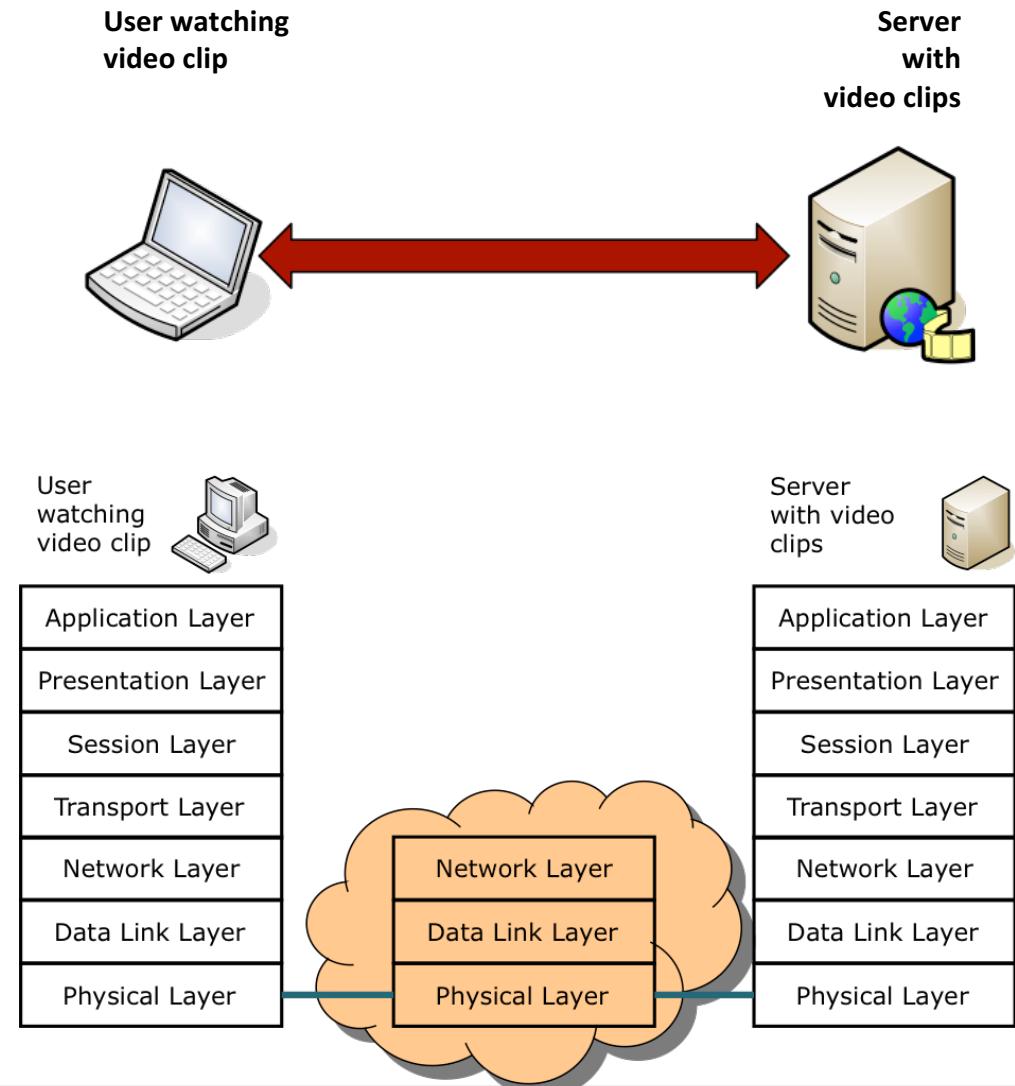


Computer Networks

Chapter 1: Motivation

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Contents

- **Communication Metaphors**
- **Mobile Communications**
- **Ubiquitous Communication**
- **Sensor Networks**
- **History of Telecommunications**
- **The Telephone Network**
- **Economic Aspects of Telecommunications**
- **Computer Networks**
- **The Internet**

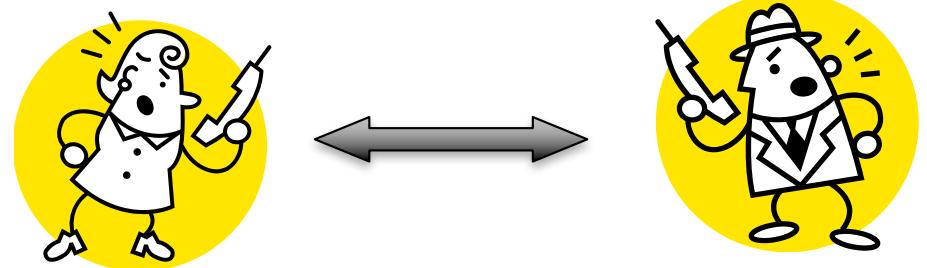
Communication Metaphors

Communication Metaphors

Four evolution steps:

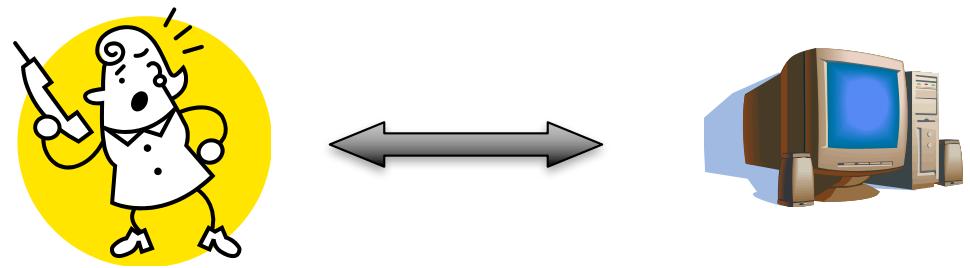
- **Phase 1:**

- Person to person
 - Direct communication, telephony, ...



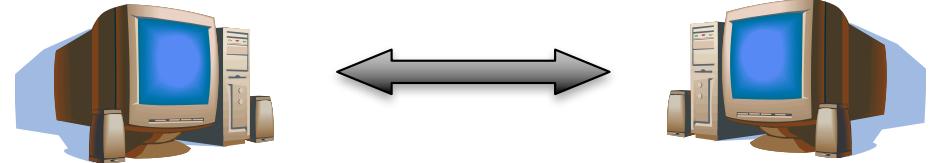
- **Phase 2:**

- Person to machine
 - Fax, Email, PC usage, ...



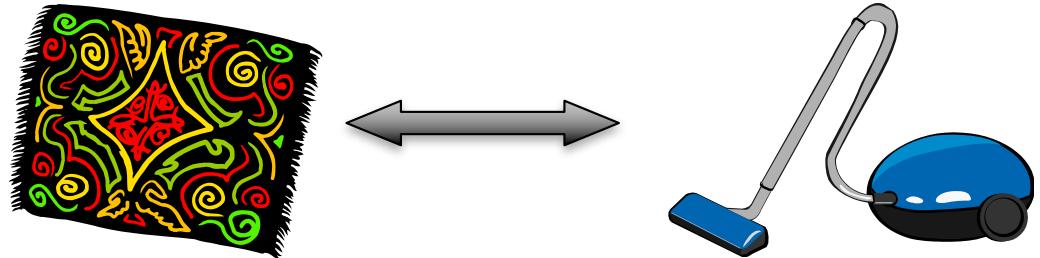
Communication Metaphors

- **Phase 3:**
 - Machine to machine
 - Computer to computer,
e.g., grid computing, sensor networks, Web 2.0
 - Network of computers ...
 - which exchange information in an autonomous way
 - which use these information by taking into account the environment
 - the obtained information are not necessarily traditional information, i.e., not only digits or text or images
 - together with other components which make the global system useful or necessary for the user



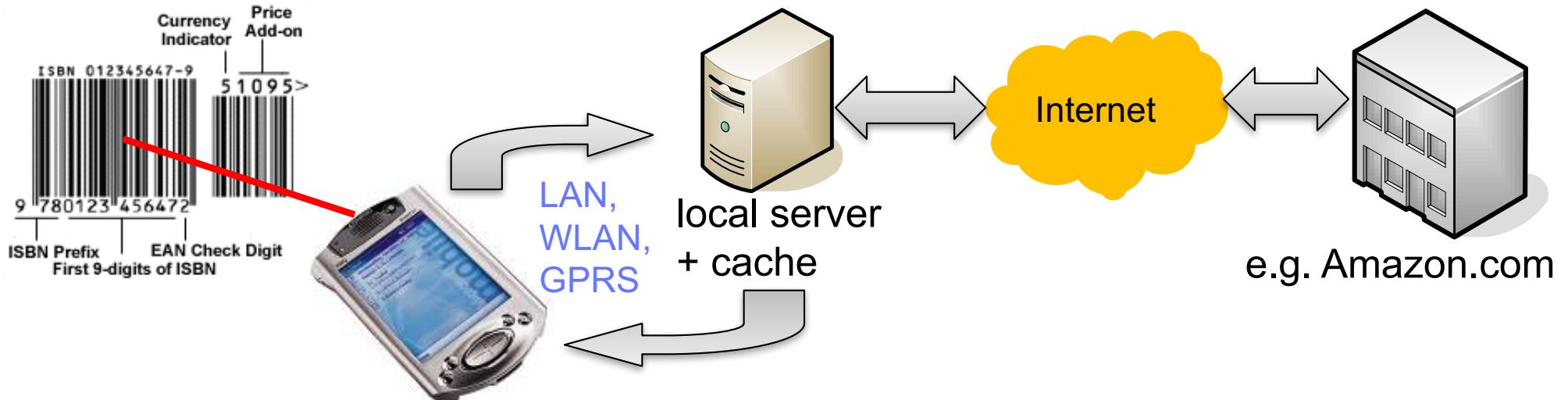
Communication Metaphors

- **Phase 4:**
 - The Internet of Things
Things to things
 - Computers become more numerous, cheaper, and smaller. They are implicitly everywhere. They are less computers but rather »things« or »objects«.
- **Applications of such systems in ...**
 - medicine (body area networks, supervision of health condition, ...)
 - entertainment (new ICE age, ICE = Information, Communication, Entertainment)
 - enterprises (fleet management, self maintenance, ...)
 - home (assisted mobility, supervision of property, regulation of consumption, e.g., of fuel/gas/electricity, ...)
 - traffic (traffic regulation, maintenance, car to car communication, ...)
 - emergency situations (crisis management)

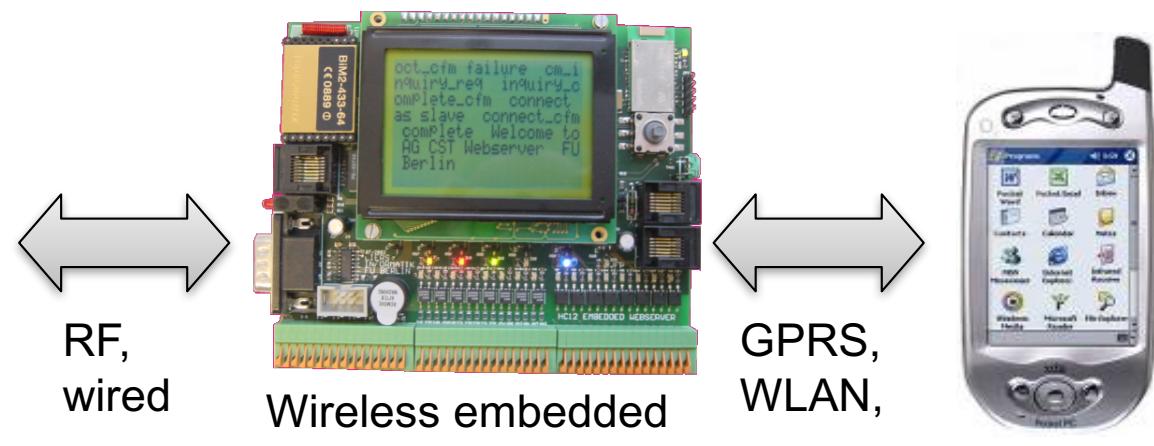


Communication Metaphors

Examples from ComSys Lab



Industry control system



RF,
wired

Wireless embedded
web server

GPRS,
WLAN,
...

Client

Mobile Communications

Mobile Communication

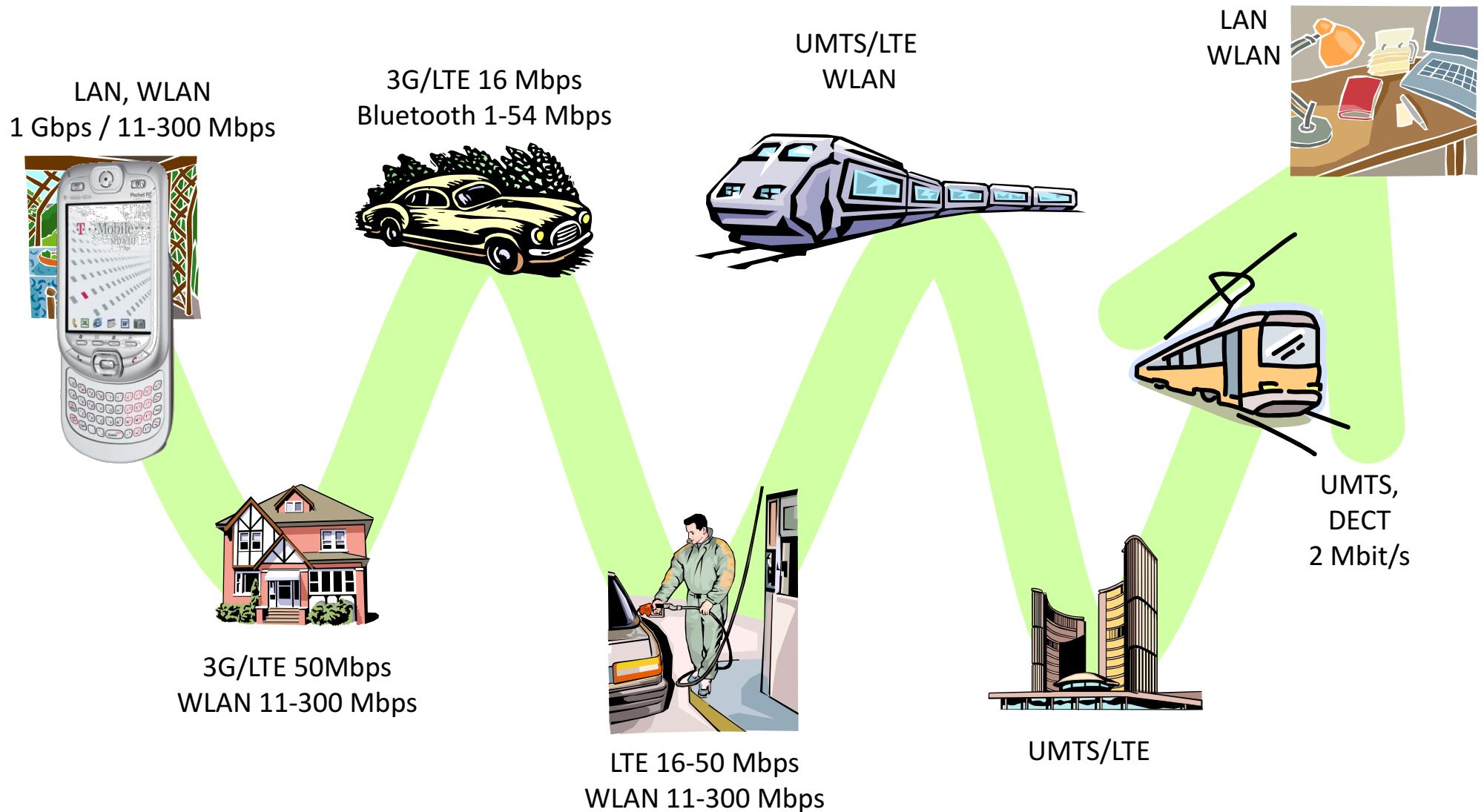
- **Everybody, at anytime, from anywhere.**

anybody, (m)anytime, (m)anywhere

- **Trendsetter: Mobile communication**
 - more than 4.8 billion subscribers
 - more than fixed network users
 - world-wide service by using satellites
- **Goal:**
 - Transmission of Voice, Data, Audio, Video, ...



Mobile and Wireless Web Services



Ubiquitous/pervasive Communication

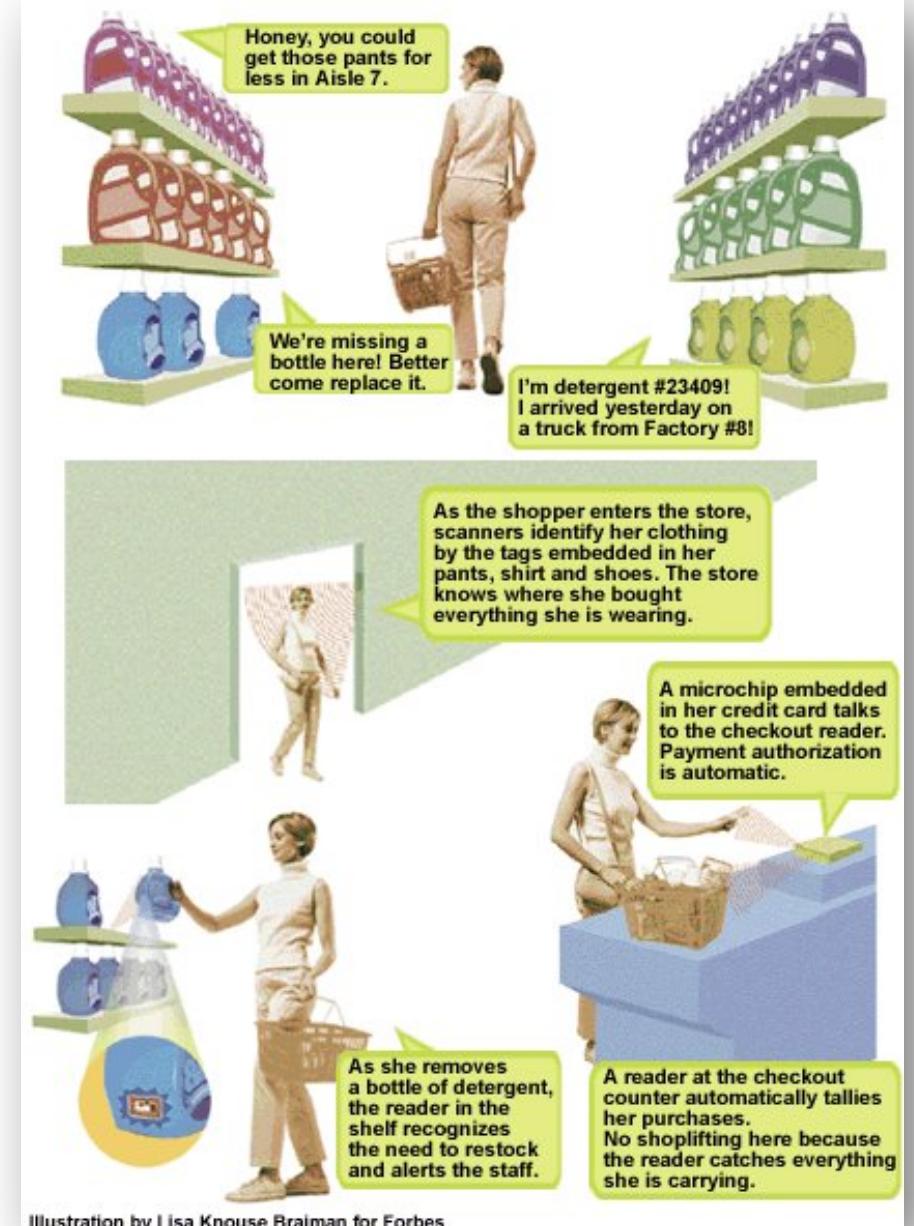
Ubiquitous/pervasive Communication

- **Ubiquity (presence everywhere or in many places)**
 - Not fixed on a place
 - Information as everywhere available commodity
 - ➡ Information Technology (IT) beyond the PC
- **Personal Technologies**
 - Wearable communication devices
 - Personal Digital Assistant (PDAs)
 - Smartphone / Smart Watch
 - Navigation devices
- **Information environment**
 - Access to IT services from everywhere
 - Intelligent, communication enabled devices/systems
 - Smart/cooperative buildings
- **Ubiquity provisioning**
 - works in the background
 - self-active
 - (partly-) autonomous from user



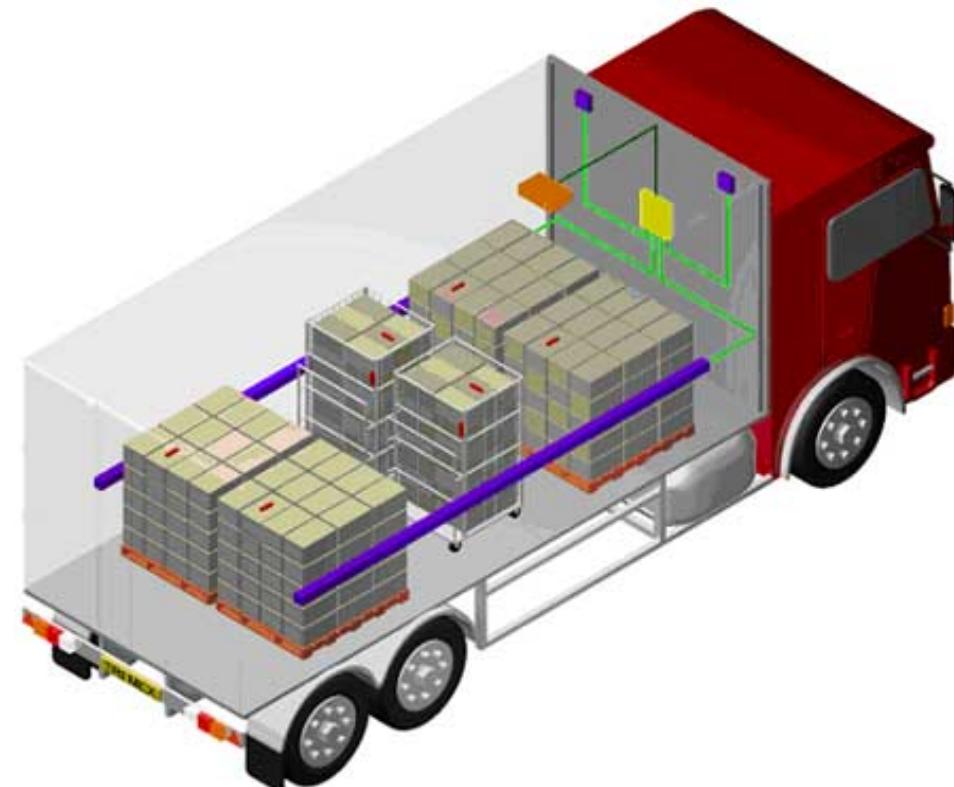
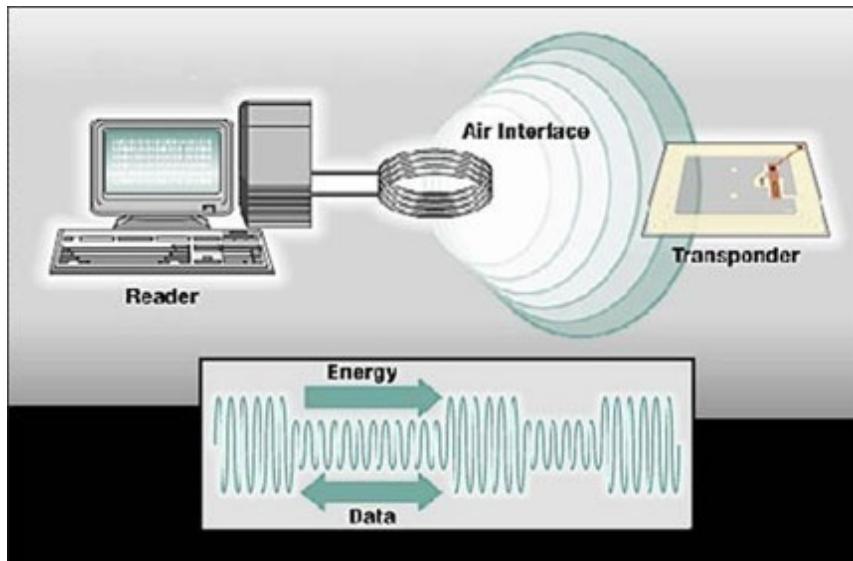
Ubiquitous/pervasive Communication

- **Pervasive Computing**
 - Tiny computer embedded in everyday devices, e.g., appliances
- **Assisted Life**
 - Travel
 - Healthcare
 - Shopping

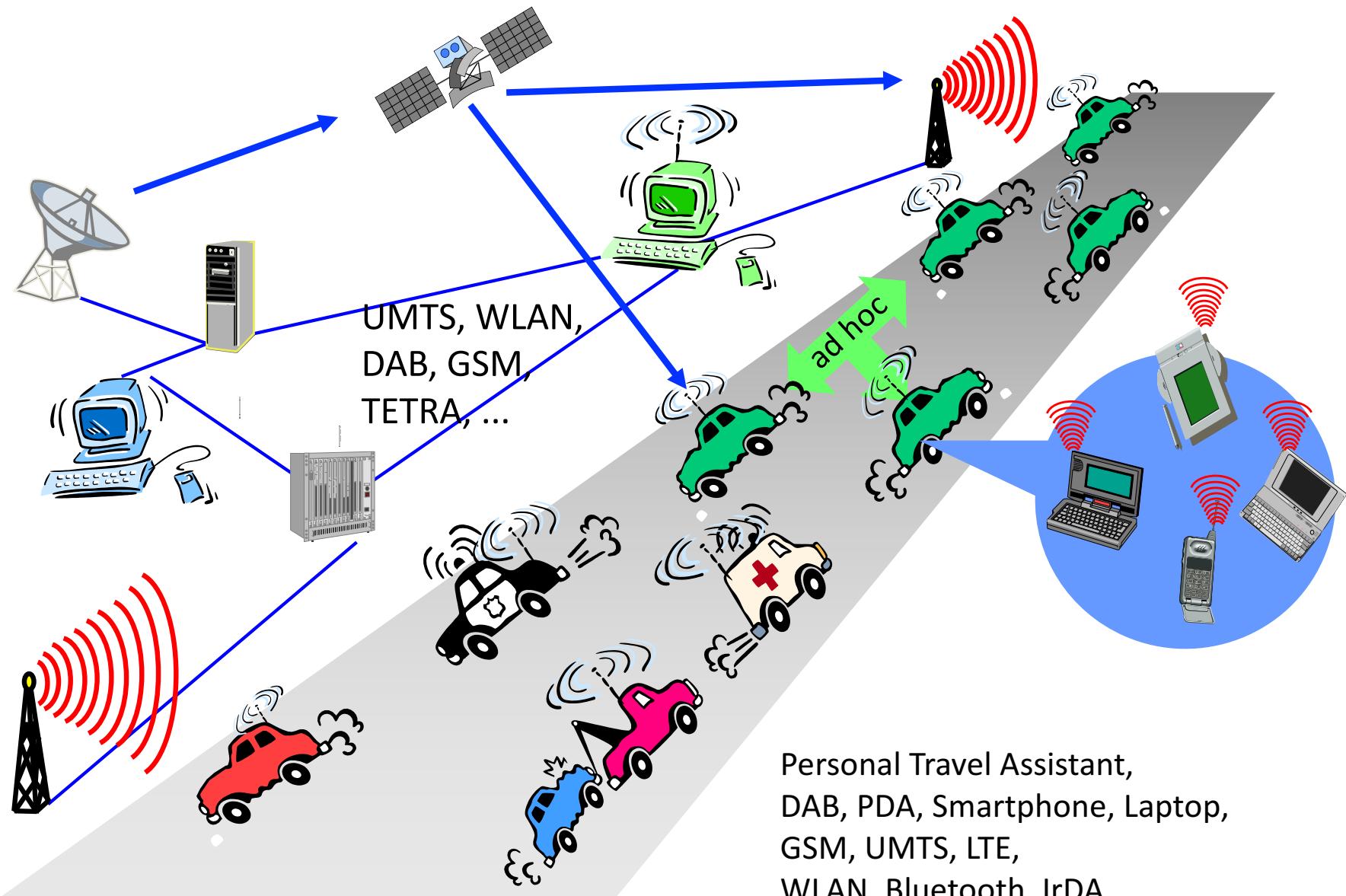


Ubiquitous Communication

- **Radio Frequency Identification (RFID) allows the identification of objects without contact.**
 - RFID Tag → Small device
 - Active / passive
 - Reading, writing, and recording of data on tag irrespective of location, type of environment, contact, or visibility

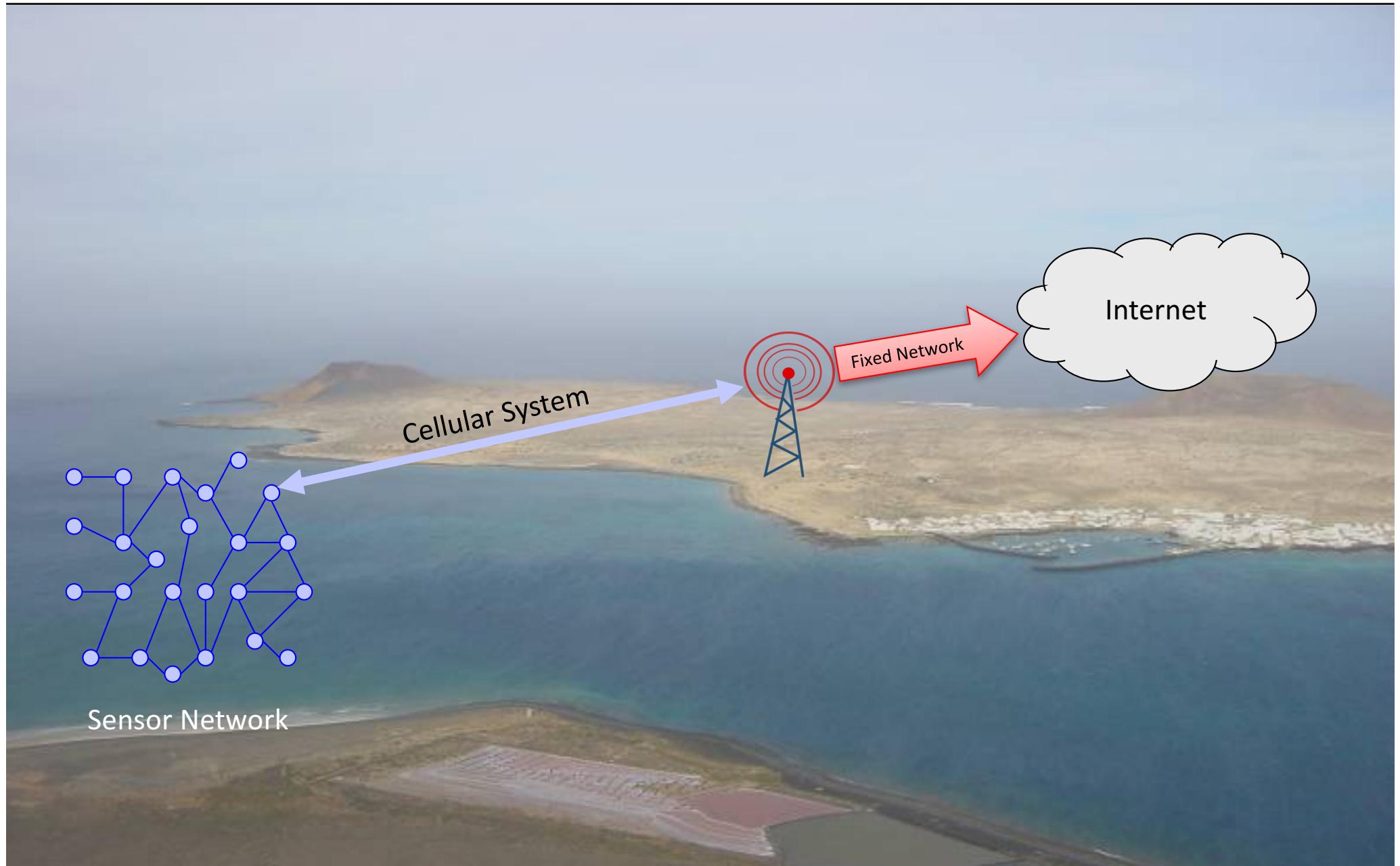


Ubiquitous Communication: On the Road

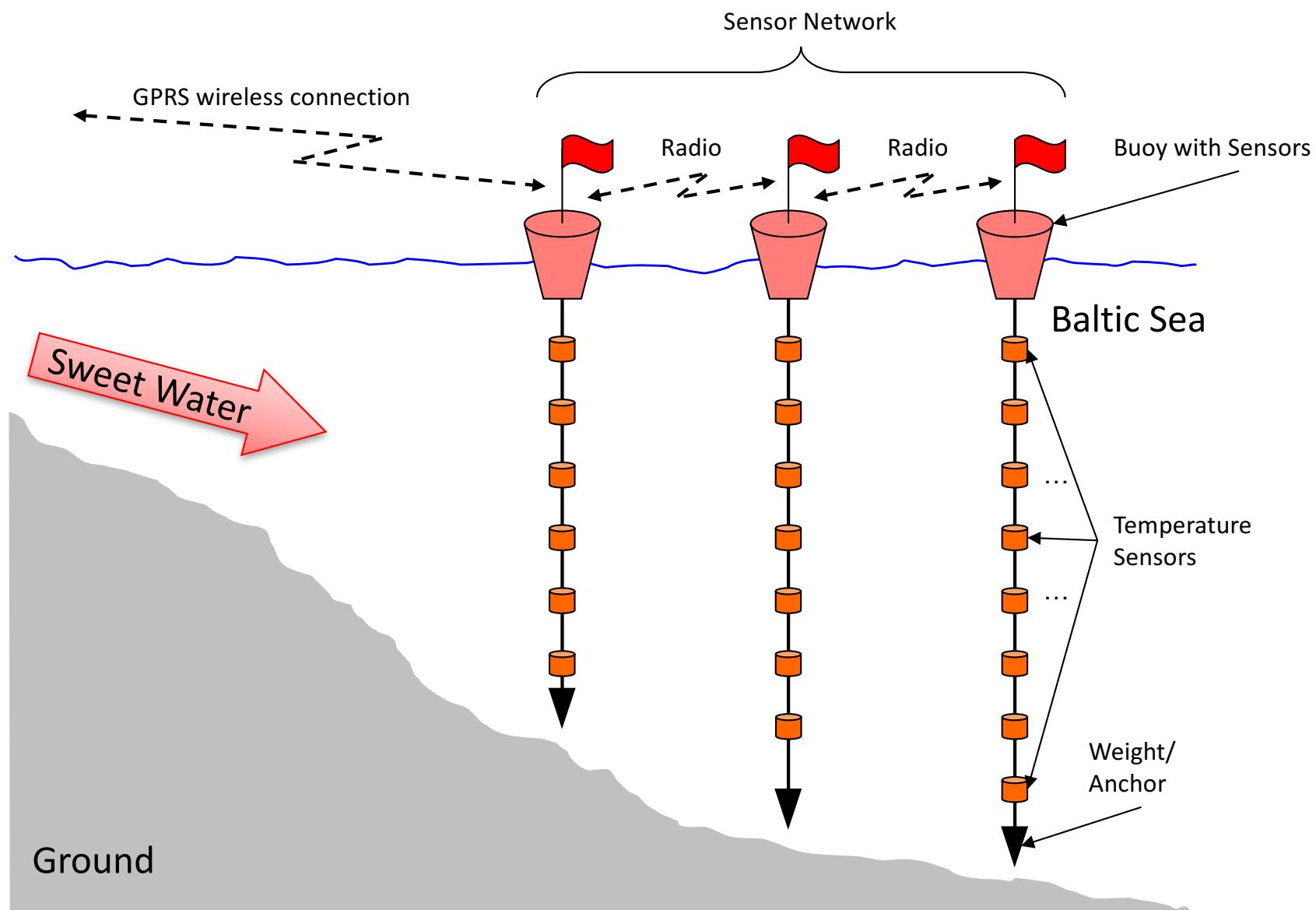


Sensor Networks

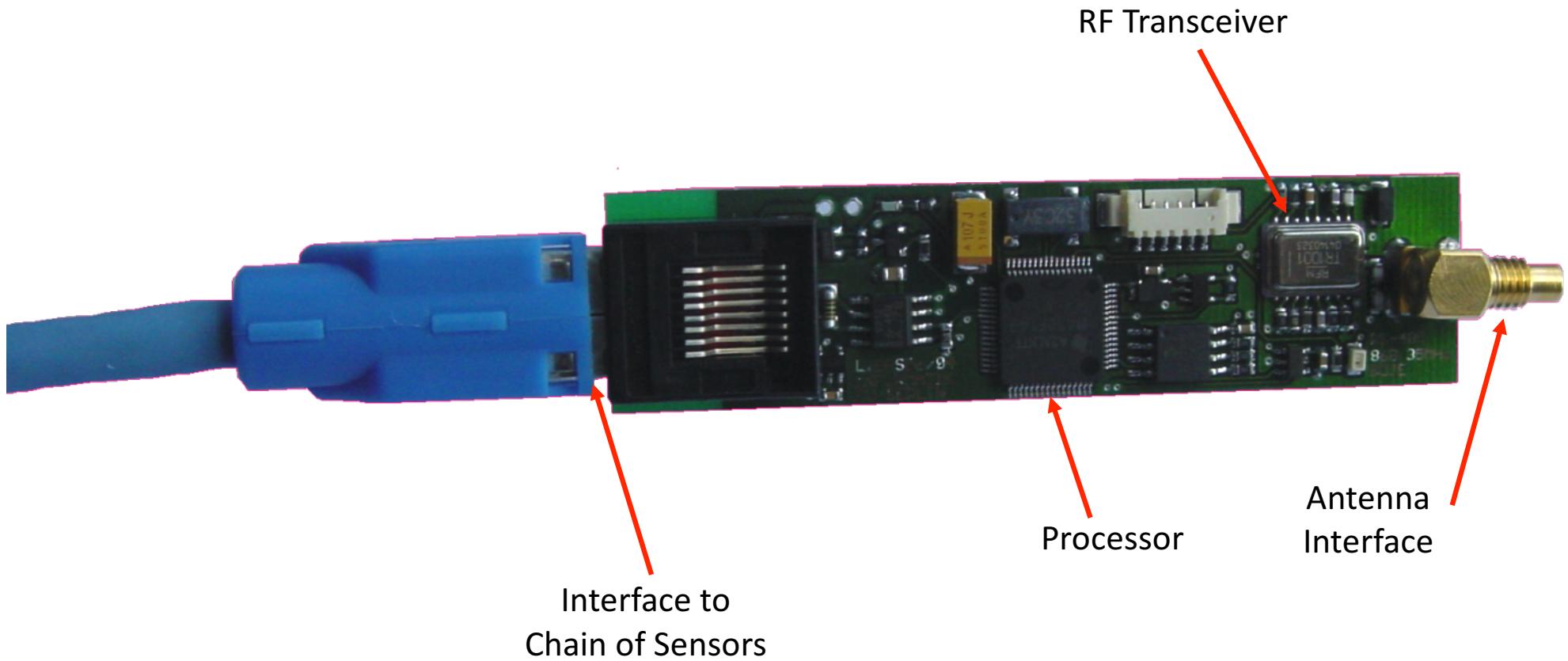
Sensor Network Application Example



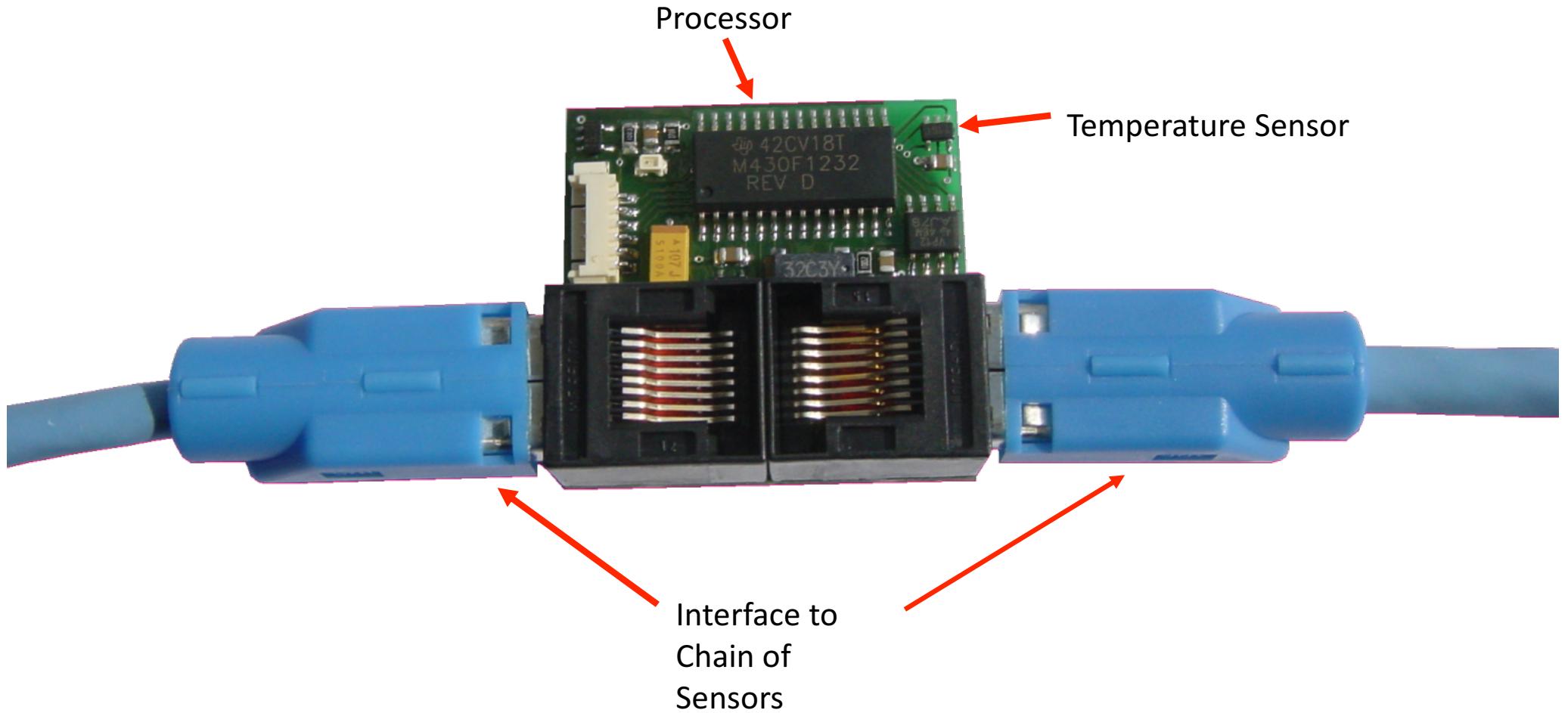
Temperature Measurement in the Baltic Sea



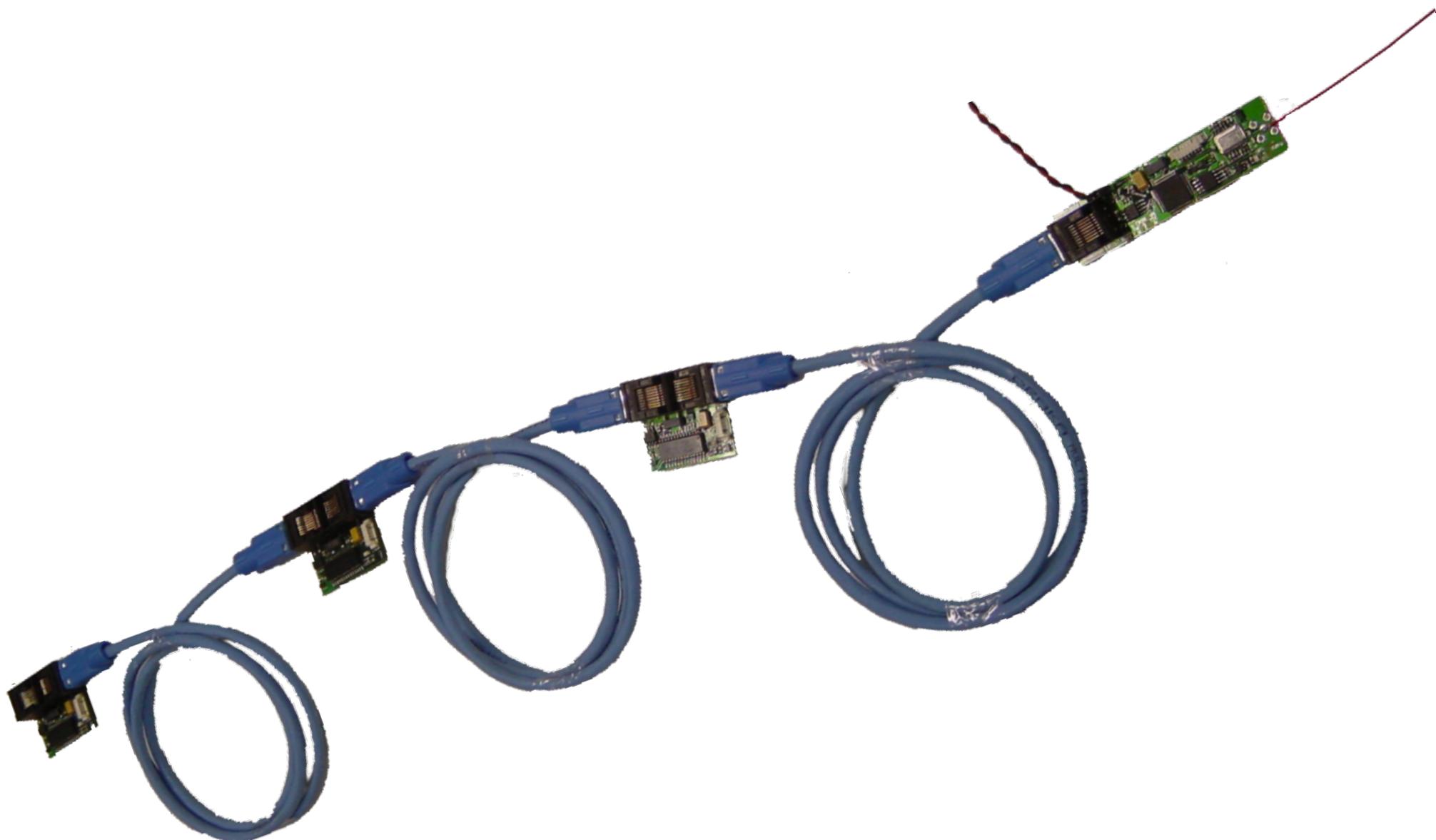
Sensor Node with Processor, RF, Sensor



Sensor Node with Processor and Sensor

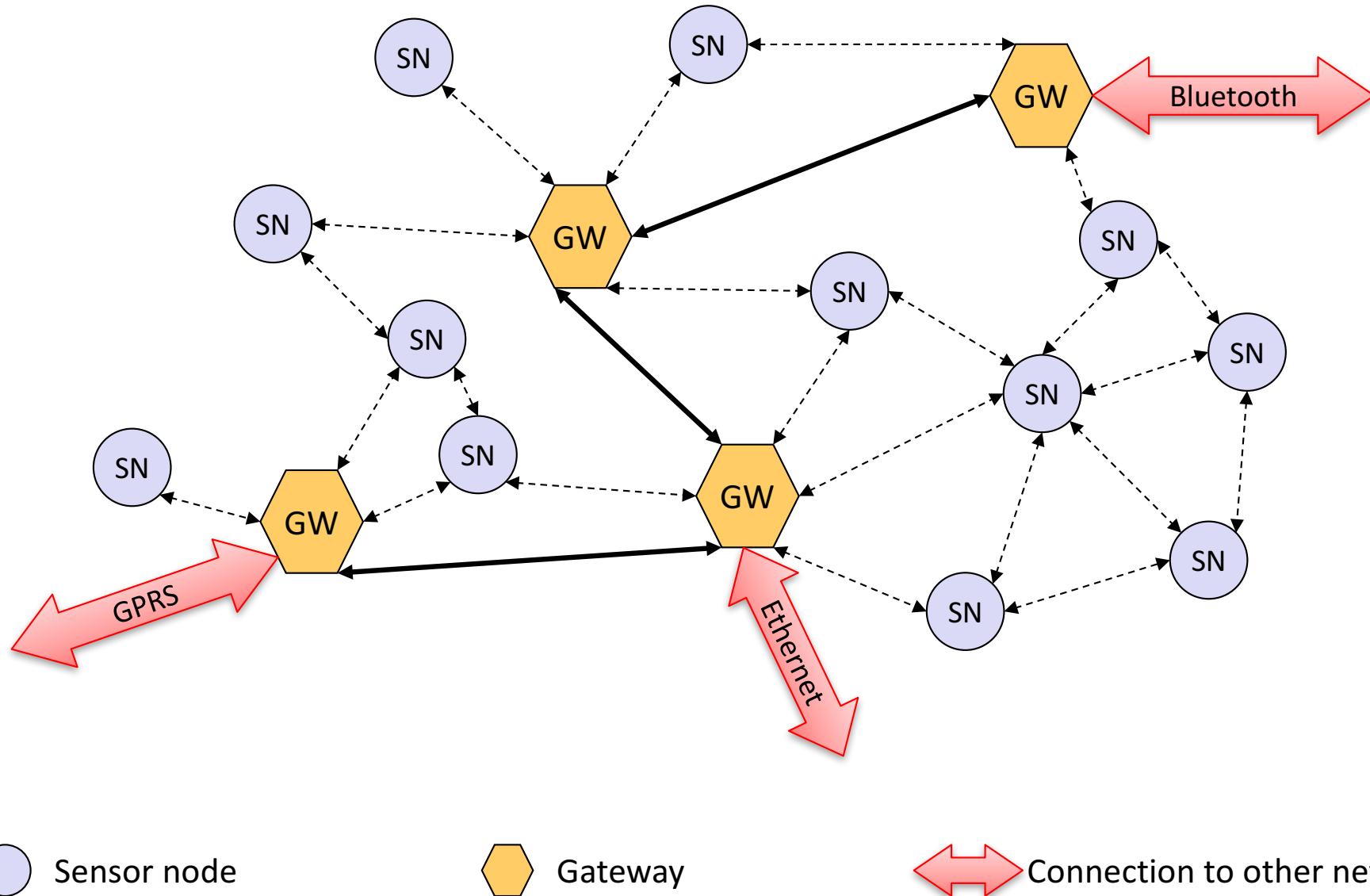


Configured Chains of Sensors



Sensor Network

Interoperation between sensors and other networks



History of Telecommunications

History of Telecommunications: Milestones

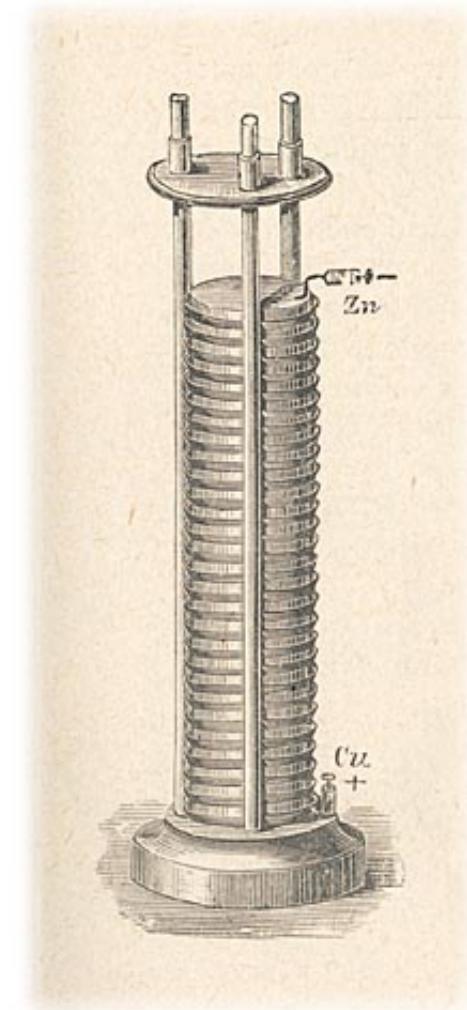
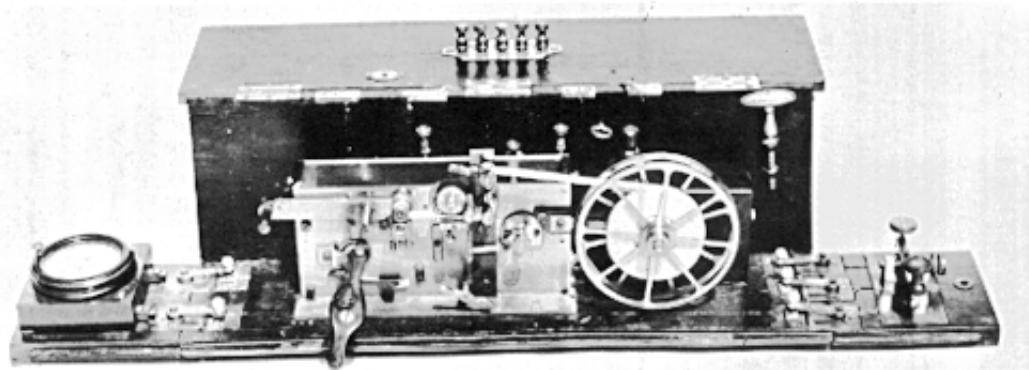
Year	Invention	Result
1840	Morse-Telegraph	Exchange of messages over long distances
1861/1876	Telephone	Voice communication over long distances
1887	Electromagnetic Waves	Radio technology
1897	Strowger selector	Automatic switching
1923	Broadcast	Mass communication
1929	Coax cable	High data rates
1964	Satellites	Basis of global communications
1966	Fiber	Even higher data rates
1984	AT&T divestiture	Break-up of AT&T monopoly into Baby Bells
1997	Wavelength Division Multiplex (WDM)	Even higher data rates up to 1Tbps (Tera = 10^{12})

History of Telecommunications

1799: Alessandro Volta invents the battery

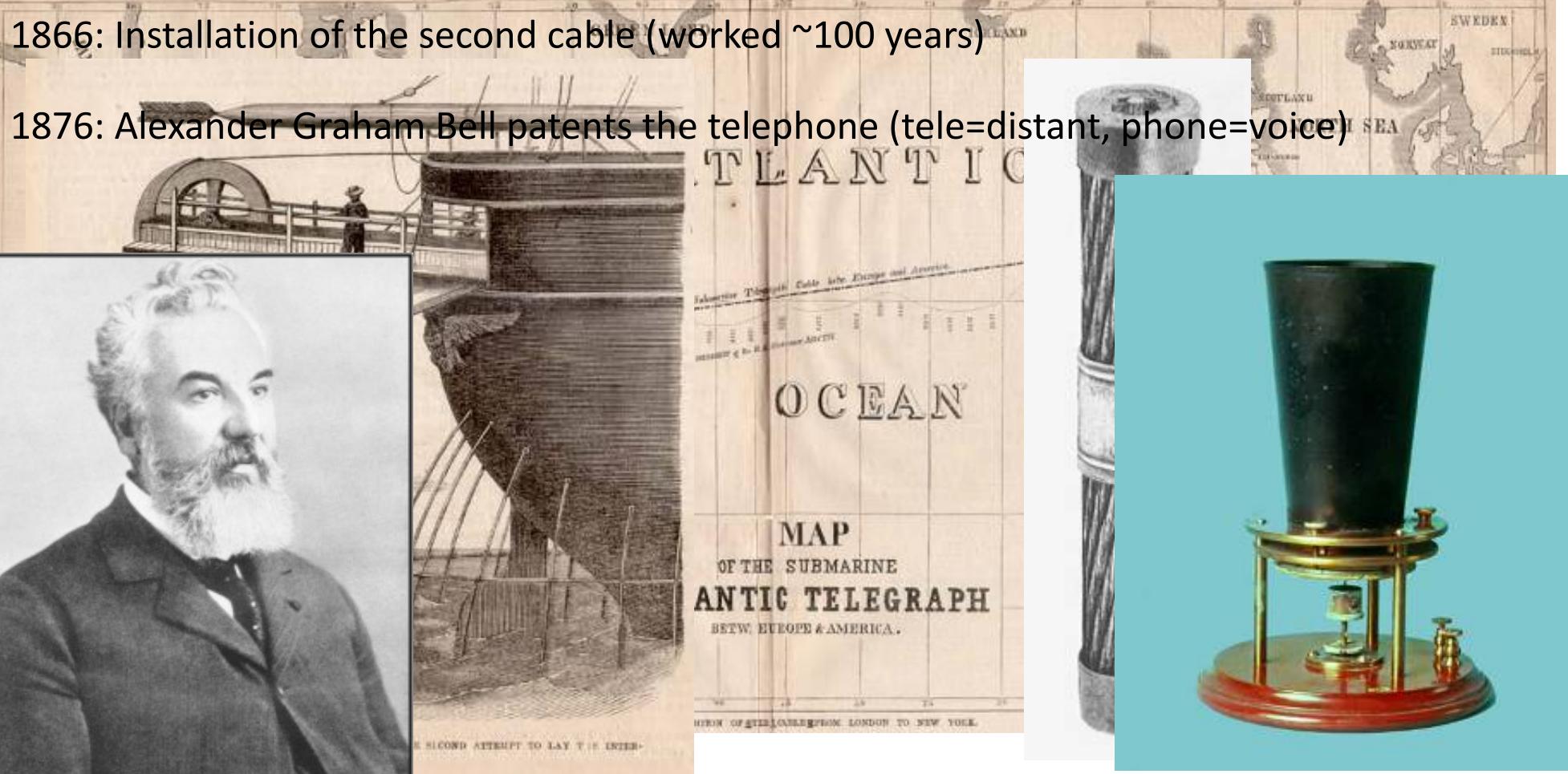
1837: Samuel Morse develops the telegraph

1844: Morse sets up a telegraph line between Washington, DC, and Baltimore



History of Telecommunications

1858: Installation of the first transatlantic cable for telegraphy
(breakdown after 4 weeks)



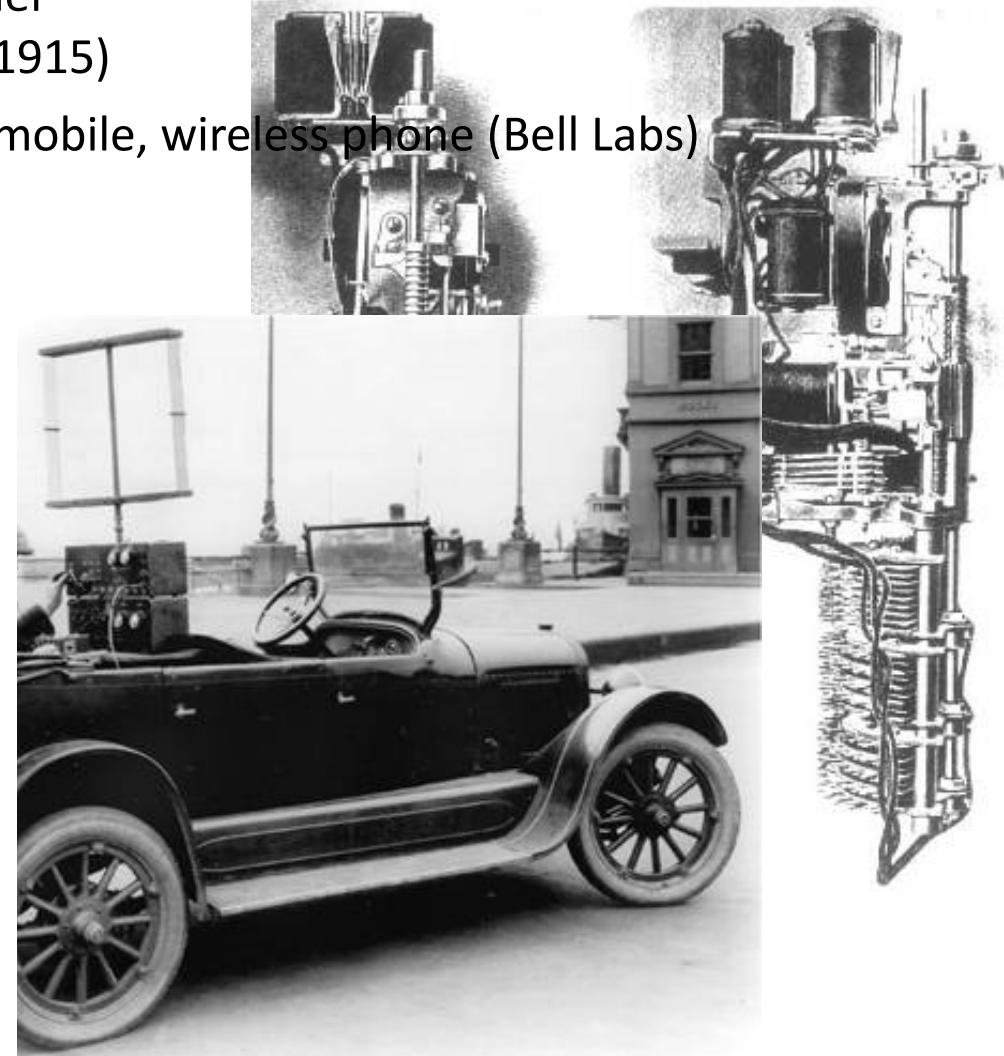
History of Telecommunications

1897: Strowger invents the electromechanical telephone exchange

1906: Lee De Forest invents the first amplifier

► transcontinental telephony (from 1915)

1924: First demonstration of bidirectional, mobile, wireless phone (Bell Labs)



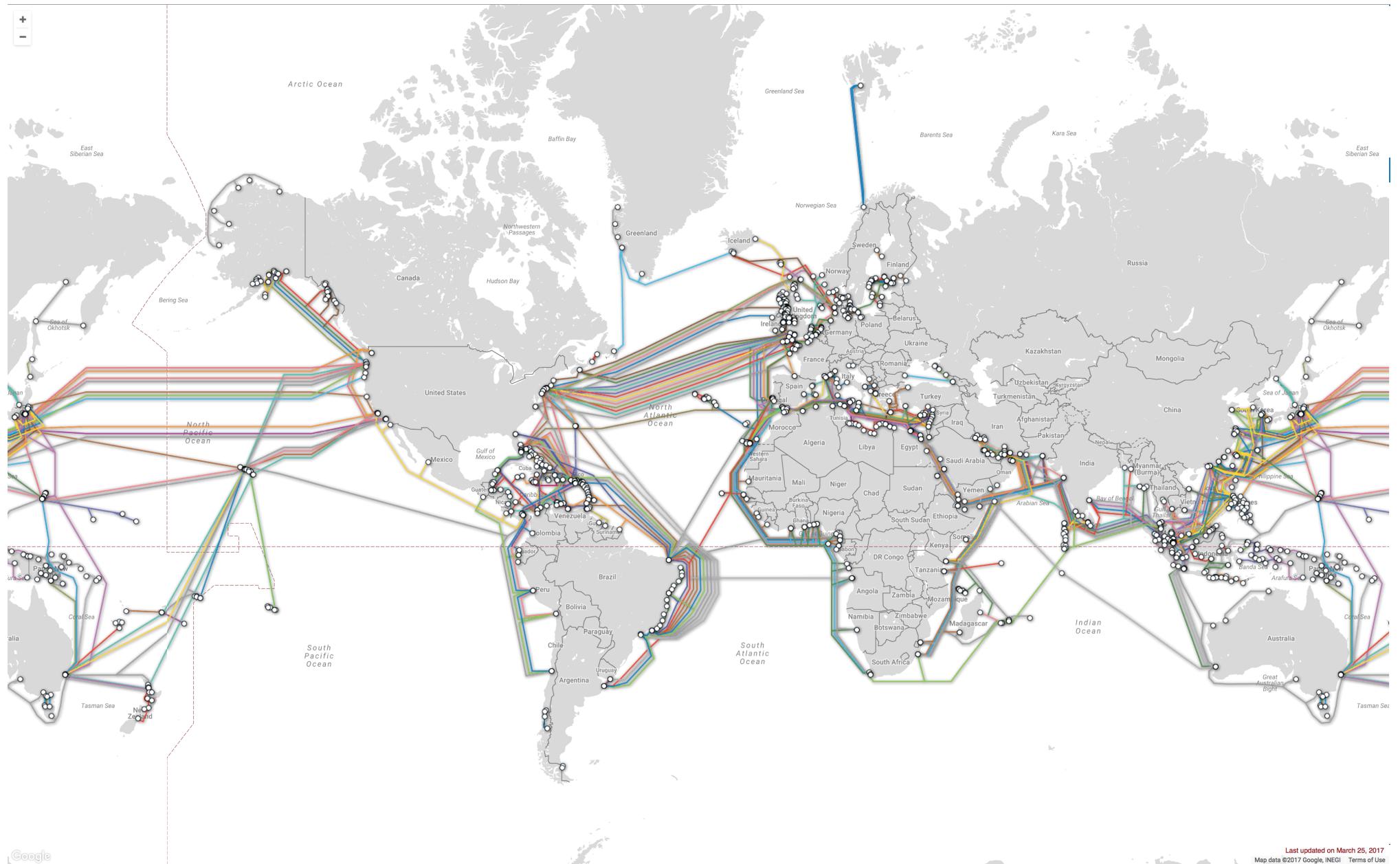
History of Telecommunications

- **1953: First transatlantic Telephone line!**
 - TAT-1 with 36 Channels

Name	Date	# Channels	Origin	Destination
TAT-1	1956 – 1978	36	Newfoundland	Scotland
TAT-2	1959 – 1982	48	Newfoundland	France
TAT-3	1963 – 1986	138	New Jersey	England
TAT-4	1965 – 1987	138	New Jersey	France
TAT-5	1970 – 1993	845	Rhode Island	Spain
TAT-6	1976 – 1994	4000	Rhode Island	France
TAT-7	1978 – 1994	4000	New Jersey	England
TAT-8	1988	First fiber line 40000	USA	France
TAT-14	2000	Fiber 16 x 10 Gbps	USA	England

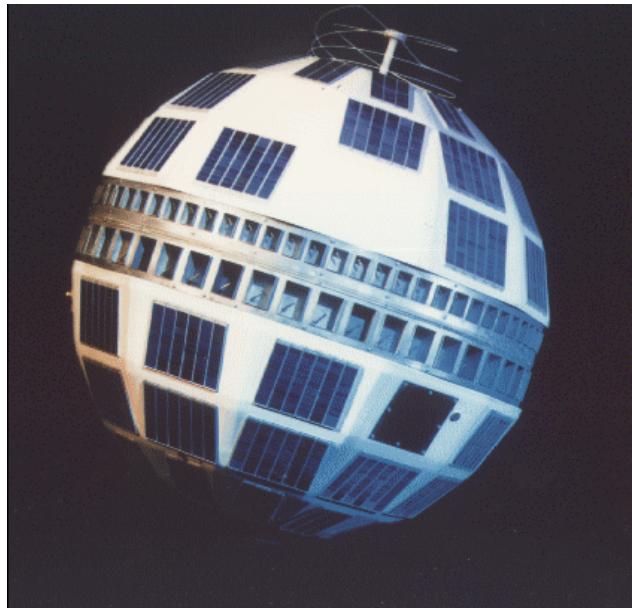
Submarine Cable Map

<http://www.submarinecablemap.com>



History of Telecommunications

- Since 60ies diverse developments in telecommunication incl. the Internet



1962: Telstar, first
communications satellite



1973: First mobile
(Motorola »Dyna-Tac«)

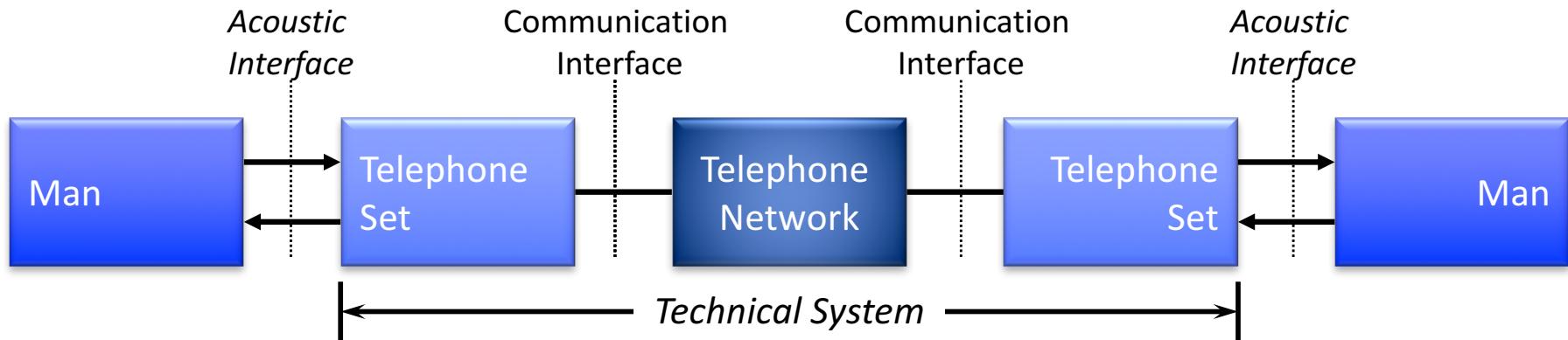


1977: First digital,
Optical network
(Chicago)

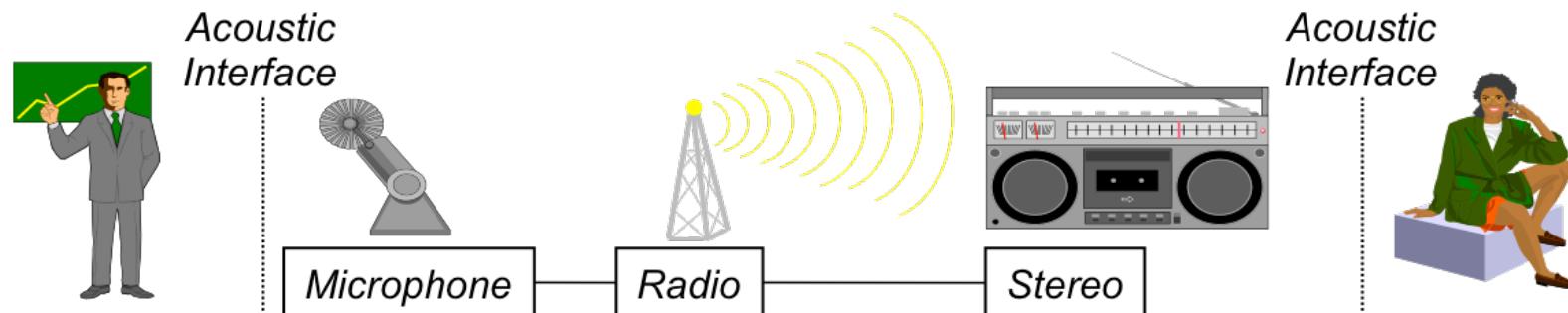
The Telephone Network

Telephone Network

- The classical telecommunication is focused on voice communication
 - Humans are the communication peers
- Model of telecommunication



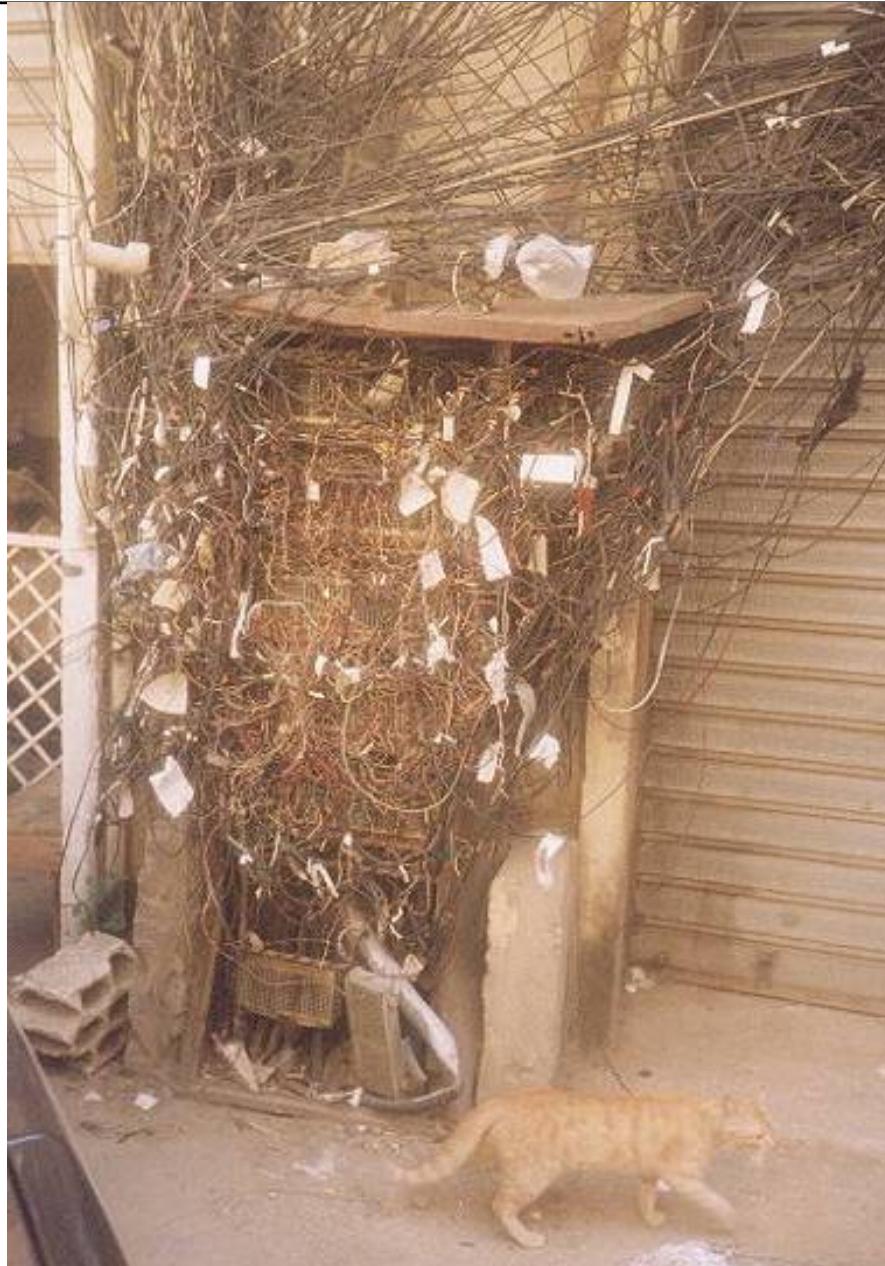
- Model of broadcasting



Telephone Network: Example from ...



Telephone Network: Example from ...

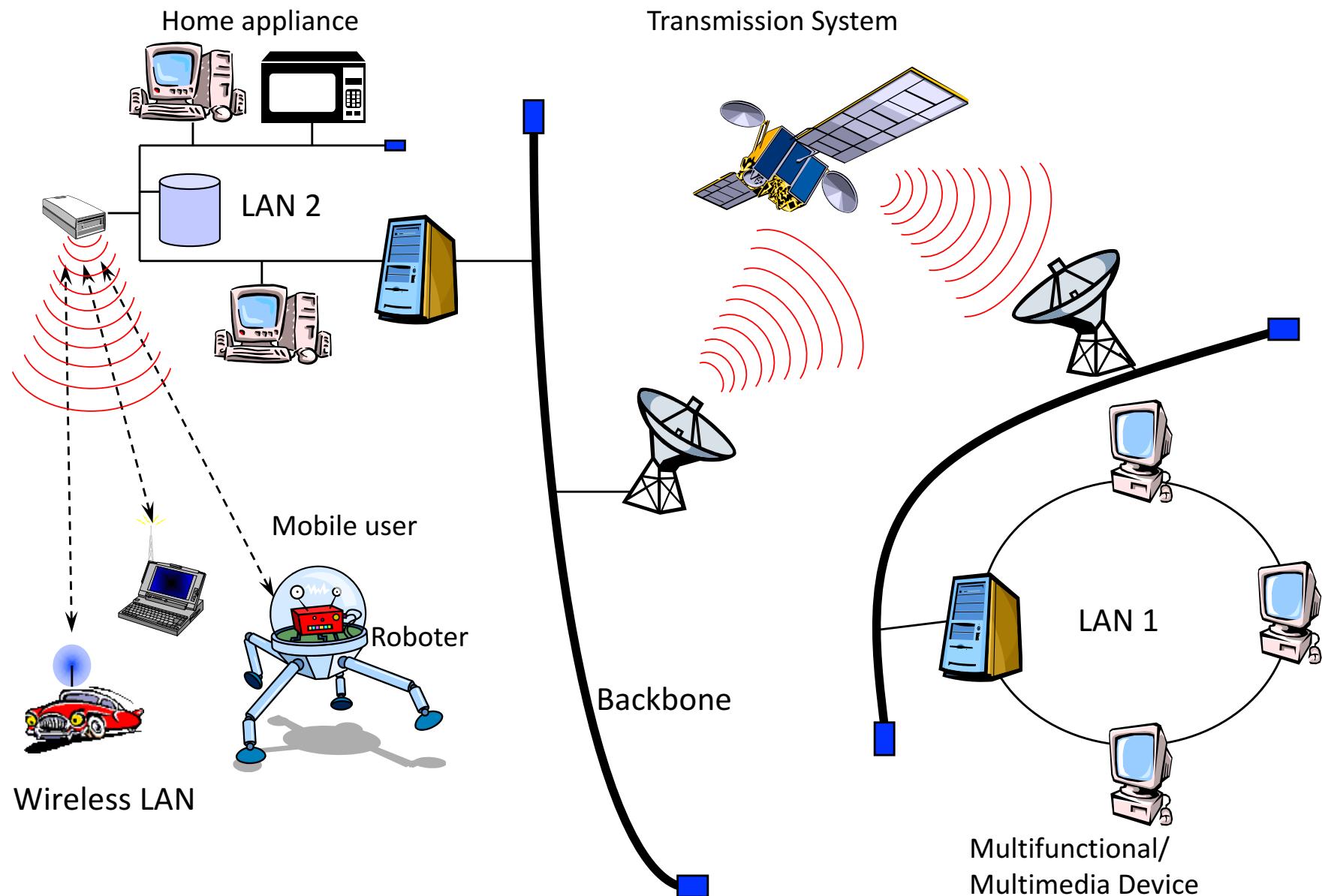


Computer Networks

Computer Networks

- **Digital Telecommunication**
 - Digitalization of **all** communication forms
 - Audio, Music, Text, Graphics, Pictures, Video, Technical Data, etc.
 - Focusing on multimedia
 - Integration of several communication forms
- **Basics: Computer-to-Computer Communication**
 - Digital Telecommunication is exclusively based on computers
 - Modern Telecommunication Networks are **Computer Networks**

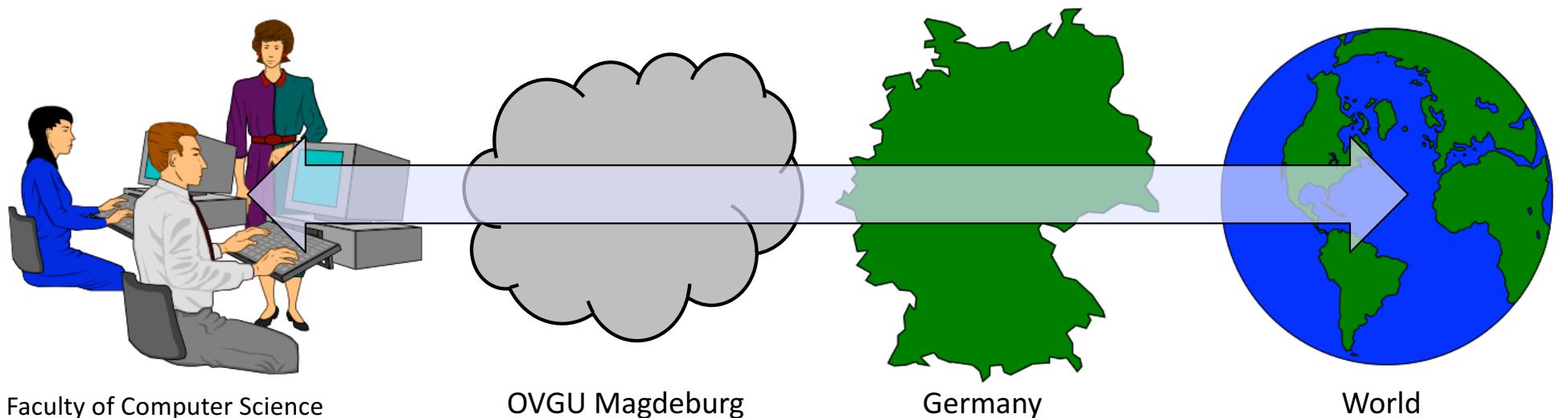
Computer Networks



The Internet

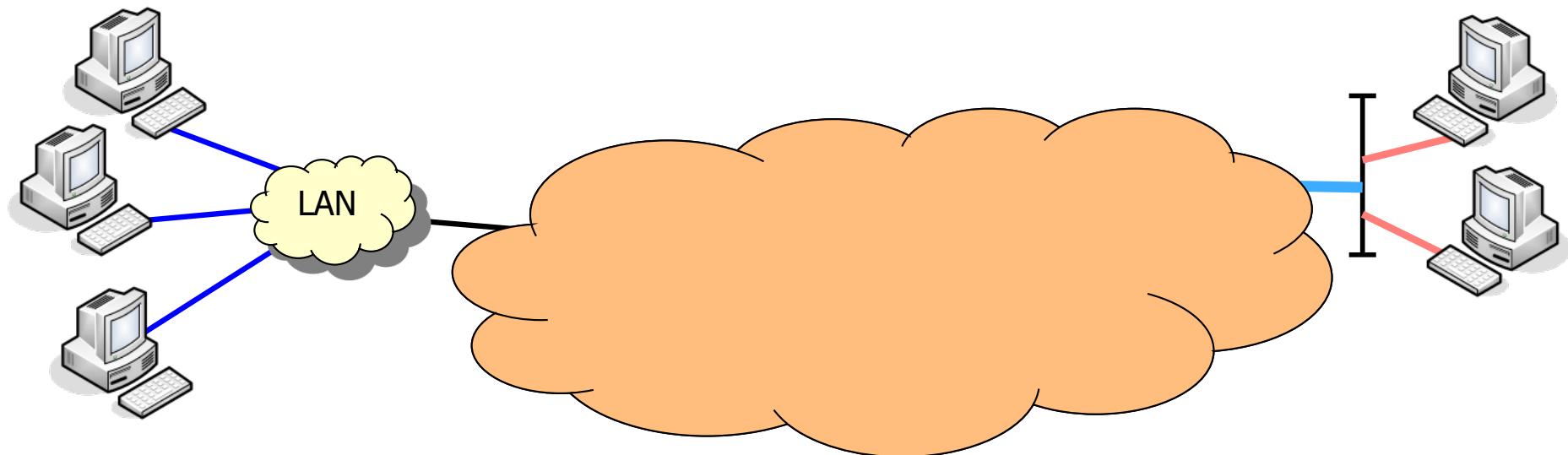
The Internet

- The Internet consists of
 - a set of computers, which
 - use the TCP/IP protocols
 - are somehow (directly or indirectly) connected
 - offer or use particular services
 - a set of users, which have access to these services
 - a set of other networks, which (somehow) are accessible



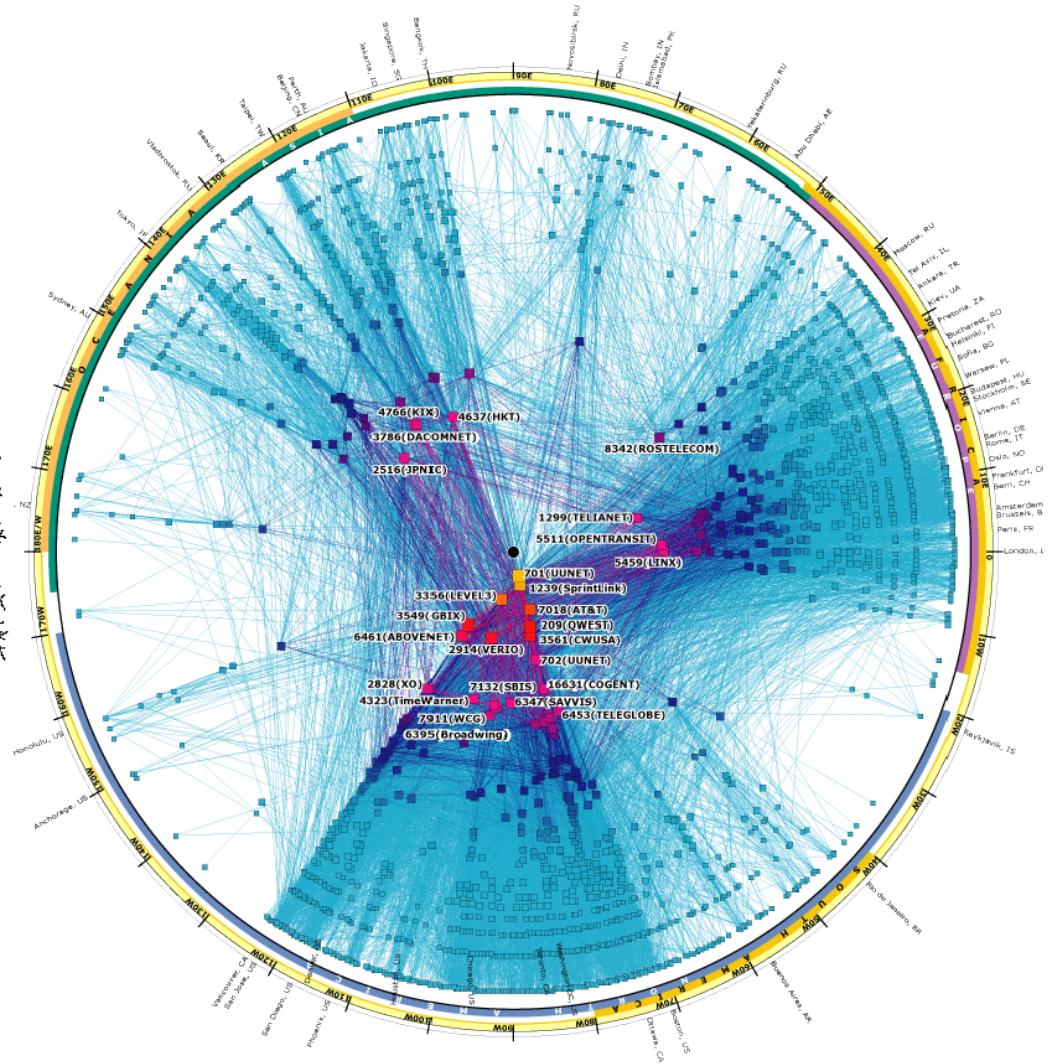
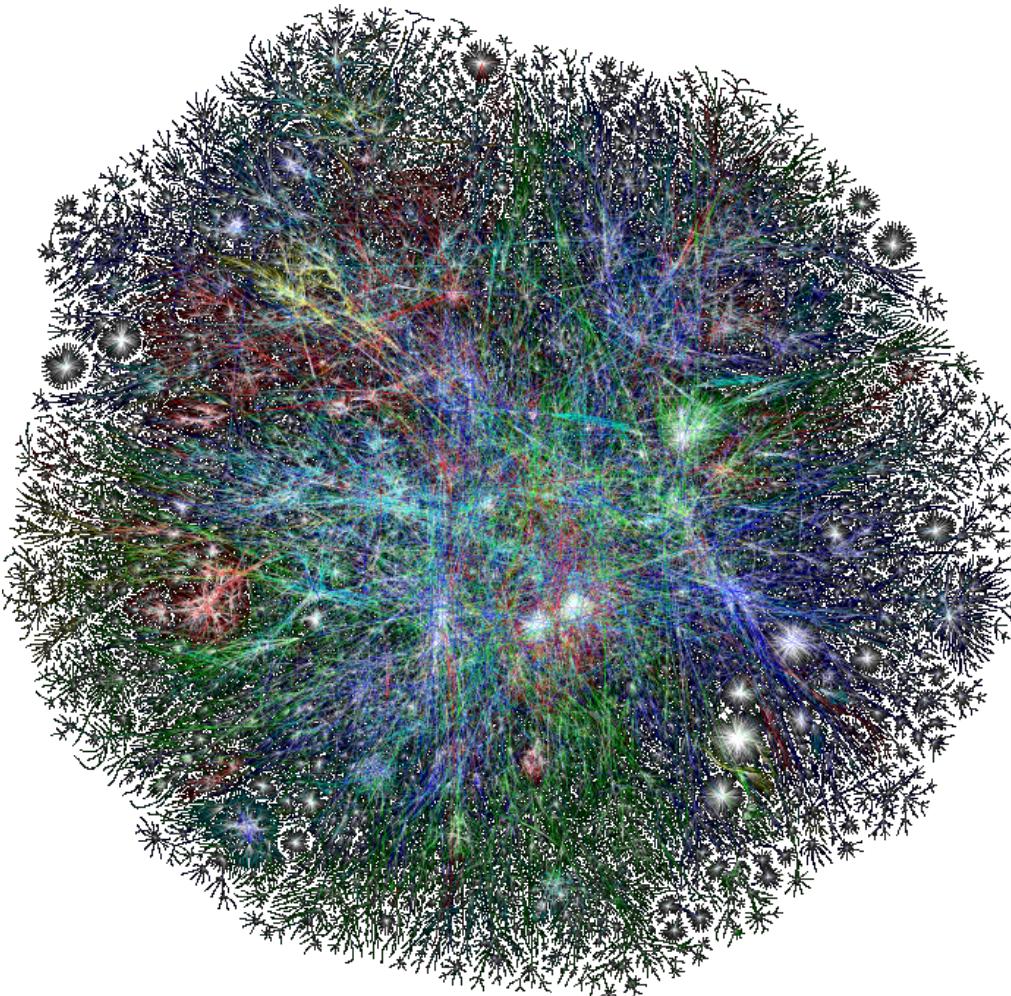
From computer networks to the Internet

- **Goal**
 - World-wide communication of heterogeneous computers
- **Structure**
 - Interconnection of computers and local networks over and partially interconnected router networks



- Definition of a uniform protocol family: TCP/IP

The Internet: The »real« Structure



The Internet: Design Principles

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

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	<ul style="list-style-type: none">▪ Design of packet-switching networks<ul style="list-style-type: none">• Paul Baran, RAND: »On Distributed Communications Networks«• No single outage point.
1967	<ul style="list-style-type: none">▪ ACM Symposium on Operating Principles Plan presented for a packet-switching network
1968	Network presentation to the Advanced Research Projects Agency (ARPA)
1969	<ul style="list-style-type: none">▪ ARPANET commissioned by DOD for research into networking<ul style="list-style-type: none">• 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	<ul style="list-style-type: none">▪ Store and Forward Networks<ul style="list-style-type: none">• Electronic mail technology extended to conferencing.
1970	ALOHAnet developed by Norman Abramson, Univ. of Hawaii

The Internet: The History

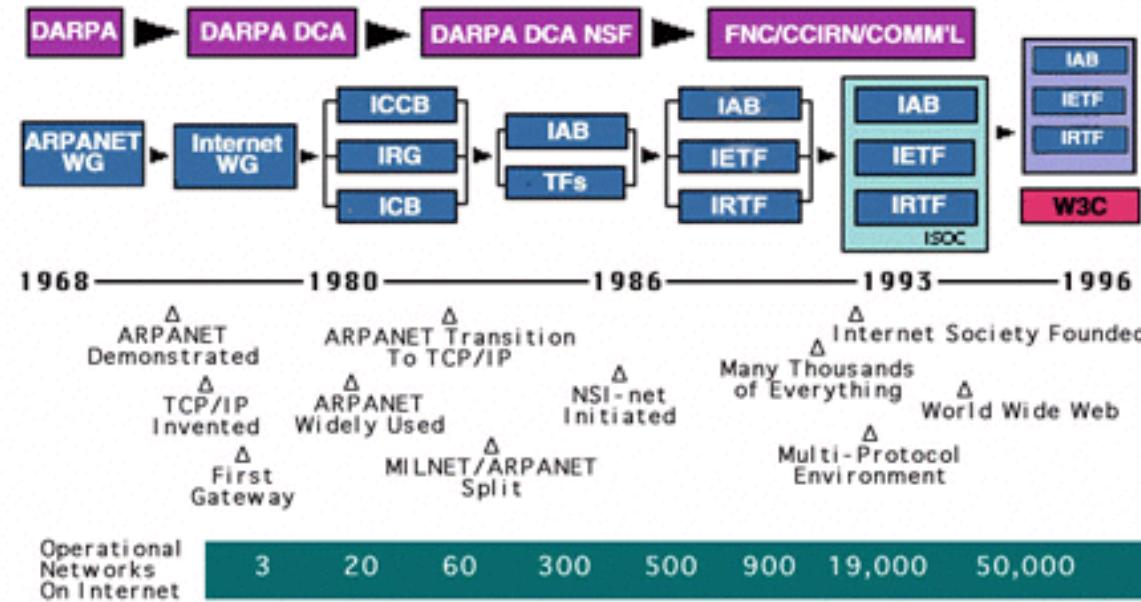
Year	Event
1971	15 nodes (23 hosts): UCLA, SRI, UCSB, U of Utah, BBN, MIT, RAND, SDC, Harvard, Lincoln Lab, Stanford, UIUC, CWRU, CMU, NASA/Ames
1972	<ul style="list-style-type: none">▪ International Conference on Computer Communications with demonstration of ARPANET between 40 machines organized by 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	<ul style="list-style-type: none">▪ INWG establishes the Transmission Control Protocol (TCP) and Internet Protocol (IP), as the protocol suite, commonly known as TCP/IP, for ARPANET.<ul style="list-style-type: none">• 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	<ul style="list-style-type: none">▪ 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: European Backbone
1992	<ul style="list-style-type: none">▪ 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



The Internet: The History



http://www.computerhistory.org/internet_history/index.shtml

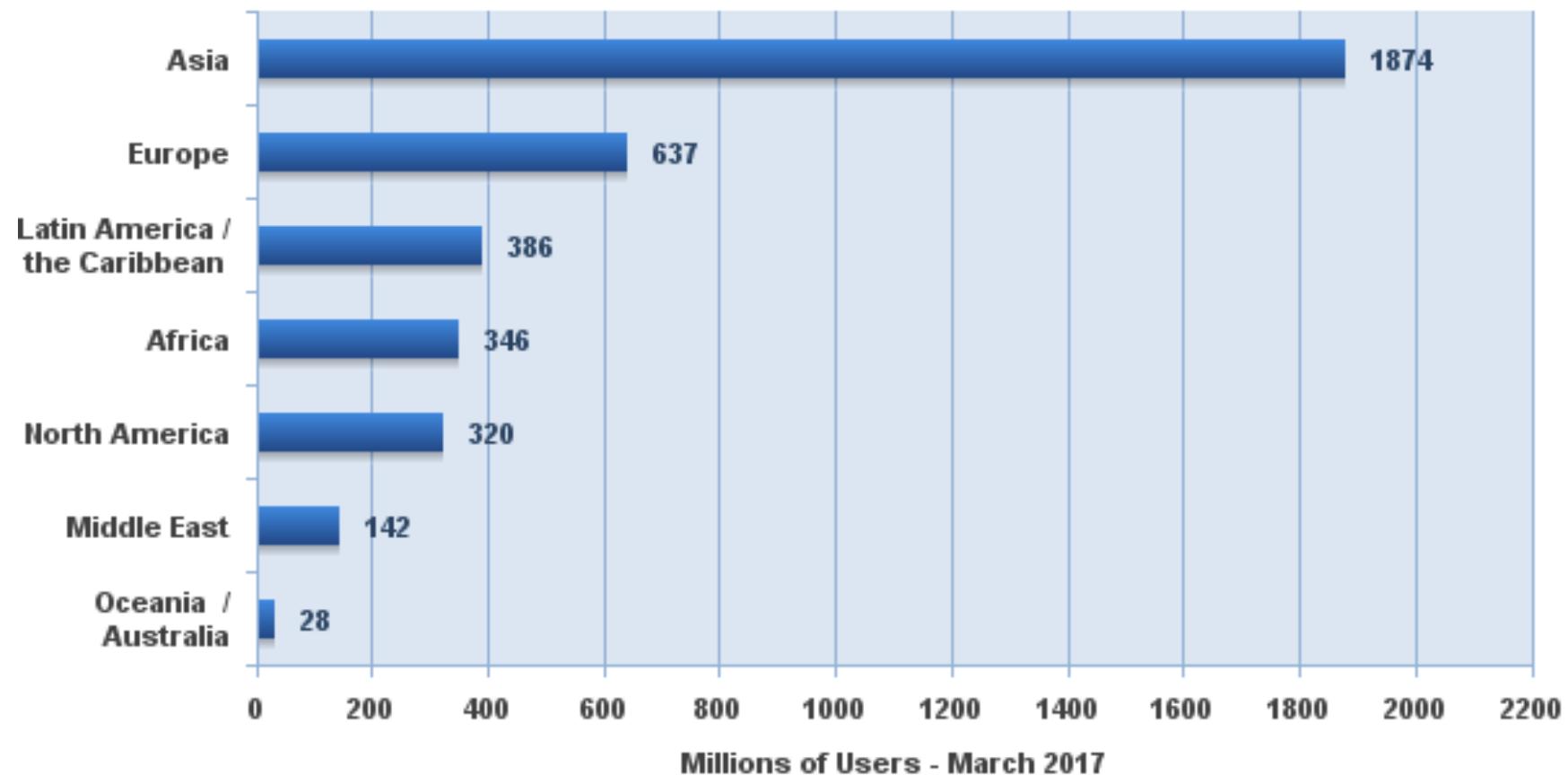
<http://www.nic.funet.fi/index/FUNET/history/internet/en/etusivu-en.html>

<http://www.zakon.org/robert/internet/timeline/>

The Internet: User statistics

www.internetworldstats.com

**Internet Users in the World
by Geographic Regions - March 25, 2017**



Source: Internet World Stats - www.internetworldstats.com/stats.htm

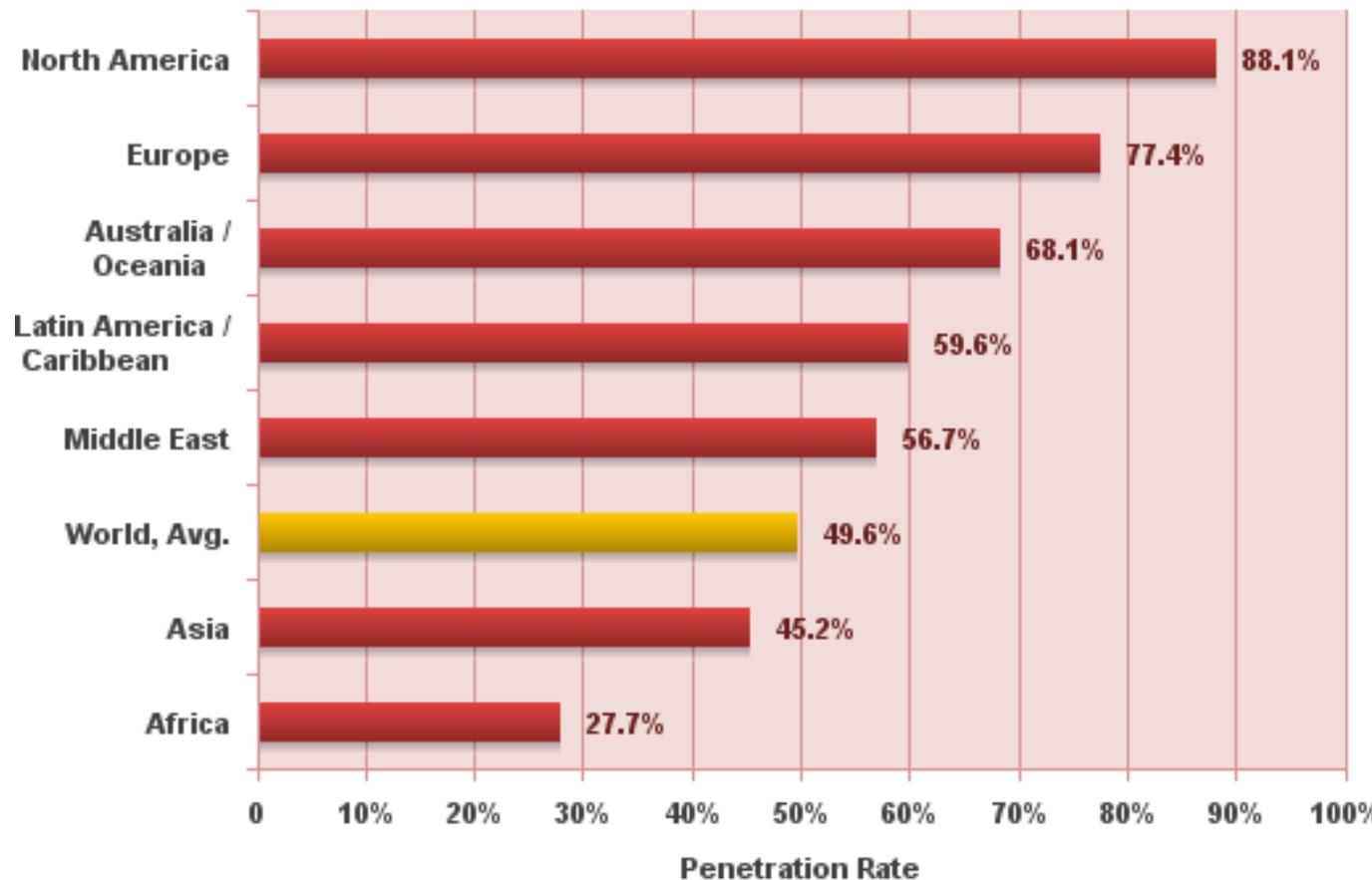
Basis: 3,731,973,423 Internet users estimated for March 31, 2017

Copyright © 2017, Miniwatts Marketing Group

The Internet: User statistics

www.internetworkworldstats.com

**Internet World Penetration Rates
by Geographic Regions - March 25, 2017**



Source: Internet World Stats - www.internetworkworldstats.com/stats.htm

Penetration Rates are based on a world population of 7,519,028,970
and 3,731,973,423 estimated Internet users on March 31, 2017.

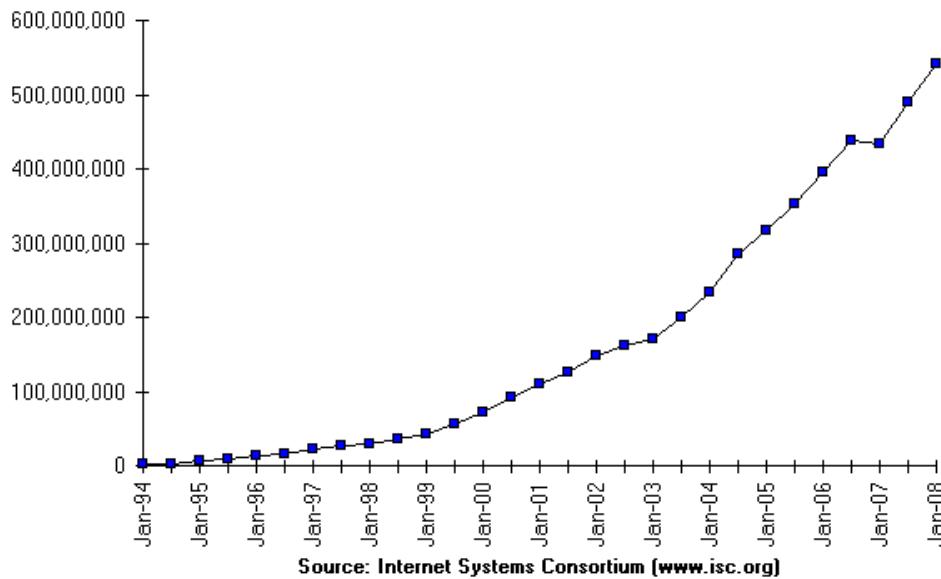
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The Internet: Domain Survey

<https://www.isc.org/network/survey/>

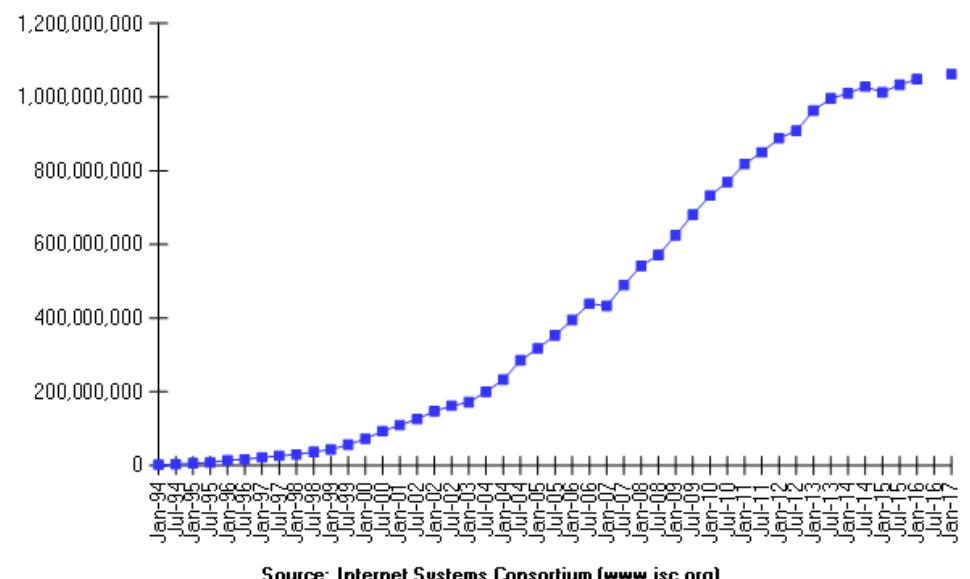
January 2008

Internet Domain Survey Host Count



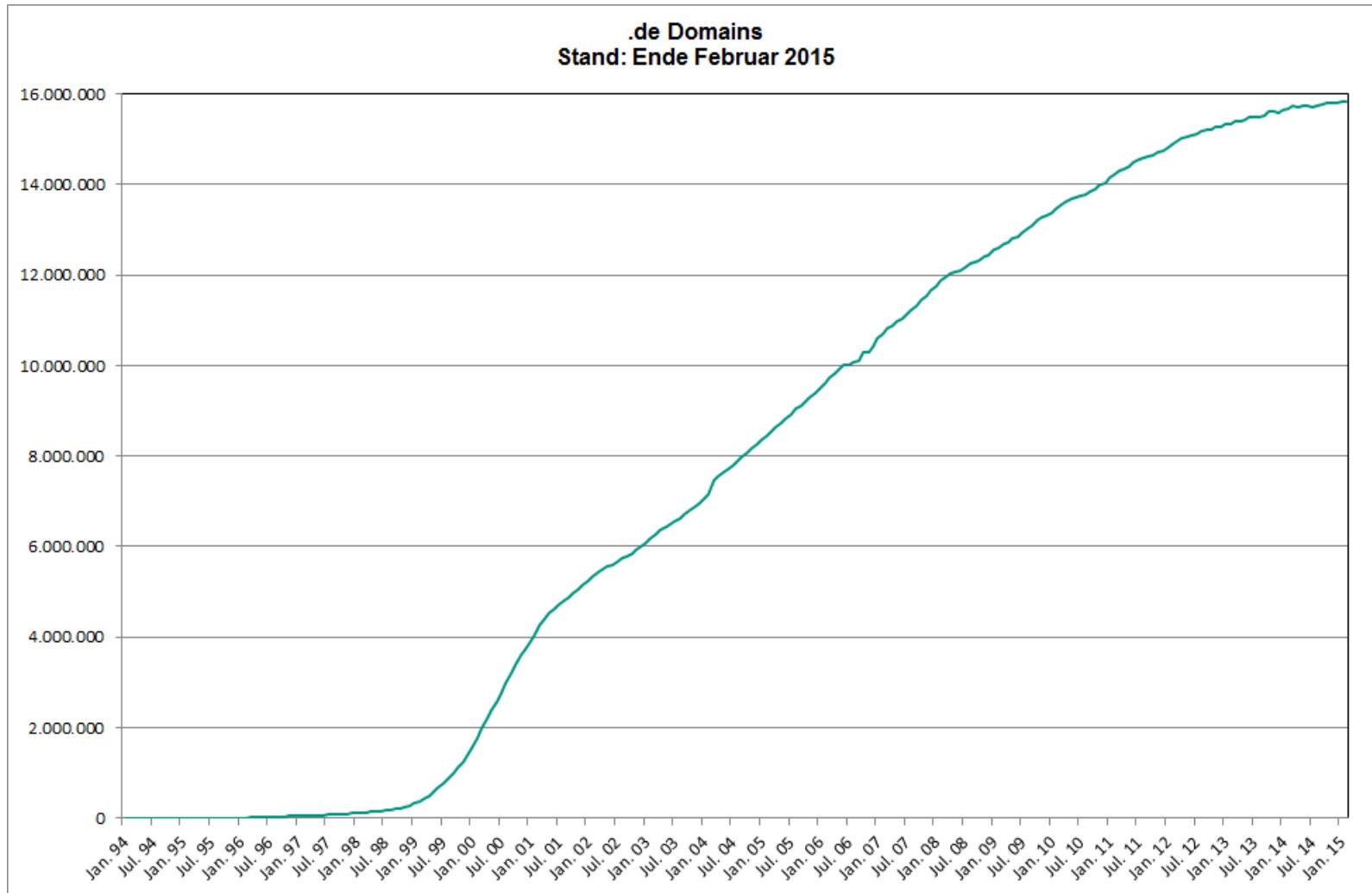
January 2016

Internet Domain Survey Host Count



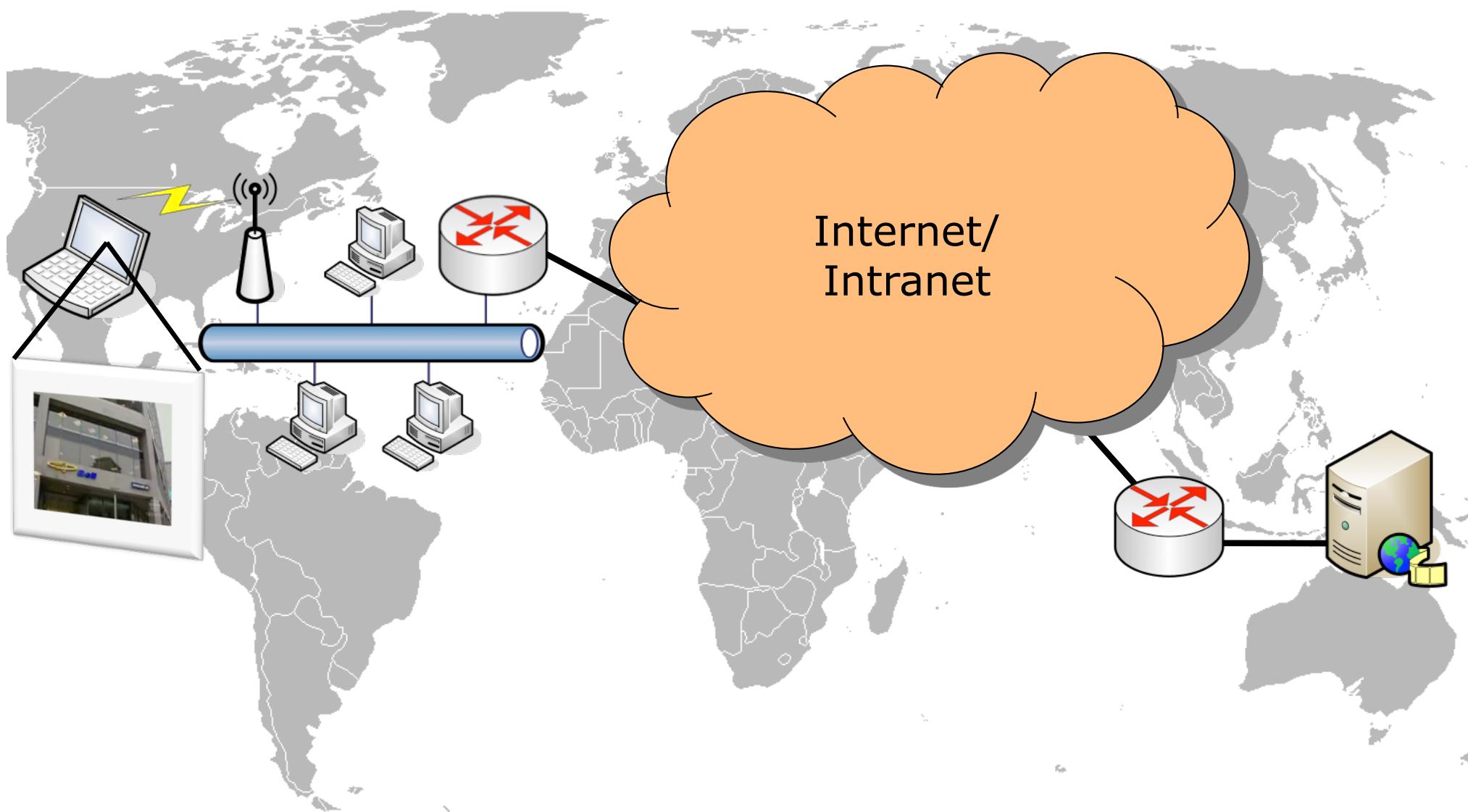
The Internet: Number of Domains in Germany

<http://www.denic.de/hintergrund/statistiken.html>



Example

Example: Video Streaming over the Internet



Summary

- **Computers do not stay alone anymore**
- **Communication metaphor evolves from human-to-human communication to everything-to-everything communication**
 - Penetration of computer networks into all aspects of life
 - Internet of the Things (IoT)
- **Existing networks are going to be integrated**
 - Telephone networks, mobile networks, computer networks, ...
- **The telecommunication market is young, but one of the fastest growing economic sectors**
- **The penetration of computer and communications are not everywhere the same in the world**