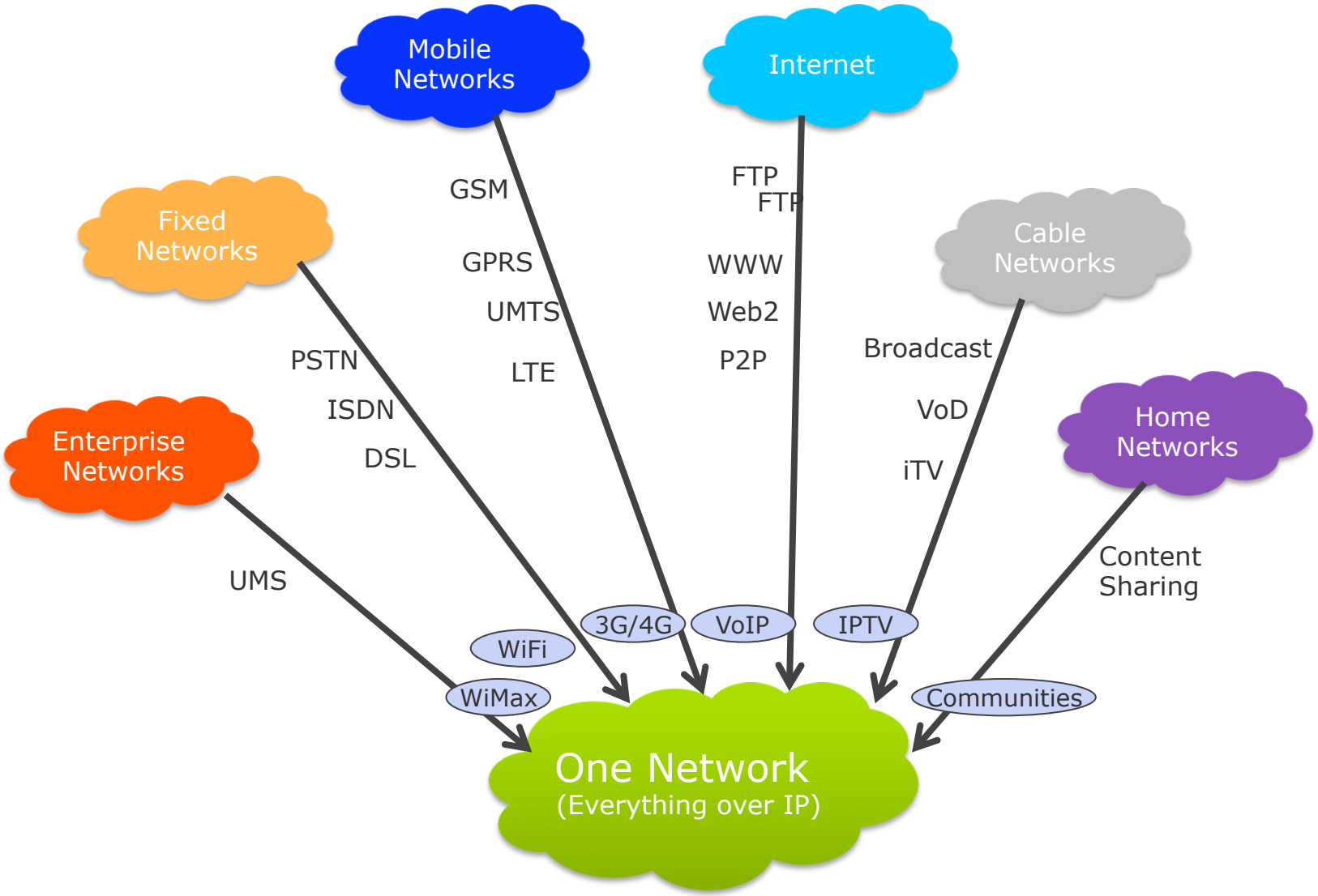


2. Later: **Data communication networks** appeared
   - ➡Every single **service** required its own network (cable TV, enterprise networks…)



In the Past: Too Much Redundancy

Convergence Towards a Single Network



Why We Should Think Further!

What the lessons learned?

- Deploying and maintaining multiple networks is expensive
- A cable does not care about what type of data it delivers
- Different services exhibit different requirements

How can we use a single network for multiple services?

⇒ Abstraction!

No challenges anymore?

- Using a cable for multiple services may introduce resource problems
  - How do you achieve the stringent QoS requirements of voice communication while the delivery channel competes with TV data?
- … and some more. But we will see it is worth to work on it!

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From Sparse to Dense

Mainframe Computing 1960s

Mini Computing 1970s

Personal Computing 1980s

Desktop Internet Computing 1990s

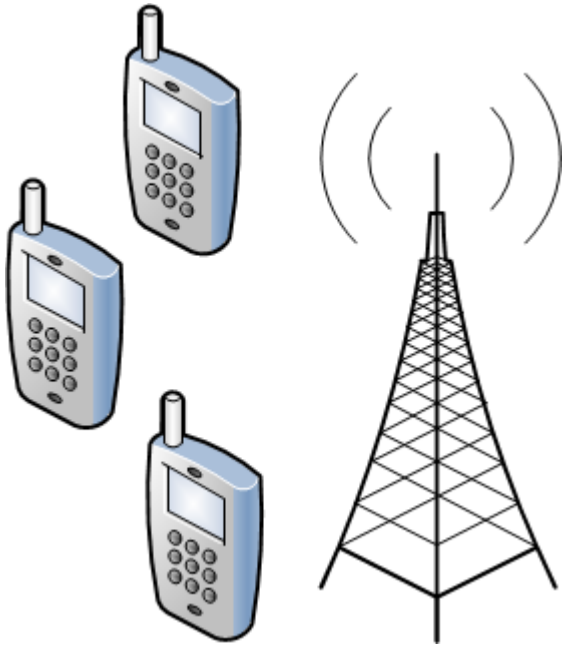
Mobile Internet Computing 2000s

From Dense to Ubiquitous

- Everybody, at anytime, from anywhere.

anybody, (m)anytime, (m)anywhere

- Trend: more mobile telecommunication
  - more than 6.8 billion user (according to ITU)
  - now more than fixed network users



- Goals:

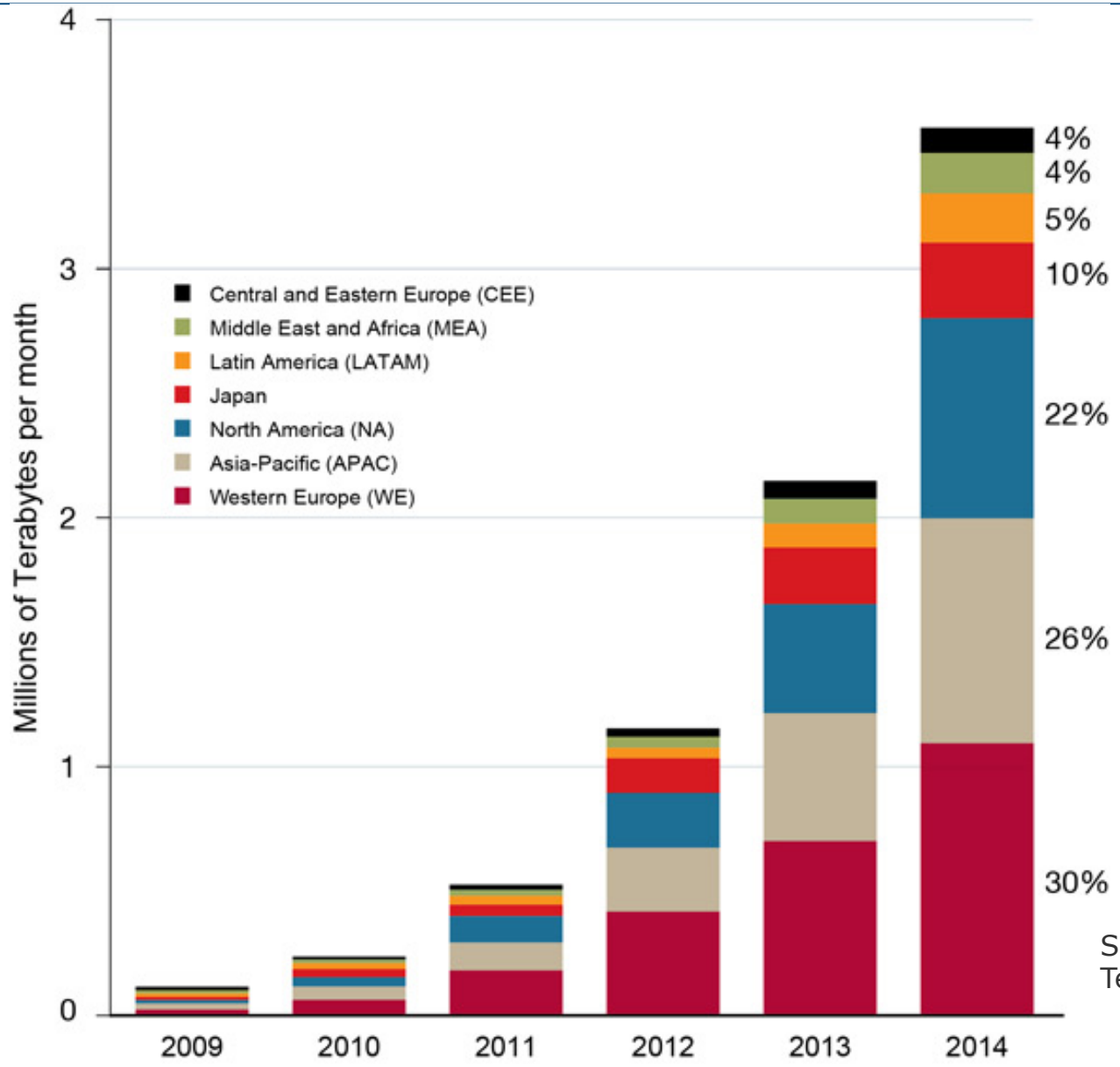
VoIP/Video

Email

Web surf

IM / social

Global Mobile Data Traffic Forecast by Region



Source: Cisco and MIT Technology Review

Wireless Performance Gains

1900

2013

Smartphone

- About 10 bit/s/100.000 km^2
- About 1000 watt

- About 10,000,000 bit/s/ha
- About 0.01 watt

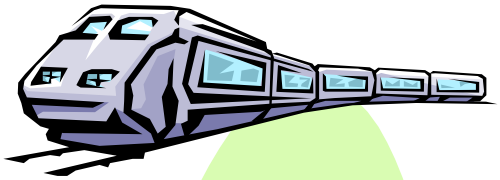
A performance gain factor of about 10^{14}
(= 100,000,000,000,000)

Mobile Communications: Available Capacity in Practice

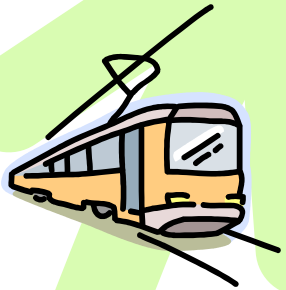
Early LAN,
WLAN
2 Mbit/s

GSM 57 kbit/s
Bluetooth 500 kbit/s

UMTS, GSM
115 kbit/s



LAN
100 Mbit/s,
WLAN
50 Mbit/s



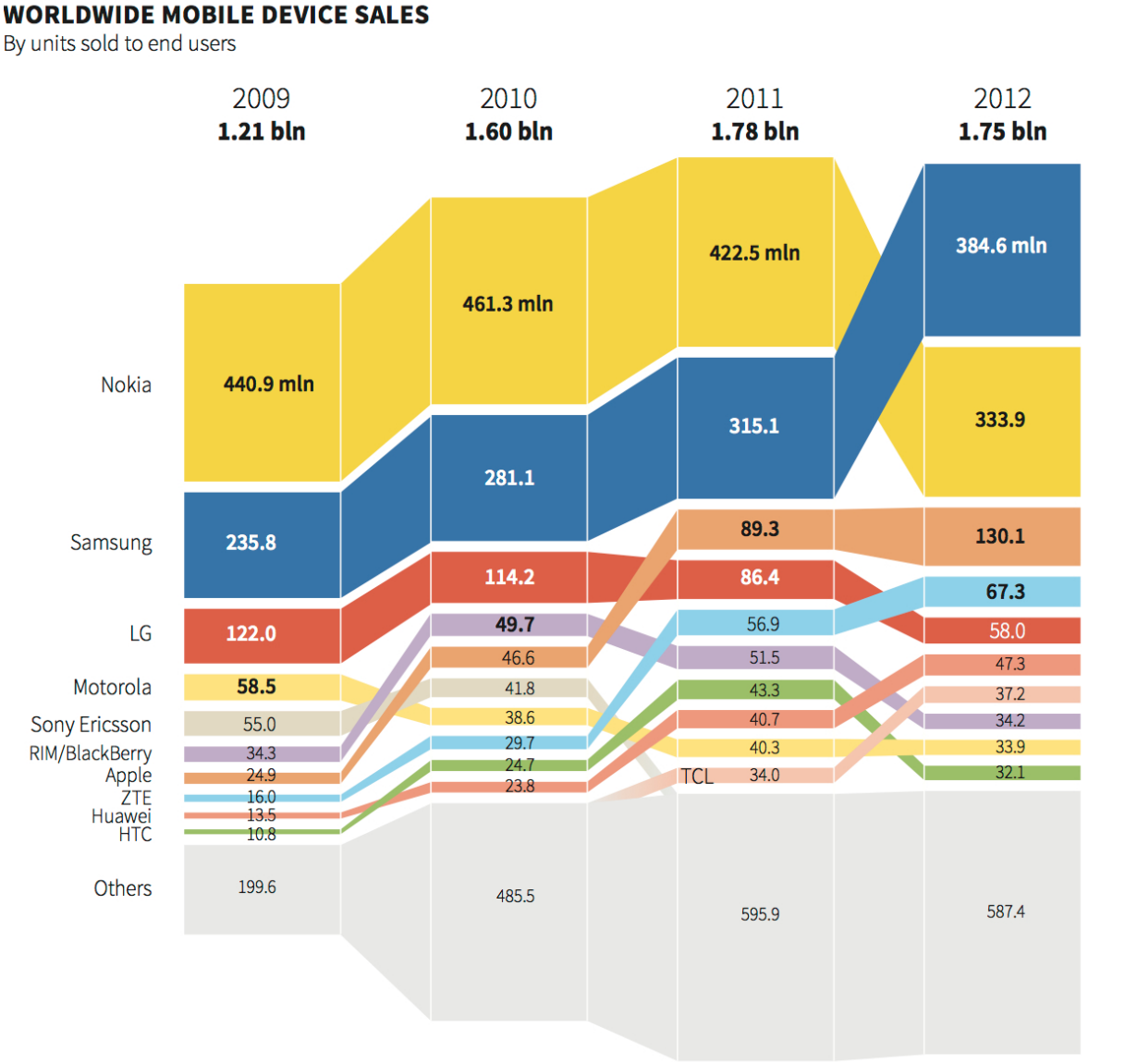
UMTS,
LTE
50 Mbit/s

GSM 384 kbit/s,
WLAN 780 kbit/s

GSM 300 kbit/s,
WLAN 11 Mbit/s

UMTS, GSM
384 kbit/s

Worldwide Mobile Devices Sales



Source: Gartner

Note: Research In Motion (RIM) rebranded itself as BlackBerry. Sony acquired Ericsson's share in mobile phone venture in Feb. 2012

K.Pong, 25/02/2013

REUTERS

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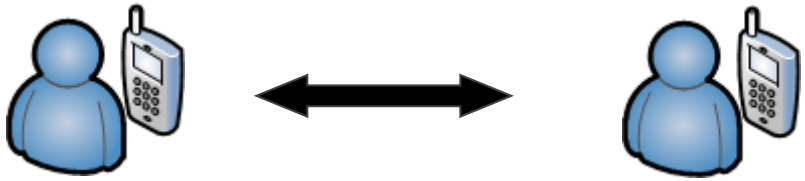
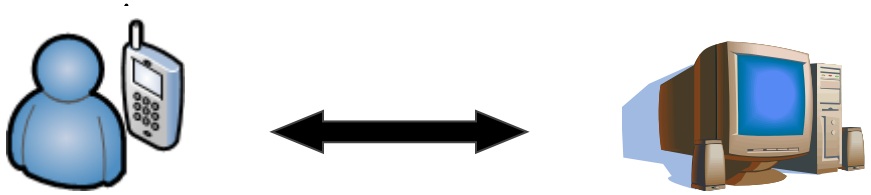
Evolution steps

- Step 1:
  - Person to person
    - Direct communication, telephony, ...

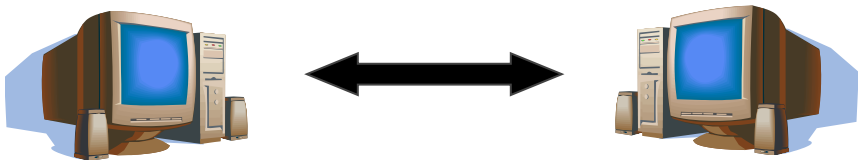


- Step 2:
  - Person to machine
    - Cloud services, Natural Language Interfaces (Siri, Google Now), ...

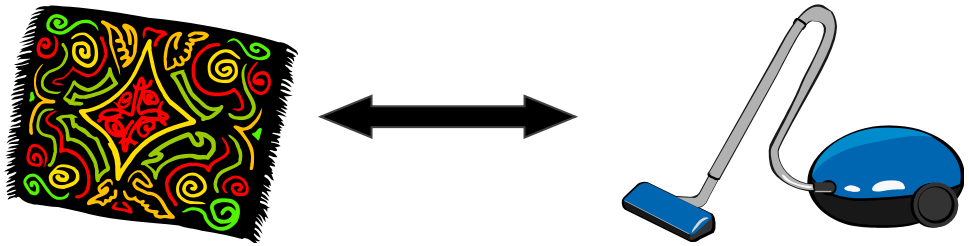


Evolution of communication

- Step 3:
  - Machine to machine
    - Computer to computer,
      e.g. Grid Computing, Data Centers



- Step 4:
  - Object to object
    The Internet of Things (IoT)
    - Computers become more numerous, cheaper, and smaller. They are implicitly everywhere; they are less computers but rather "things" or "objects".

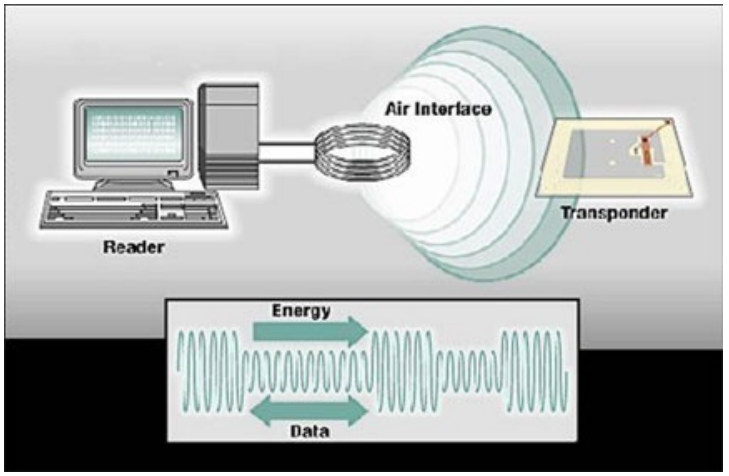


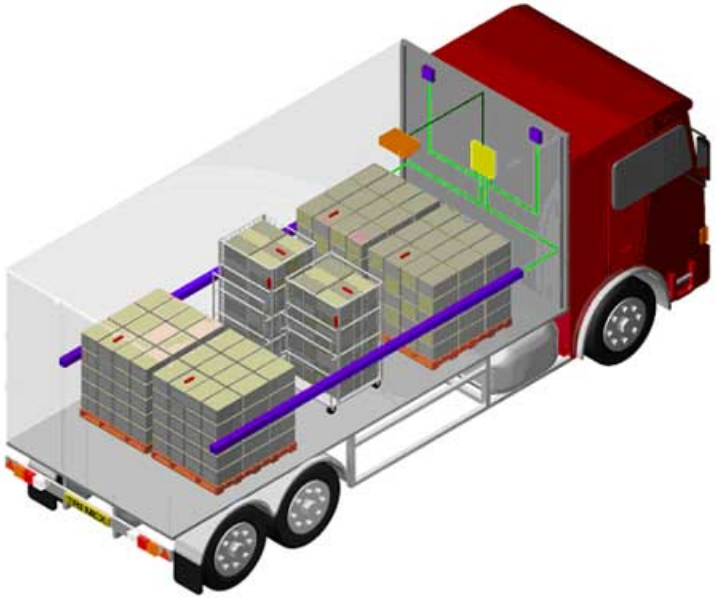
IoT = Environment Automation

- Possible and/or already existing IoT applications in many areas:
  - in medicine (body area networks, supervision of health condition, ...)
  - in entertainment (the new ICE age, ICE = Information, Communication, Entertainment)
  - in enterprises (fleet management, self maintenance, ...)
  - at home (assisted mobility, supervision of property, regulation of consumption, e.g. of fuel or of gas or of electricity, ...)
  - in traffic (traffic regulation, maintenance, car to car communication, ...)
  - in emergency situations (crisis management)

Environment Automation: Example using RFID

- Radio Frequency Identification (RFID) is a technology to identify all types of objects without contact by using radio frequency
- Unlike bar-coding, RFID technology enables the reading, writing, and recording of data on the applied tag irrespective of location, type of environment, contact, or visibility
- Thus RFID opens up new opportunities in the areas of identification logistics, material management, production, and service.





Environment Automation: Example using RFID

- Pervasive computing
  - Tiny computer embedded in everyday devices, e.g., appliances
- Assisted life
  - Travel
  - Healthcare
  - Shopping
- Disadvantage
  - Privacy

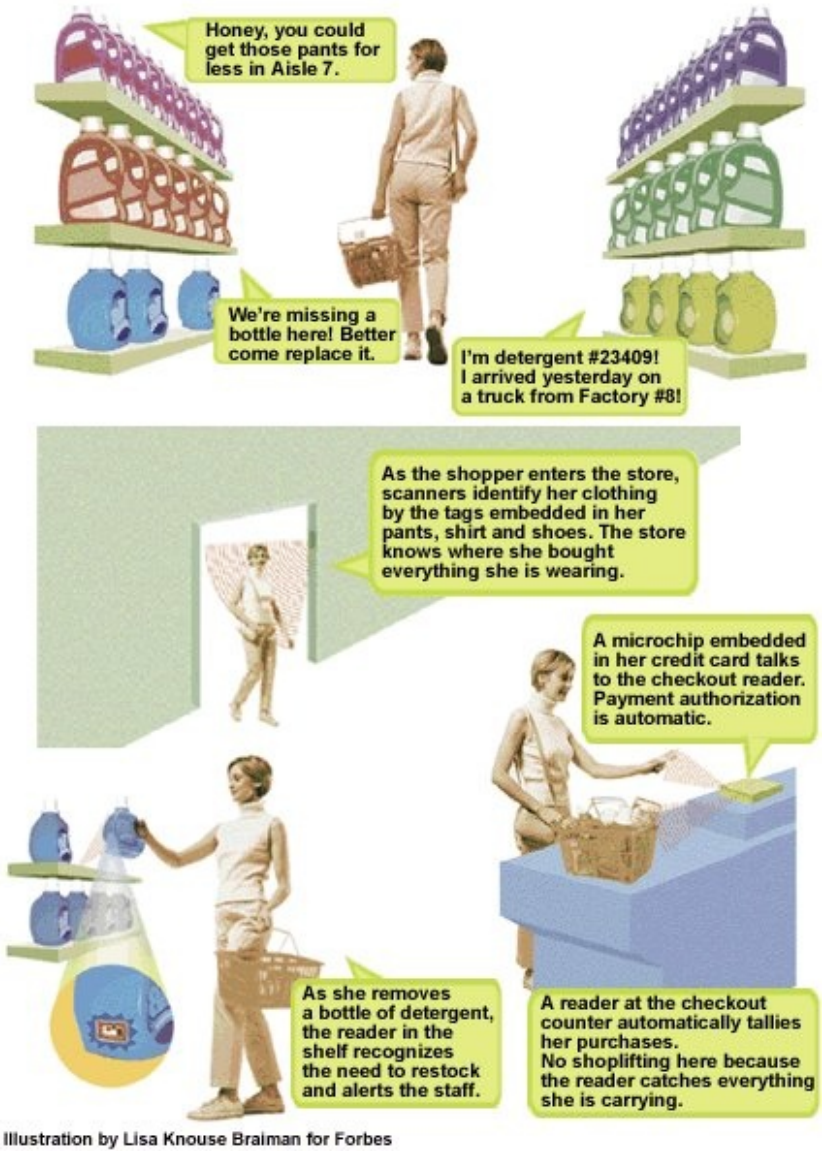


Illustration by Lisa Knouse Braiman for Forbes

Environment Automation: Example using RFID

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http://ibiblio.org/Dave/drfun.html
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Intermediate Summary

We saw

- A tremendous change in telecommunication
  - From telegraph to the Internet, from wired to wireless, from large to small devices
- Trend towards convergence of networks
  - We learned along the way, and things will still change!

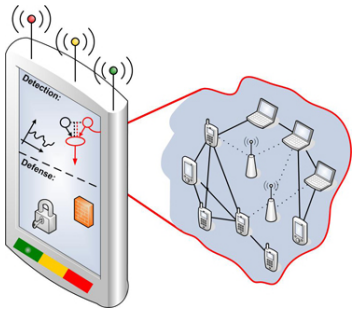
You want to build telecommunication solutions that

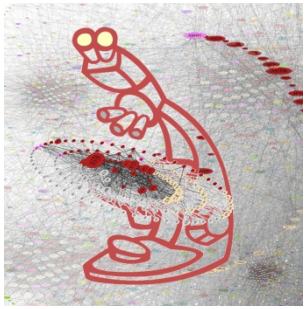
- Survive multiple decades
- Work in different environments
- Co-exists with other solutions

This course should give you background on how to design and implement such solutions.

On-Going Related Activities in our Research Group

- Communication protocols standardization (IETF)
- RIOT - an operating system for the Internet of Things (open source online community)
- Development of large-scale testbeds (FIT, DES, Senslab)
- Development of new IoT hardware
- Security aspects in wireless and wired networks (together with DFN-CERT, for example)
- Measurement of real, large networks, e.g., the Internet (together with ISPs and Internet Exchange Points)
- Design and analysis of future Internet architectures (e.g., ICN)
- …





http://cst.mi.fu-berlin.de/projects/

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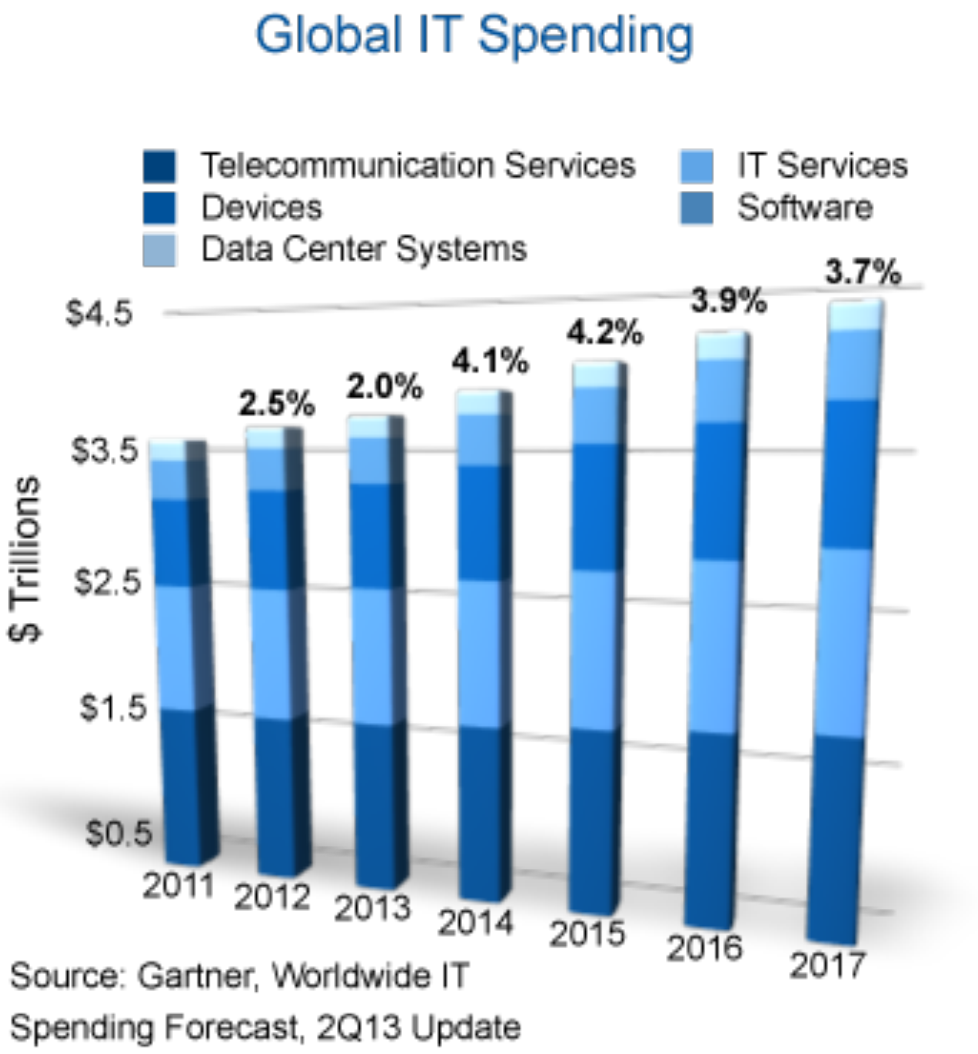
Economic Aspects: Business SSectors

- **Supplier**
  - Produces hard-/software-technologies, e.g., Cisco, Huawei, Samsung, Alcatel-Lucent, …
- **Common Carrier**
  - Offers transportation services, e.g., Deutsche Telekom, Vodafone, KPN, etc.
- **Service Provider**
  - Offers value-added services on the basis of the Common Carrier, e.g., Internet Service Provider, Intelligent Networks, 0800-, 0190- services
- **Content Provider**
  - Offers contents, e.g., news, magazines, publisher, stores, etc.
- **User**
  - Shall pay everything

- A company may belong to several groups (e.g. Google, Motorola & CDNs)
- Converging industries (Content providers, Suppliers, Service providers)

Economic Aspects: The Telecommunications Market



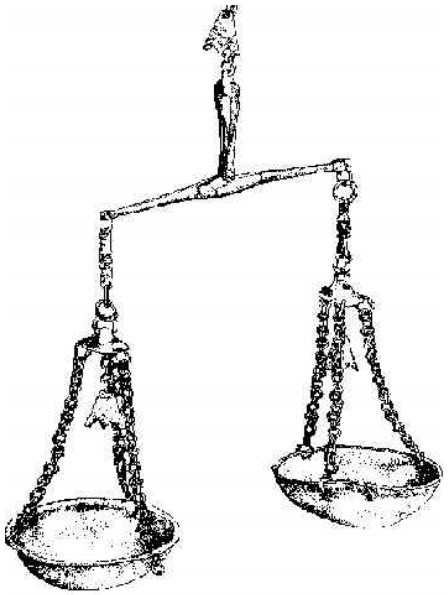
Modern Communication Networks: Legal Aspects

With great power…

- Communication networks enable a fast and cheap exchange/distribution of information. There is however a large number of social, ethical, cultural, juridical ... side effects.

… come great side effects

- Eventually dubious or forbidden contents
- Responsibility
- Juridical aspects (legislation)
- Potential censorship?
- Control over the productivity of employees, of the whereabouts of people
- Annoyance through anonymous or unwanted messages (SPAM)
- …



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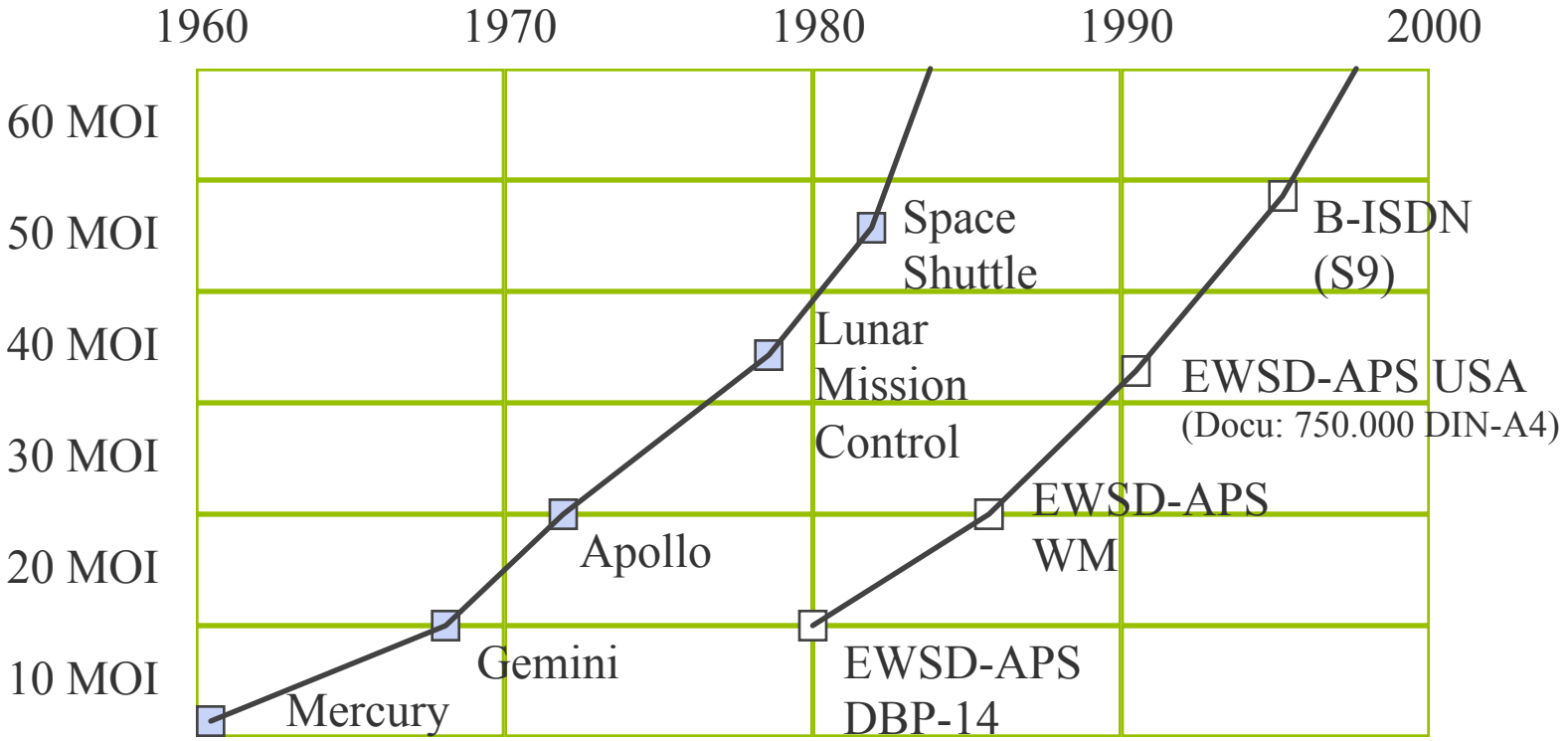
Computer Networks

- **From atoms to bits**
  - *Before Internet*: information sent as atoms, expensive
  - *After the Internet*: sent as bits over the network, much cheaper
  - This is reshaping whole industries
- Digitalization of **all communication forms**
  - Audio, Music, Text, Graphics, Pictures, Video, Technical Data, etc.
  - Multimedia (combination of the above)
- Modern telecommunication networks are **Computer Networks**
  - Computer networks transmit these bits
  - This course will be focus on how the bits are moved
  - The most important computer network: the Internet

Computer Networks: Software

- Complexity of software for networks
  - Example: ISDN router (Siemens' Electronic Digital Switching System)



MOI = Million Object-Code-Instructions

So What is the Internet ?

Three aspects

1. Service: the Internet is a bit delivery service

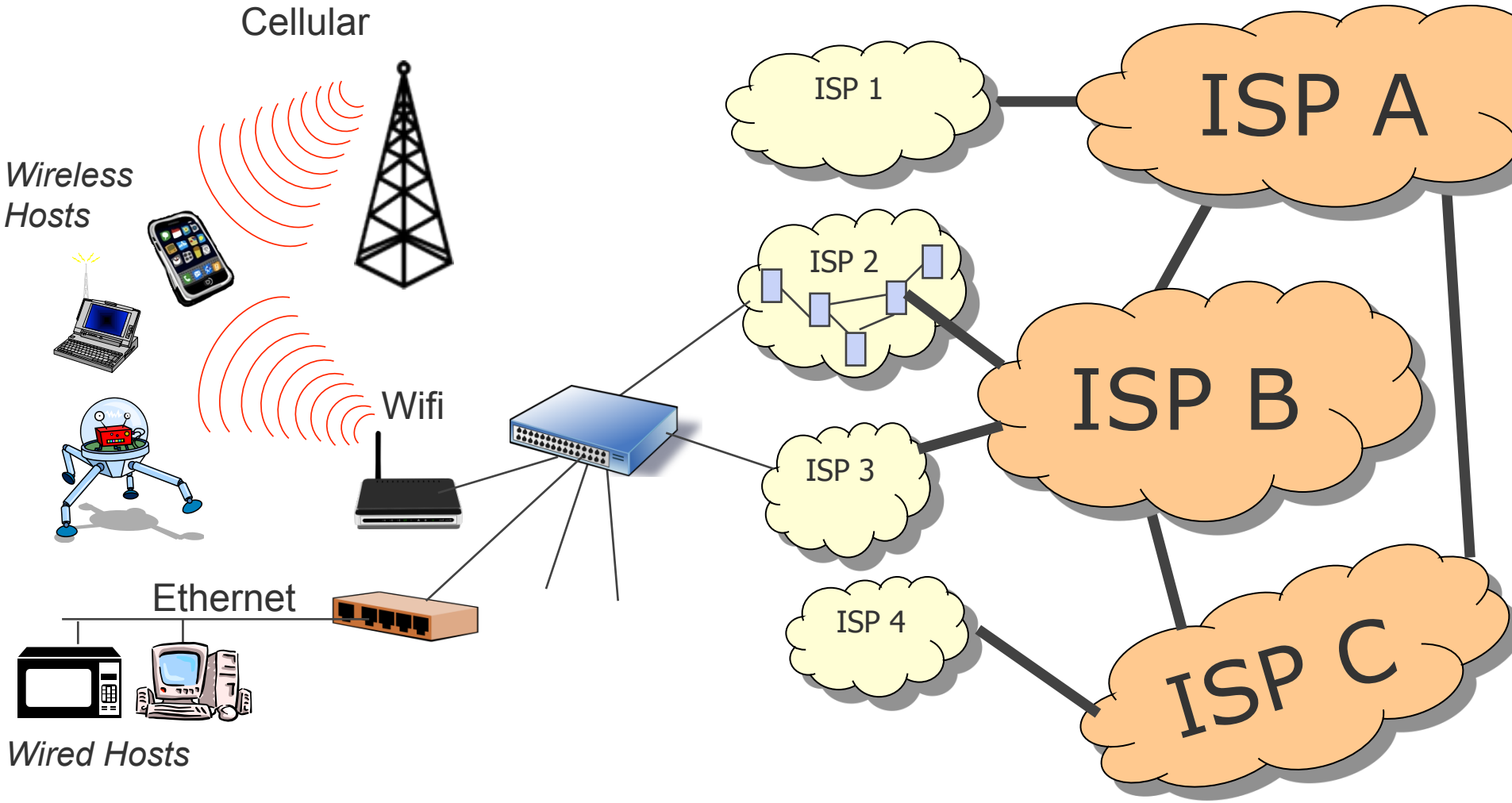
2. 'Formal': the set of all reachable parties (= IP addresses)

3. Topology: the interconnected machines

(Note, the Internet is not the World Wide Web.
The Internet allows services such as the
World Wide Web on top.)

So What is the Internet ? The Topology Aspect

ACCESS LINKS	ACCESS POINTS	SWITCH & ROUTERS	TIER 2 ISP (REGIONAL)	TIER 1 ISP (GLOBAL)



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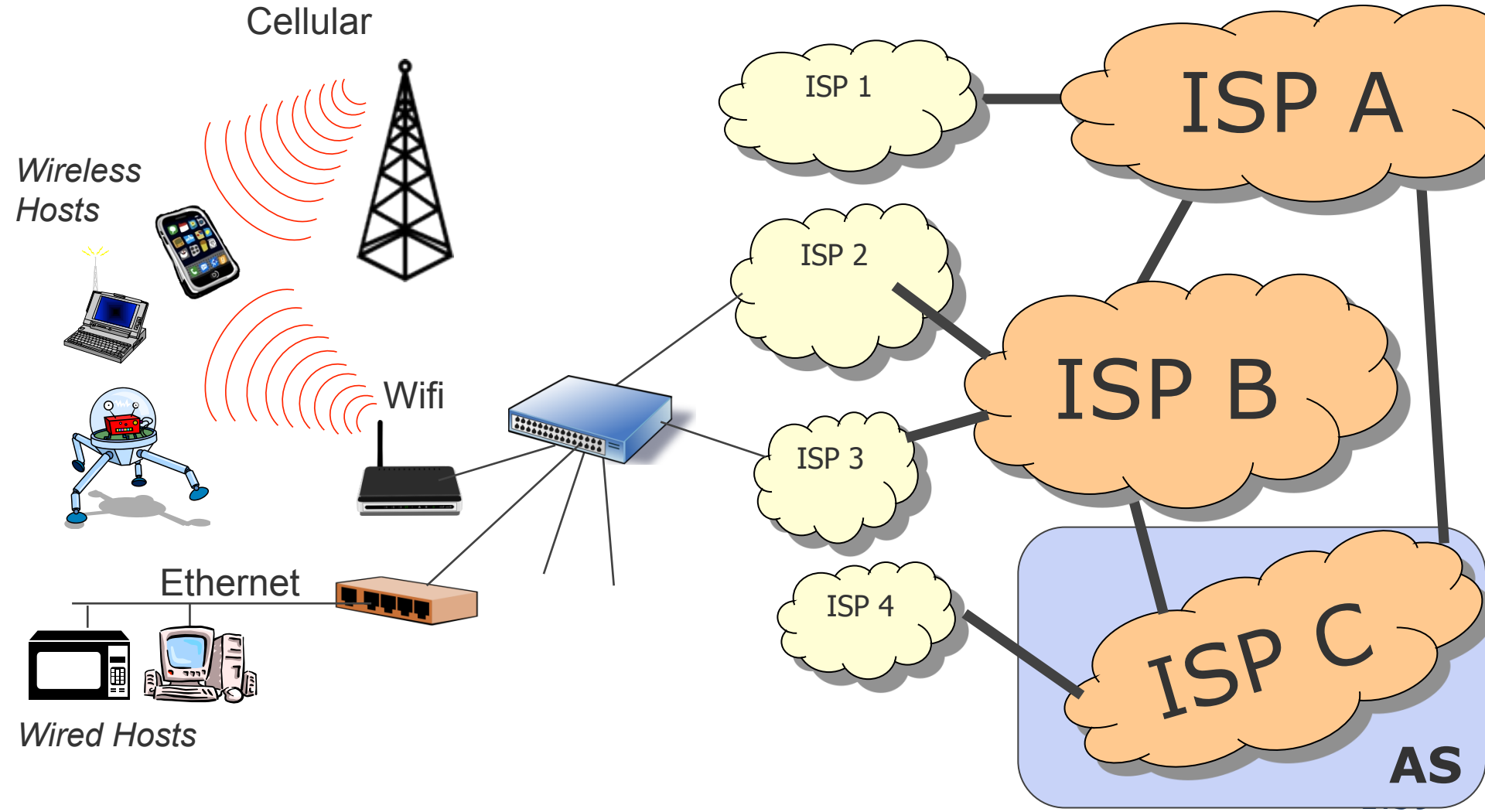

So What is the Internet ? The Topology Aspect

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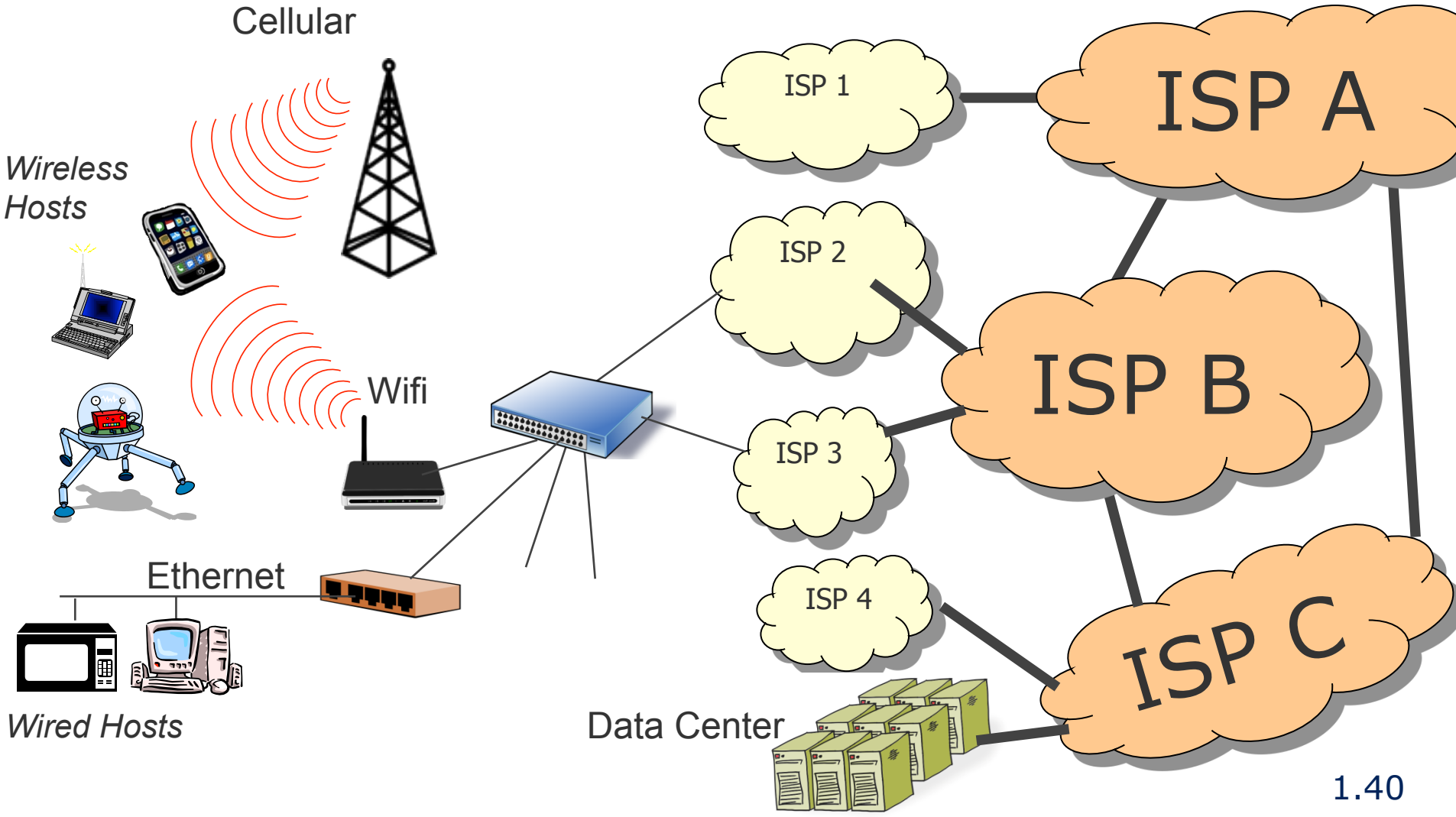
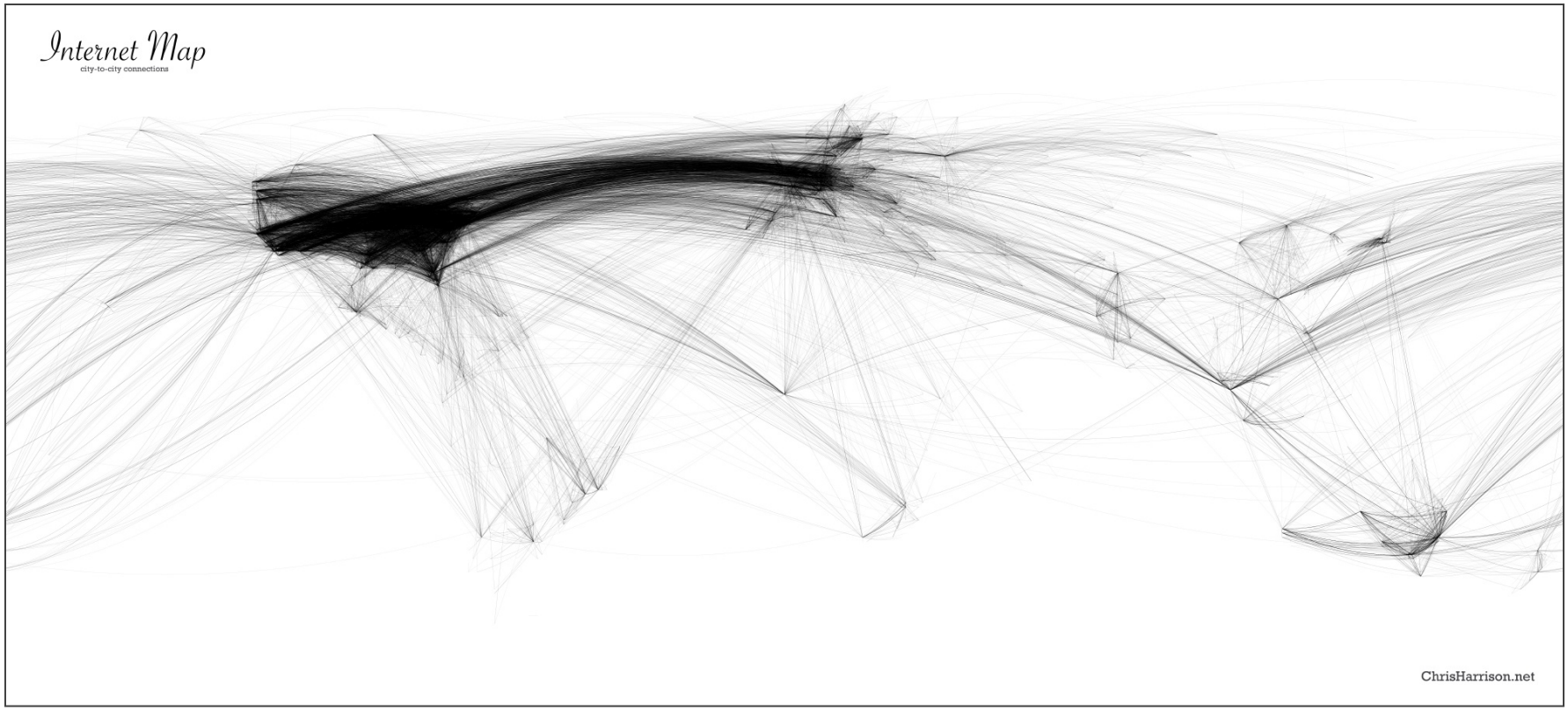
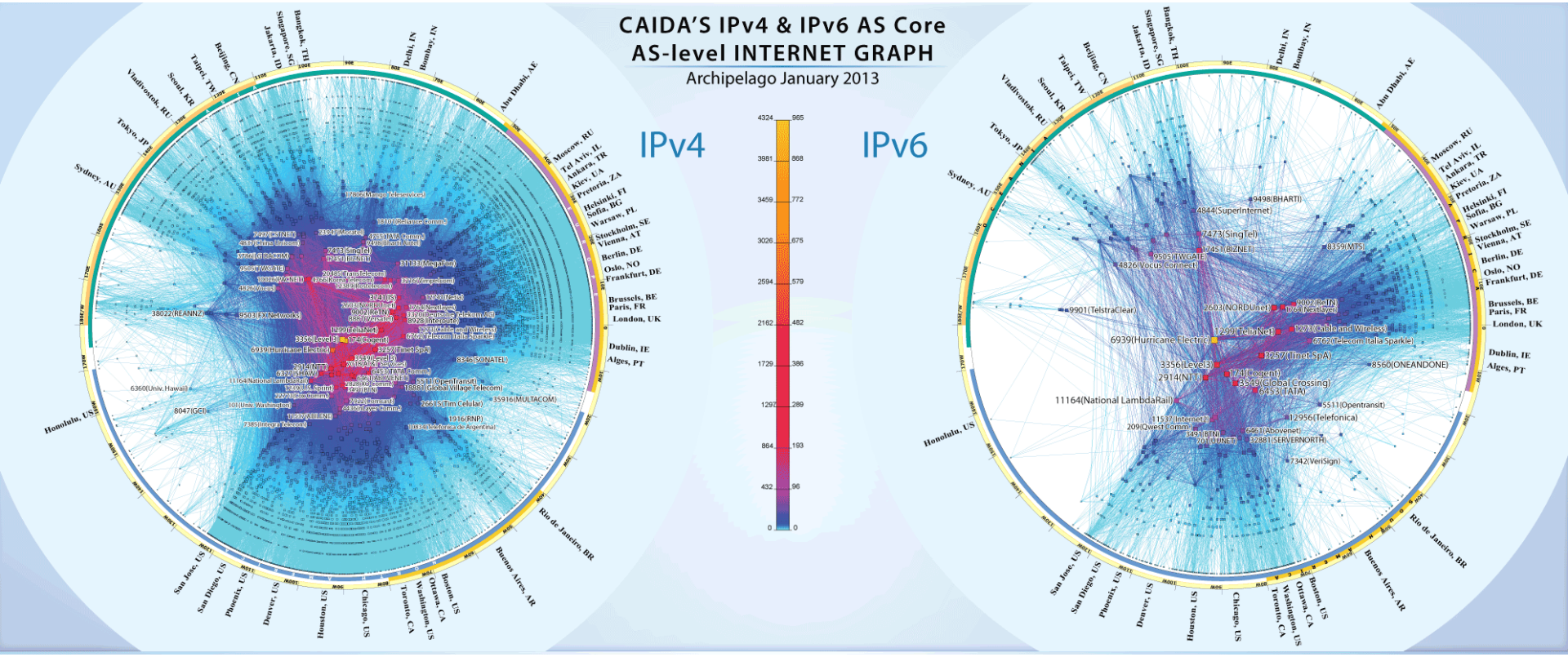


Topology: Some Tier 1 ISP Long-Distance Links

- World City-to-City Connections, Courtesy of ChrisHarrison.net

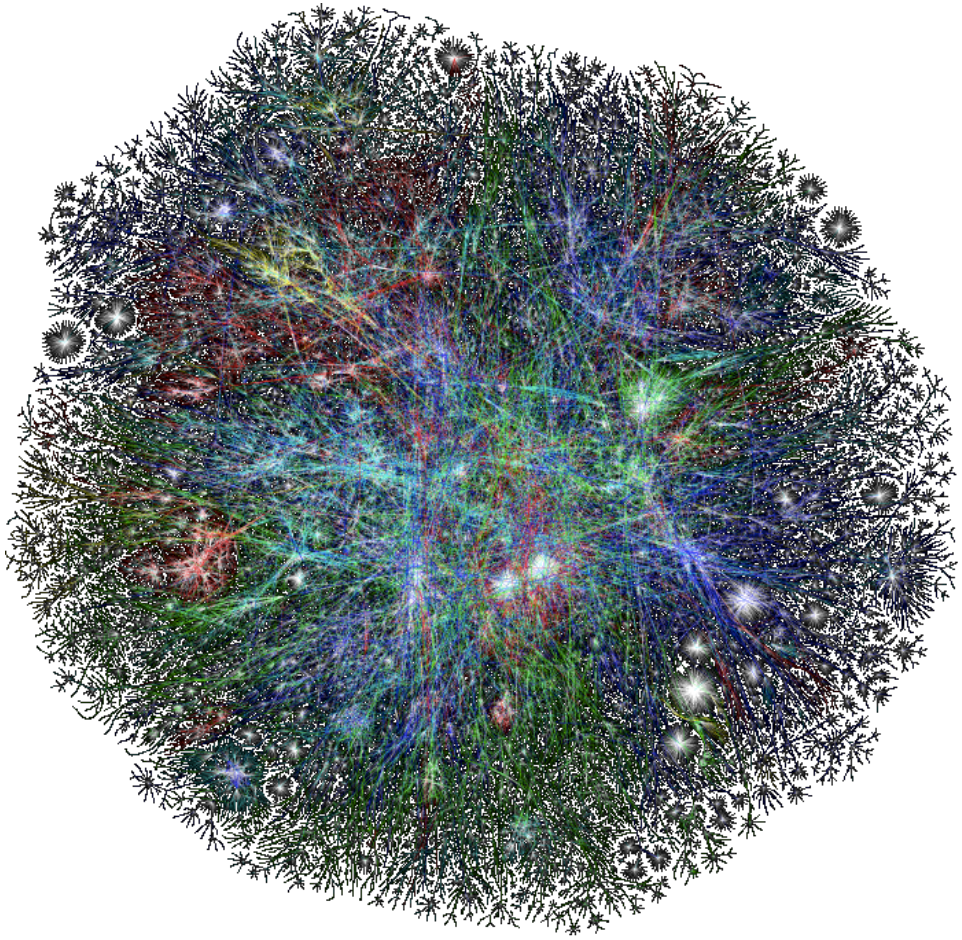


Topology: Links between ISPs

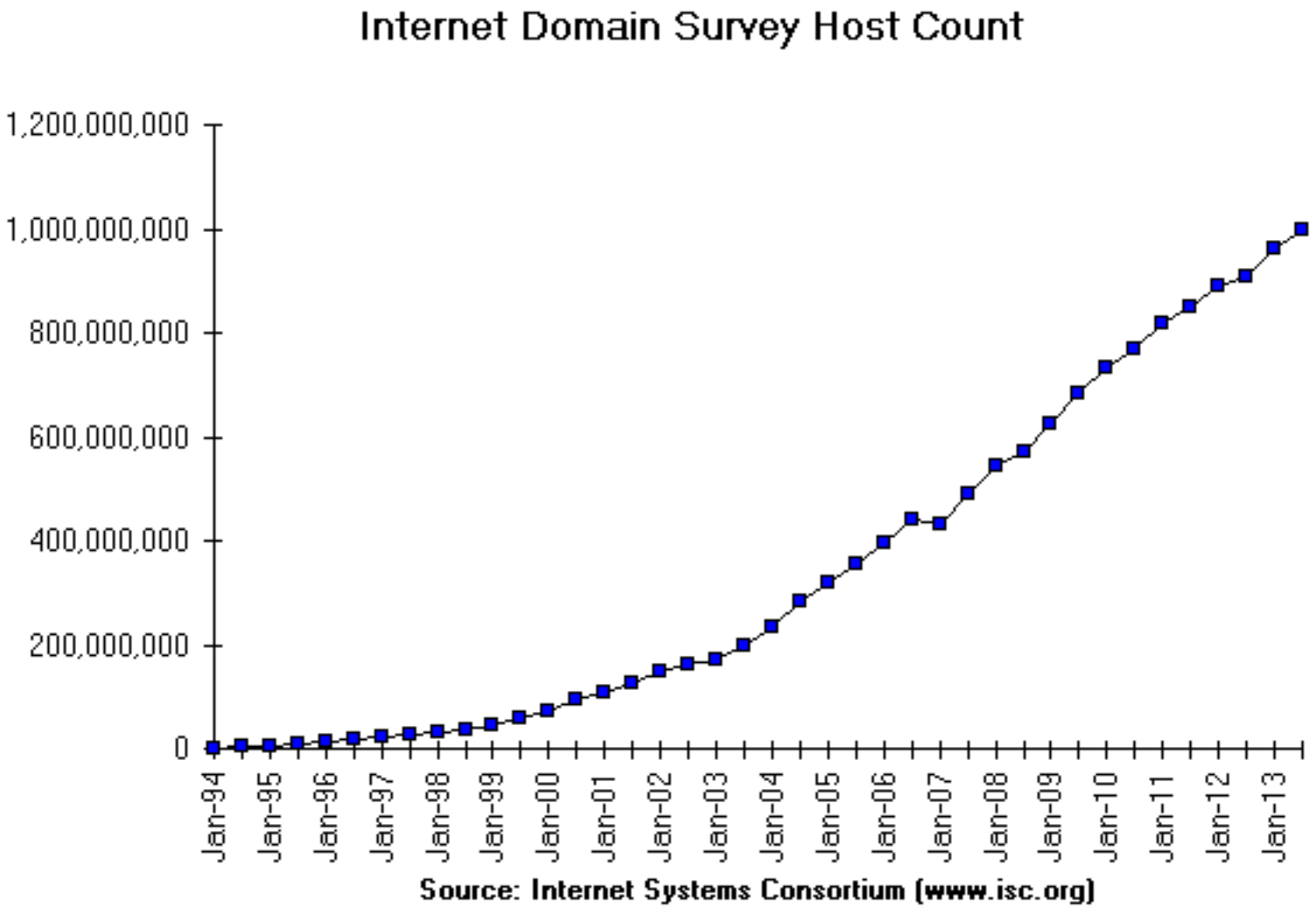


Source: http://www.caida.org

Topology: Vizualizing the Full Map? Big Data.



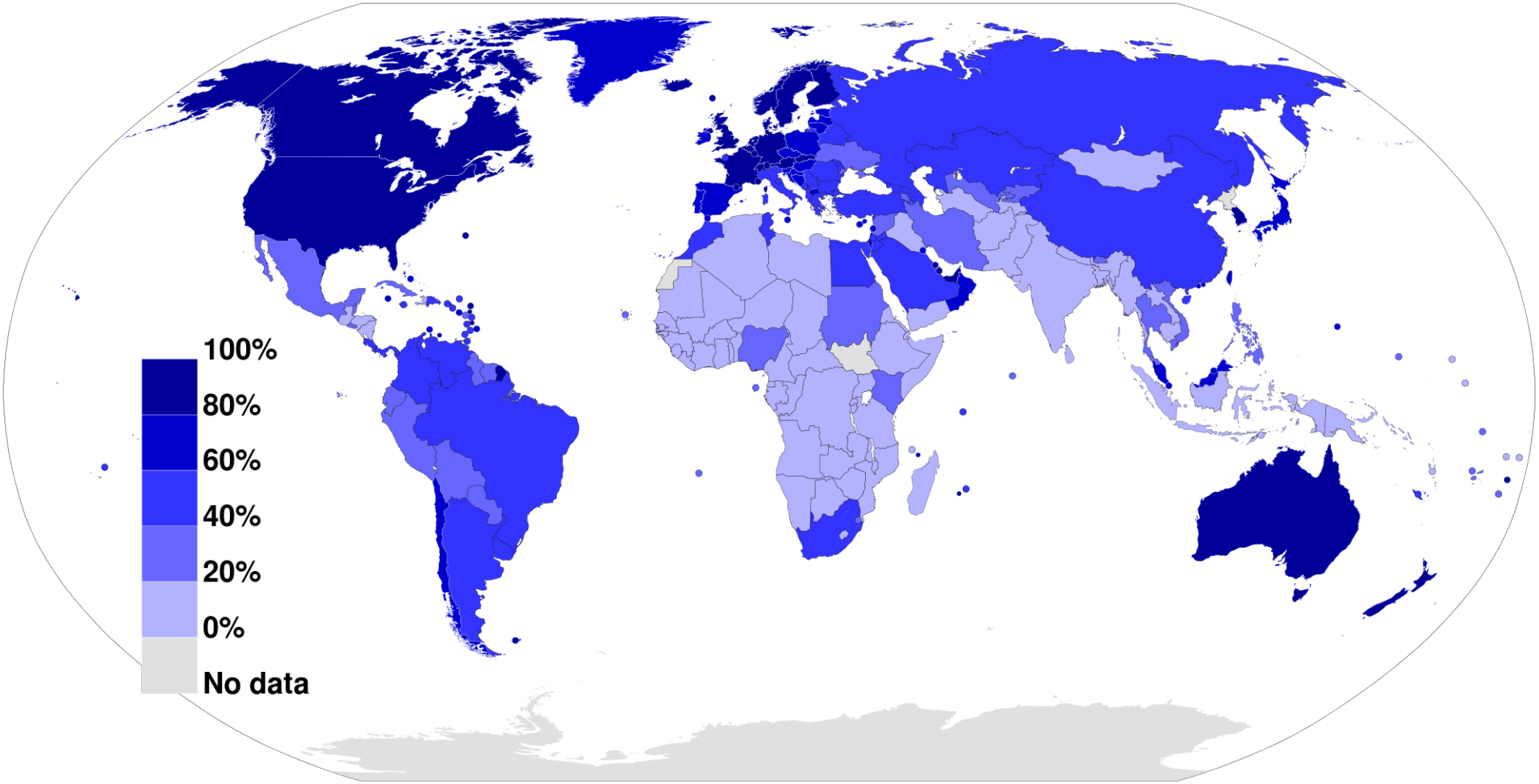
The Internet: Number of Hosts



Source: Internet Systems Consortium (www.isc.org)

Topology: Location of Internet users

- Internet Penetration Rate by Region (source ITU, Jeff Ogden)



The Internet: The History

Year	Event
1957	USSR launches Sputnik, first artificial earth satellite. In response, US forms the Advanced Research Projects Agency (ARPA) within the Department of Defense (DoD) to establish US lead in science and technology applicable to the military.
1960s	▪ Design of packet-switching networks – Paul Baran, RAND: "On Distributed Communications Networks" – No single outage point.
1967	ACM Symposium on Operating Principles - Plan presented for a packet-switching network
1968	Network presentation to the Advanced Research Projects Agency (ARPA)
1969	▪ ARPANET commissioned by DOD for research into networking – Uses Network Control Protocol (NCP) through Information Message Processors (IMP) developed by Bolt Beranek and Newman, Inc. (BBN) – First node at UCLA, soon after at Stanford Research Institute (SRI), UCSB, and the University of Utah. First Request for Comment (RFC): "Host Software" by Steve Crocker
1970s	▪ Store and Forward Networks – Electronic mail technology extended to conferencing.
1970	ALOHAnet developed by Norman Abrahamson, Univ. of Hawaii

The Internet: The History

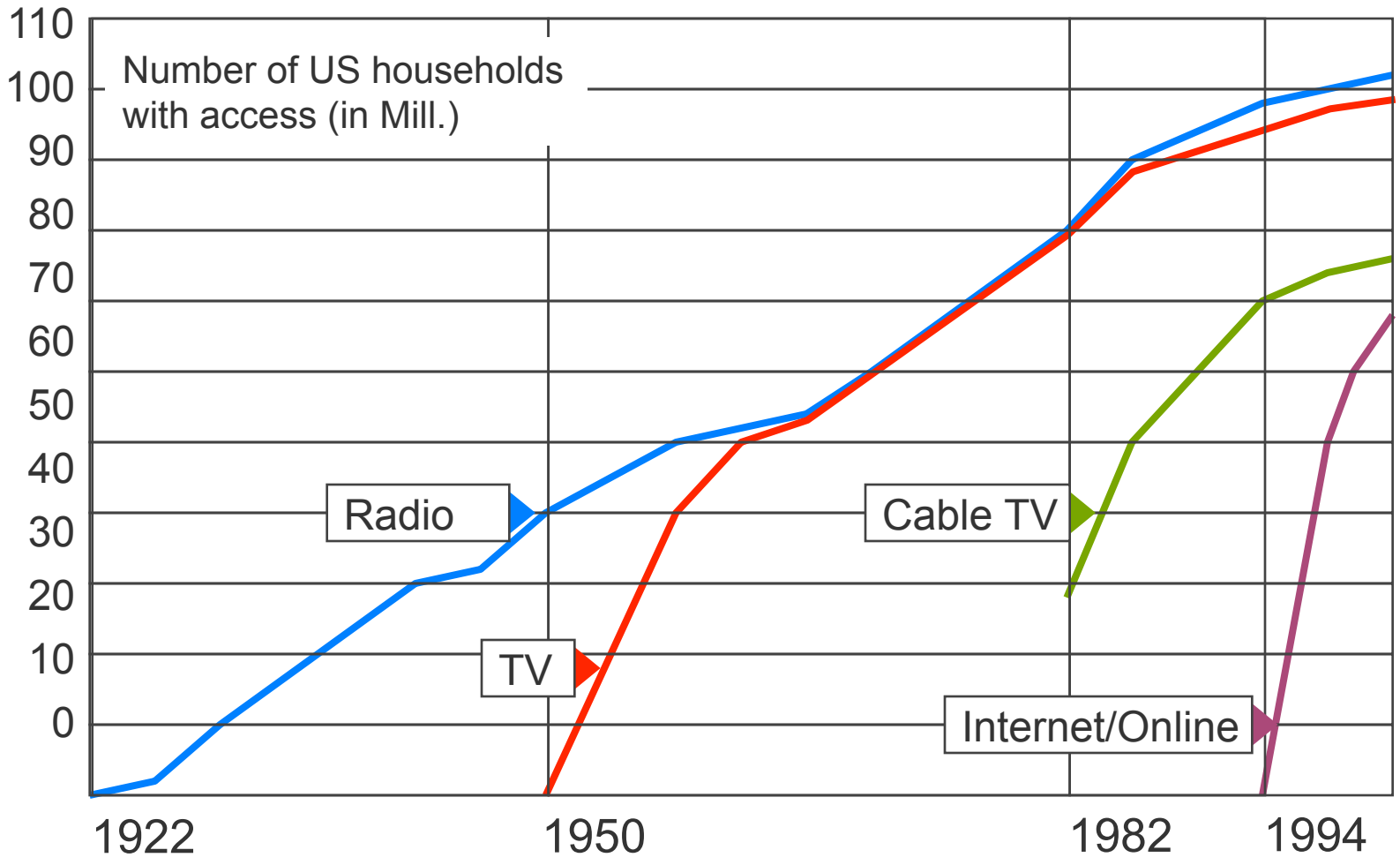
Year	Event
1971	15 nodes (23 hosts): UCLA, SRI, UCSB, U of Utah, BBN, MIT, RAND, SDC, Harvard, Lincoln Lab, Stanford, UIU(C), CWRU, CMU, NASA/Ames
1972	▪ International Conference on Computer Communications with demonstration of ARPANET between 40 machines organized by Bob Kahn. ▪ InterNetworking Working Group (INWG) created to address need for establishing agreed upon protocols. Chairman: Vinton Cerf.
1973	First international connections to the ARPANET: England and Norway
1982	▪ INWG establishes the Transmission Control Protocol (TCP) and Internet Protocol (IP), as the protocol suite, commonly known as TCP/IP, for ARPANET. – This leads to one of the first definition of an "internet" as a connected set of networks, specifically those using TCP/IP, and "Internet" as connected TCP/IP internets.
1983	▪ Name server developed at Univ. of Wisconsin, no longer requiring users to know the exact path to other systems. ▪ ARPANET split into ARPANET and MILNET with the latter becoming integrated with the Defense Data Network created the previous year.
1984	Domain Name Server (DNS) introduced.
1988	Internet worm burrows through the Net.

The Internet: The History

Year	Event
1988	IP-Link to the Internet from Germany over Eunet-IRB Dortmund and XLink (eXtended Lokales Informatik-Netz Karlsruhe)
1989	Number of hosts breaks 100,000.
1991	EBONE: EuropeanBackbone
1992	▪ Internet Society is chartered (www.isoc.org). ▪ World-Wide Web released by CERN. ▪ Number of hosts breaks 1,000,000.
1995	Internet gets public through WWW
1996	University Corporation for Advanced Internet Development - Internet2
1999	Internet2-Backbone: Abilene
1998-2002	Rise and fall of the dotcoms

More detailed history at:
http://www.zakon.org/robert/internet/timeline/
and other links....

The Internet: Incredibly Fast Deployments



(Source: Bertelsmann)

Contents

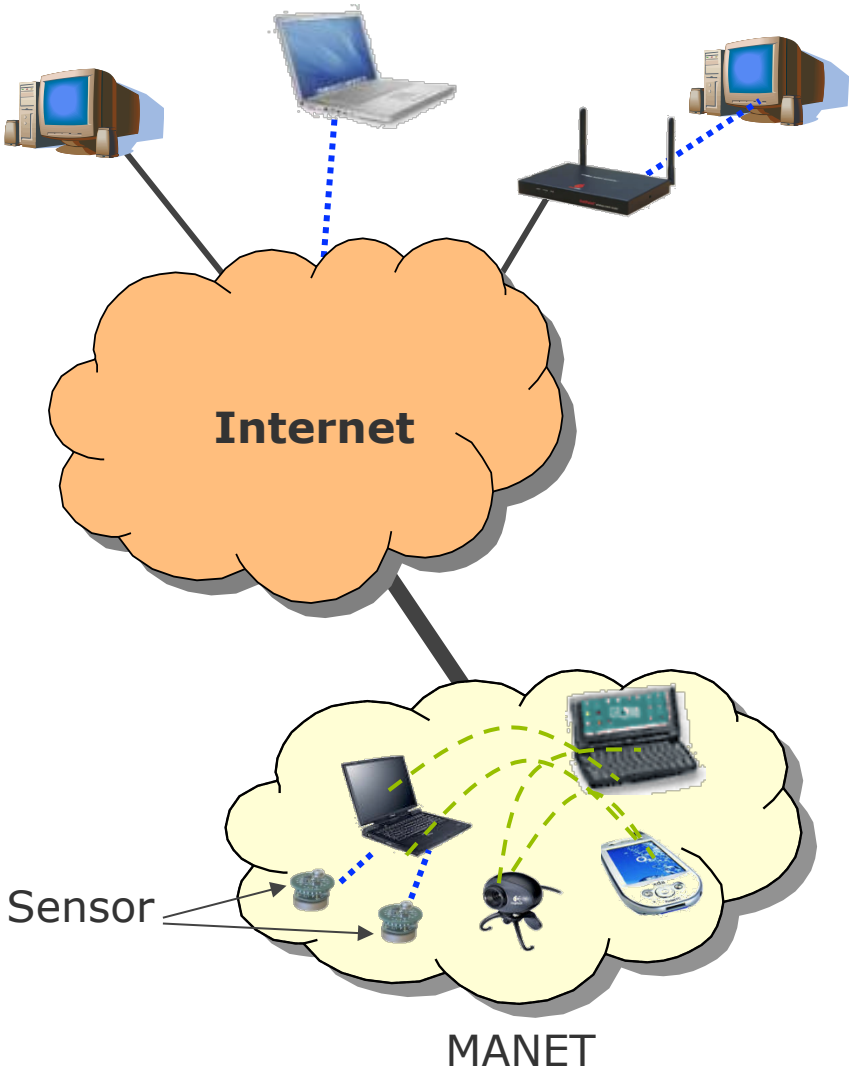
- Evolution of telecommunications
  - Brief prehistoric overview
  - From multiple networks to a single network
  - From wired to wireless
  - From communication for humans to communication for machines
- Economic & social aspects of telecommunications
- Computer Networks & the Internet
- Why this course?

Question: How can the Internet Scale that Large?

- Design Principles of the Internet
  - Minimalism and autonomy
    - The network operates by itself
    - It does not require internal changes when new networks are added
  - Best-effort service model
    - The network tries to transmit data as good as possible, but does not guarantee a reliable service
  - Soft-state (stateless)
    - The routers **do not** need to **maintain** end-to-end communication information
  - Decentralization
    - No single entity administers the Internet

On-Going Research in Many related Domains

- Network Architectures and Communication Protocols
  - Wired networks
    - Local Area Network (LAN)
    - Internet and Wide Area Networks (WAN)
  - Wireless networks
    - Wireless Local Area Network (WLAN)
    - Spontaneous Wireless Networks: Mobile Ad-hoc Network (MANET), Wireless Sensor Network (WSN), Smart Dust…
    - GSM, 3GPP, LTE…
  - Protocols
    - HTTP, TCP/UDP, IP
    - IEEE 802.11a,b,g,n,…
  - Internet of Things and M2M
    - Anytime, Anywhere, Anything



Importance of the Subject

- Since 20 years, the Internet has already:
  - Imposed a huge shift to society, you, me, almost everyone
  - Created 100 trillion € business for the industry worldwide
- Over the next 20 years, we can expect the Internet will:
  - Impose another huge shift to society
  - Become significantly larger and more complex
- We teach this course because:
  - Your job & your private life will require you to understand the concepts at work
  - To understand tomorrow's Internet, you should understand how it works now

Course Organization

- The Internet as a Blackbox: Applications
  - Basic terminology & concepts (protocols, API…)
  - Dive into DNS, Email, HTTP, SNMP & their interface to the blackbox
- Opening the Blackbox: The IP Protocol Stack
  - Basic terminology & concepts (layers, standard stack…)
  - Dive into each layers
- New trends in the domain of computer networks

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