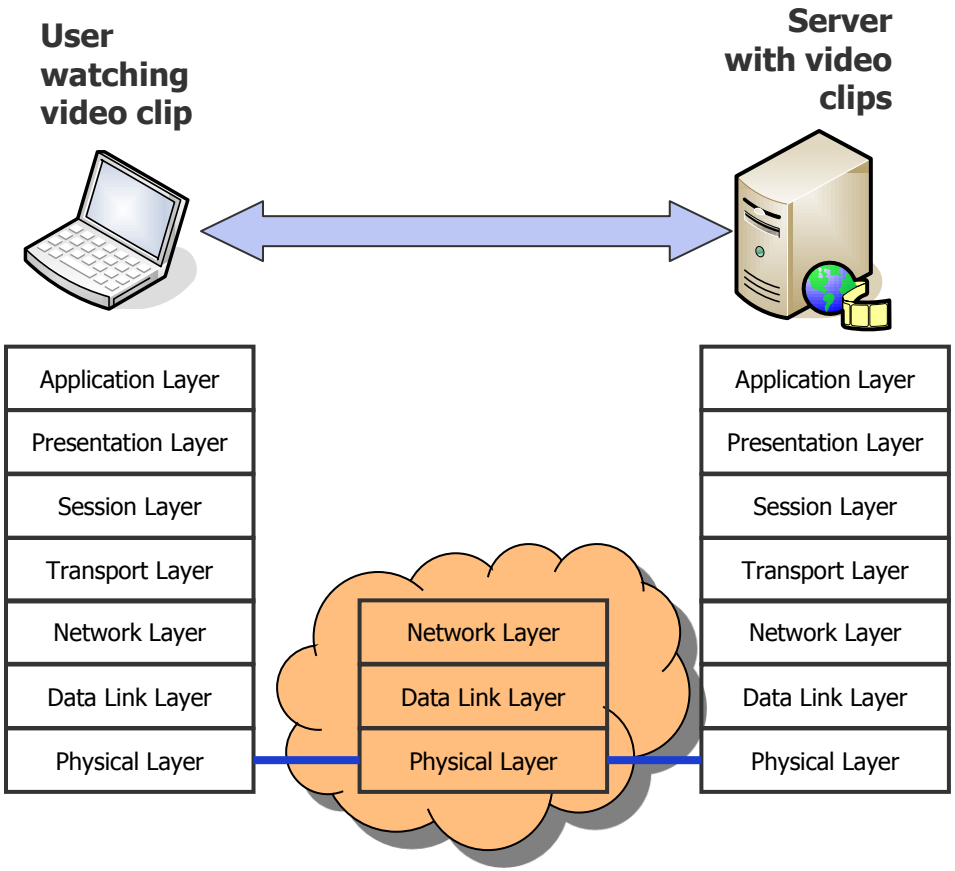
Freie Universität Berlin

Telematics
Chapter 1: Motivation



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Contents

- History of telecommunications
- Evolution of communication
- Economic aspects of telecommunications
- Computer networks
- The Internet
- Why we teach this course?
- Example for the course

History of telecommunications

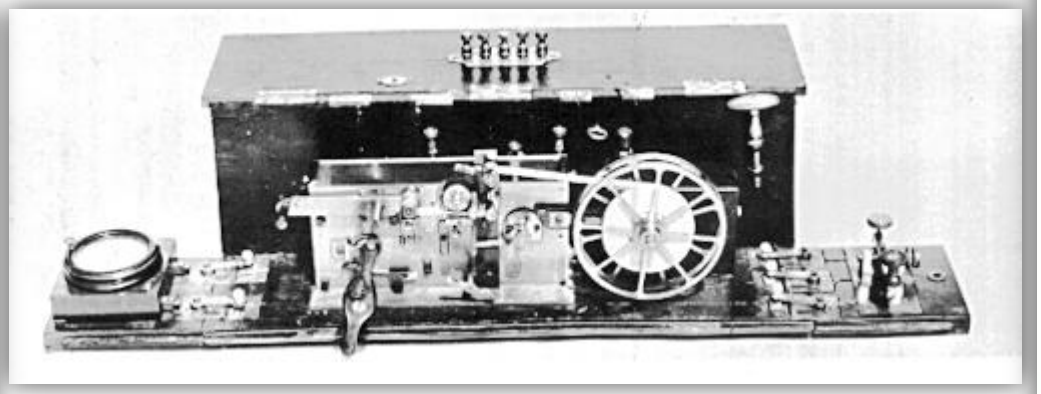
A very short history …

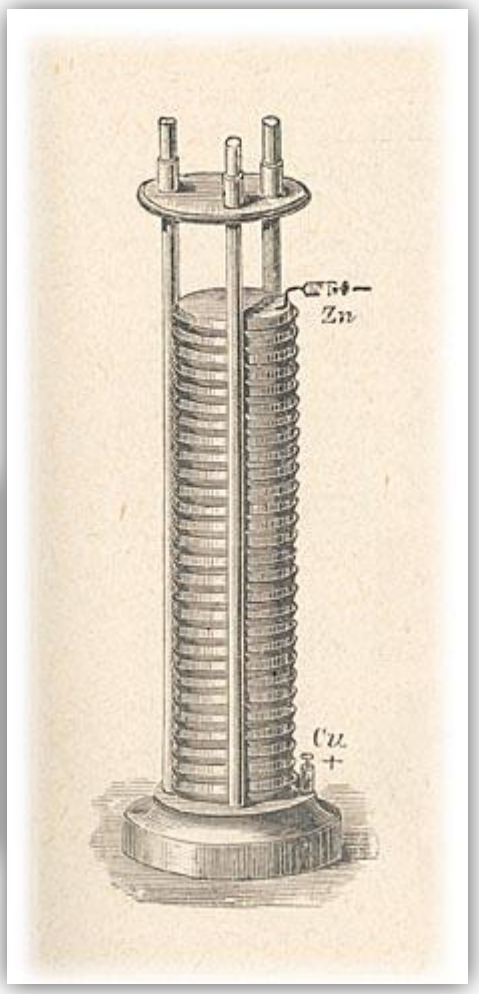
History of telecommunications

1799: Alessandro Volta invents the battery

1837: Samuel Morse develops the telegraph

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



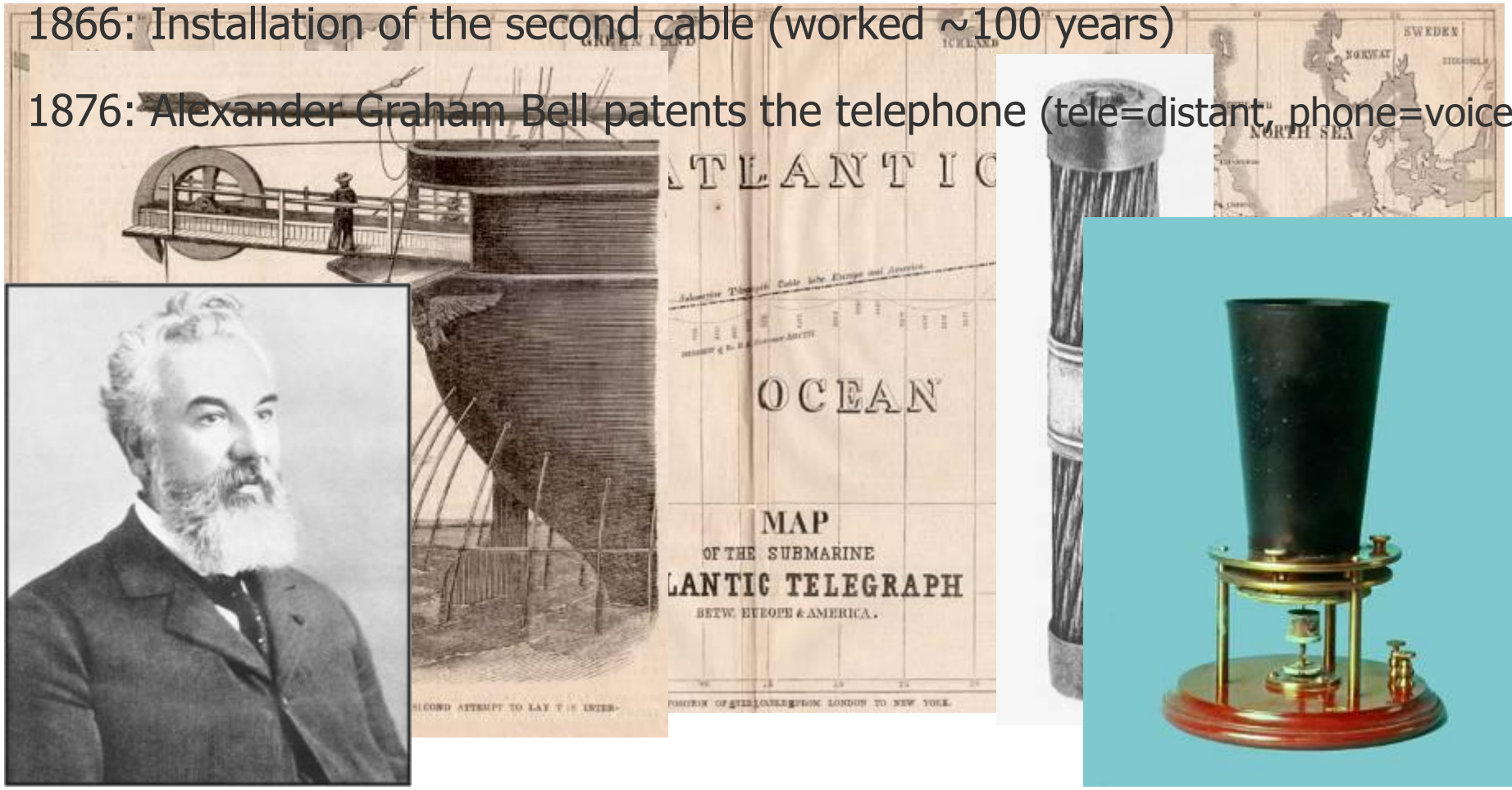


History of telecommunications

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

1866: Installation of the second cable (worked ~100 years)

1876: Alexander Graham Bell patents the telephone (tele=distant, phone=voice)

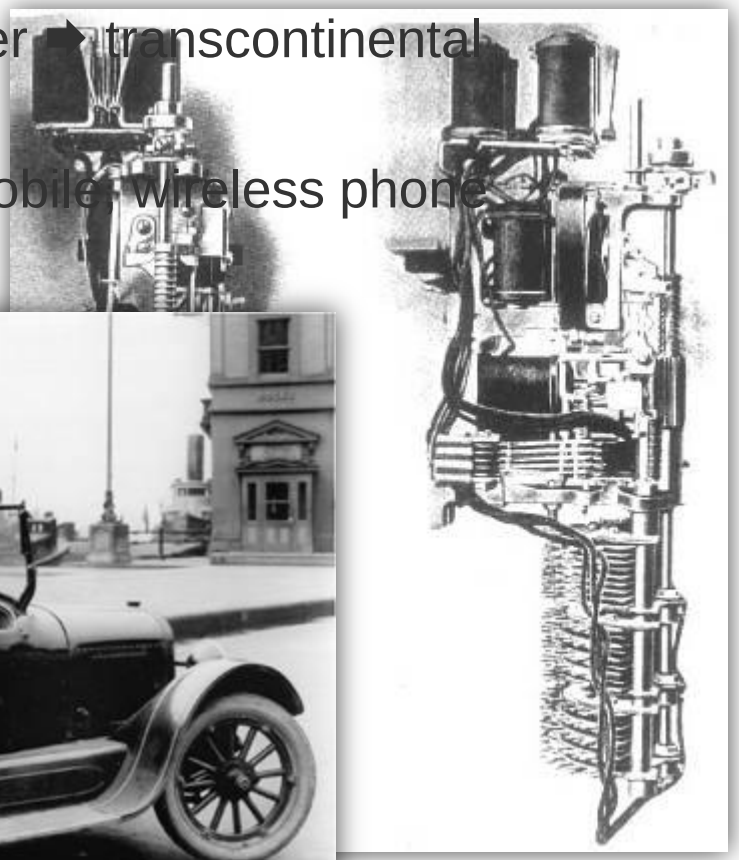


History of telecommunications

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)



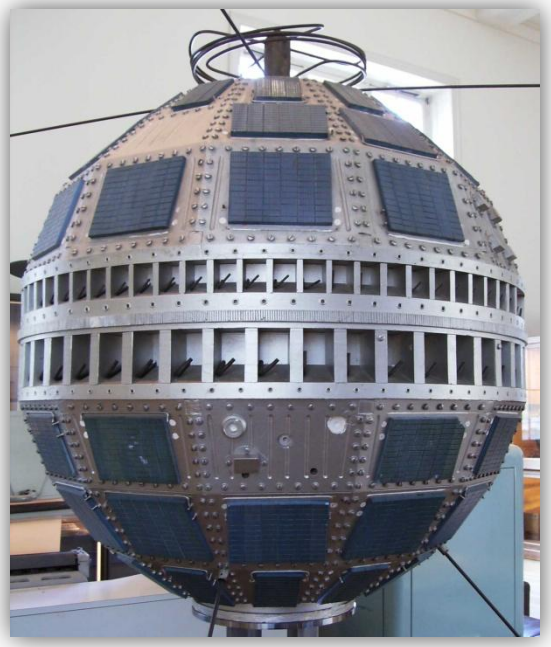
History of telecommunications

- 1953: First transatlantic telephone line! (TAT-1 with 36 Channels)

Name	Date	Number of 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

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)

History of telecommunications: Milestones

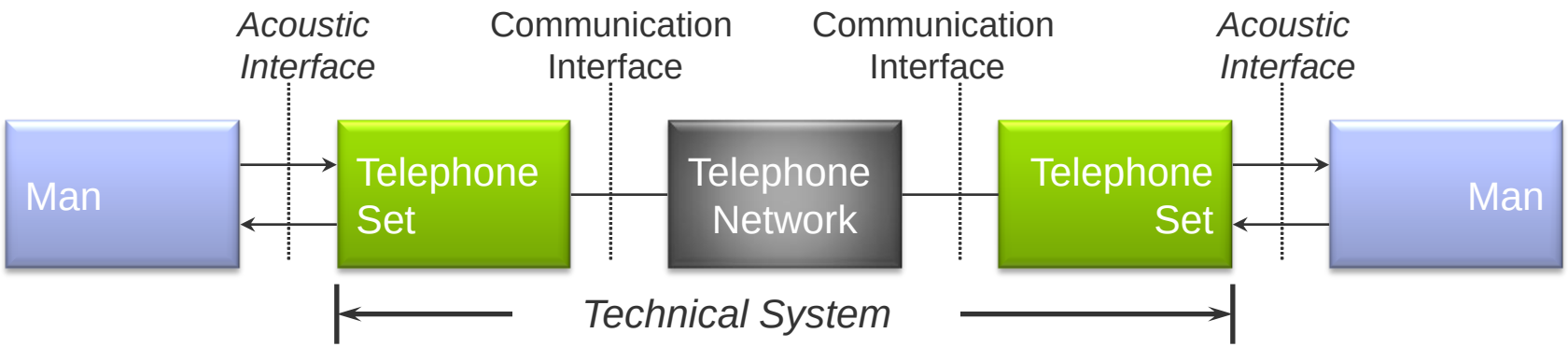
Year	Invention	Result
1840	Morse-Telegraph	Exchange of messages over long distances
1861/76	Telephone	Voice communication over long distances
1887	Electromagnetic Waves	Radio technology
1897	Strowger switch	Automatic switching
1923	Broadcast	Mass communication
1929	Coax cable	High data rates
1964	Satellites	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	Even higher data rates up to 1Tbps (Tera = 10^{12})
…	…	…

Evolution of communication

From many networks to one network

Evolution of communication

- The classical telecommunication is focused on voice communication
  - Humans are the communication peers
- Voice communication network



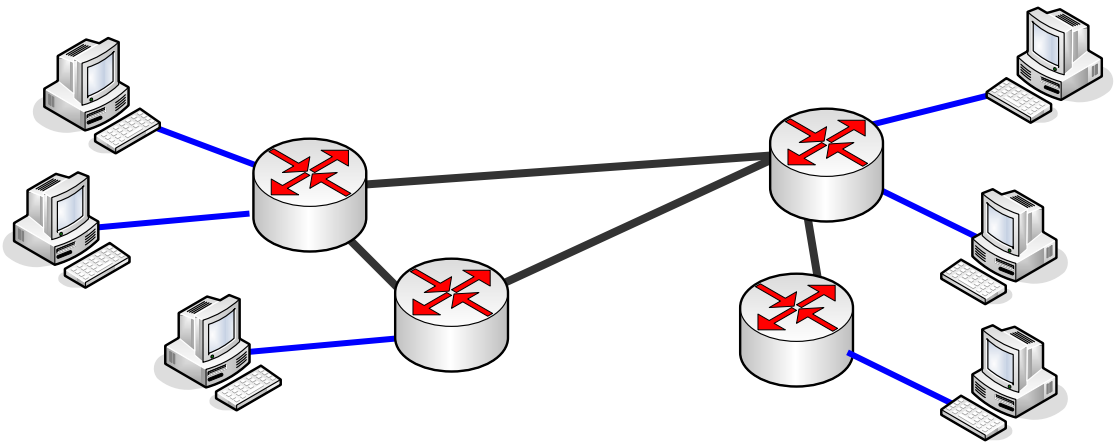
- Requirements
  - Acceptable voice quality
  - Availability
  - Scalability
  - Cost

Evolution of communication

Evolution of communication

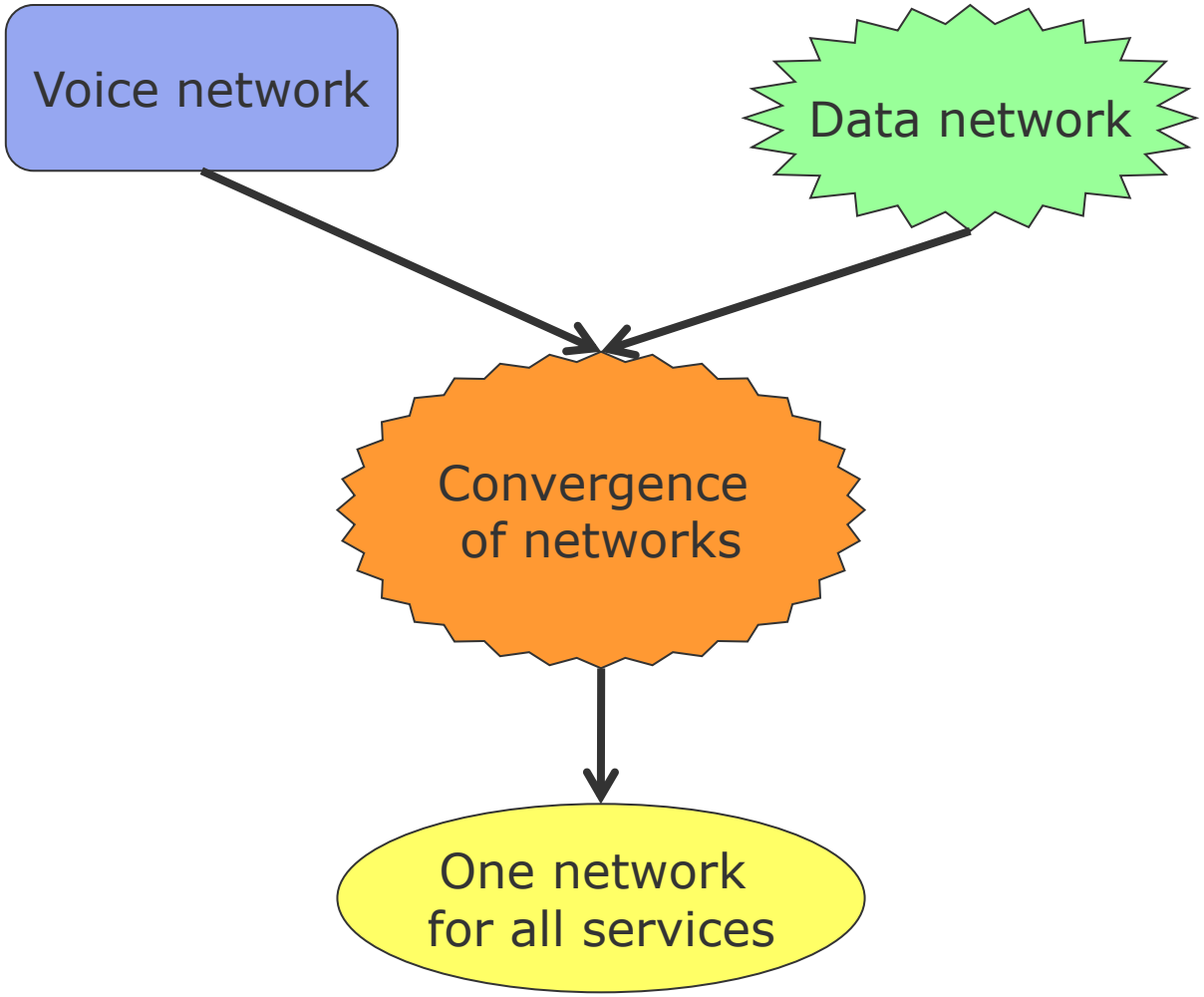
Evolution of communication

- Besides voice communication also data communication networks were created
  - No voice communication

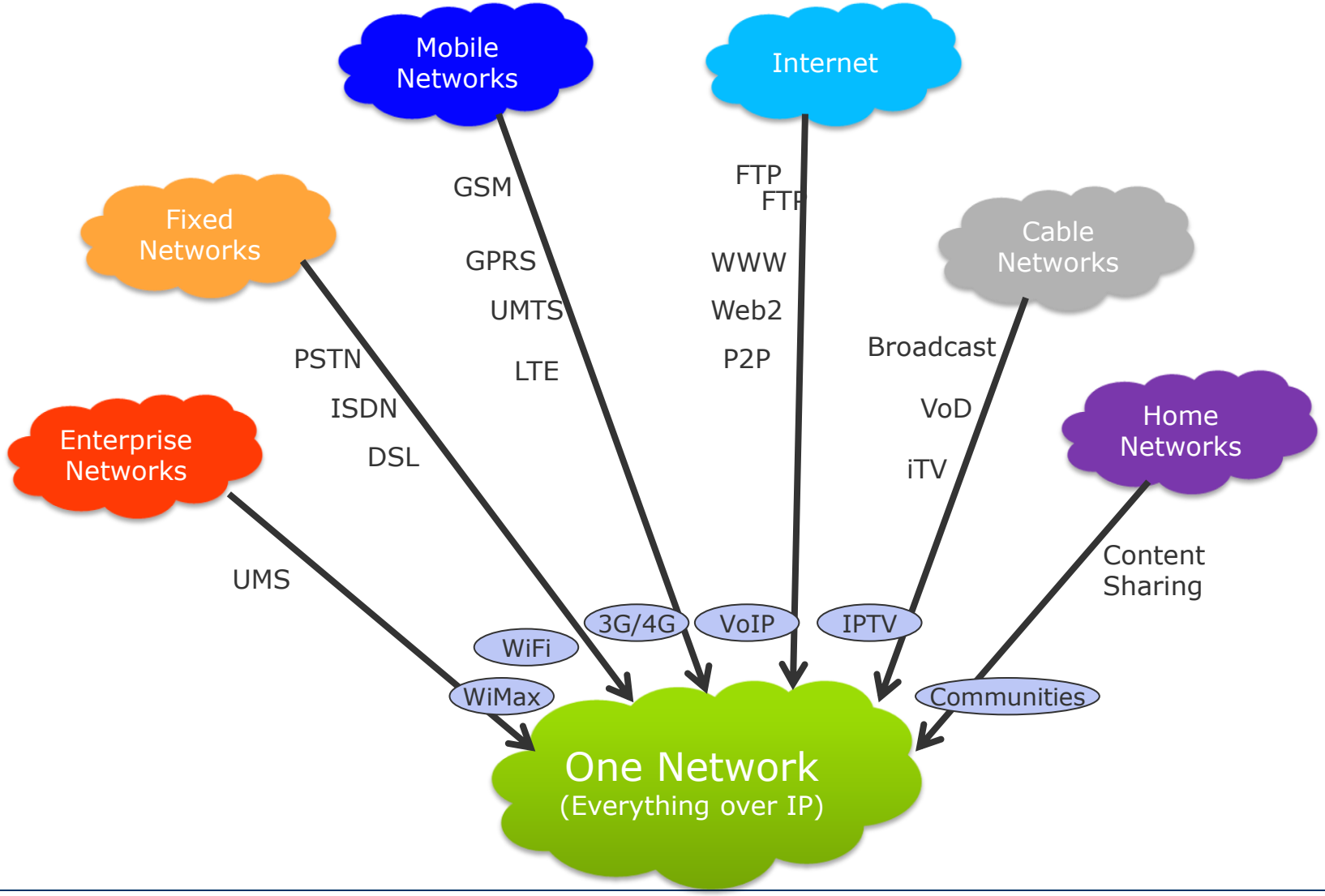


➡ Every single **service** demands for its own network

Evolution of communication



Evolution of communication



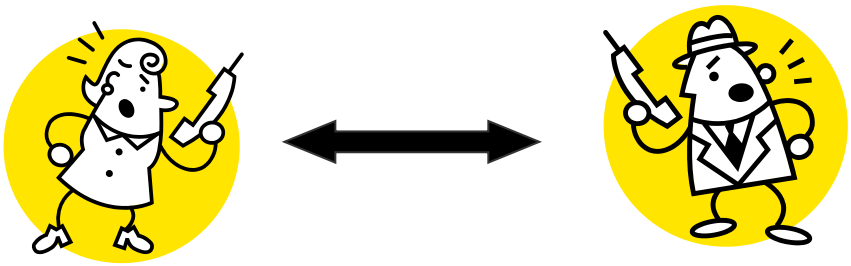
Evolution of communication

From humans and machines

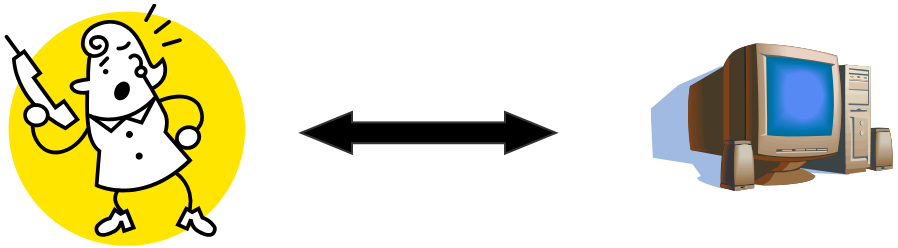
Evolution of communication

- Four evolution steps

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

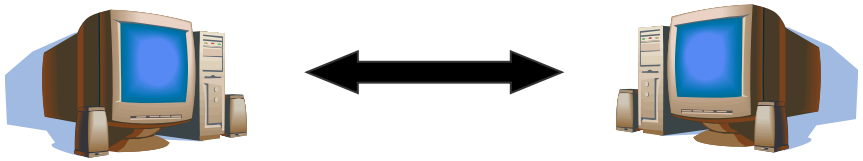


- Step 2:
  - Person to machine
    - Fax, Email, PC usage, ...



Evolution of communication

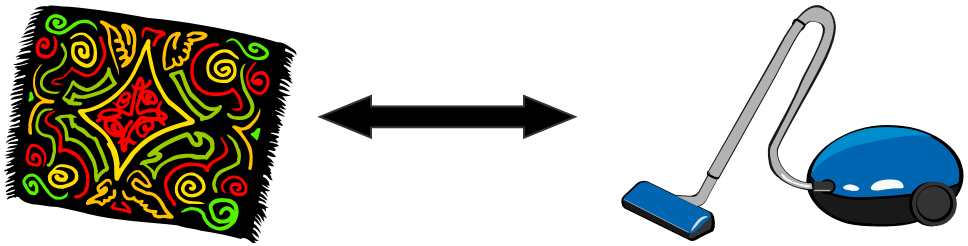
- Step 3:
  - Machine to machine
    - Computer to computer,
      e.g. Grid Computing, sensor networks, Web 2.0



    - Network of computers:
      - which exchange information in an autonomous way
      - which use these information by taking the environment into account
      - 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

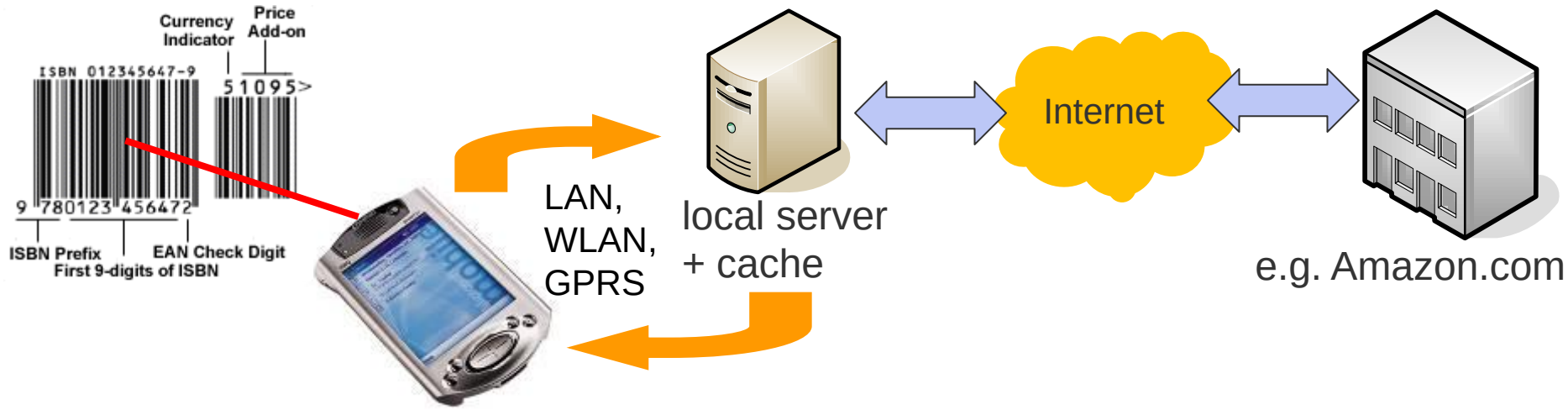
Evolution of communication

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



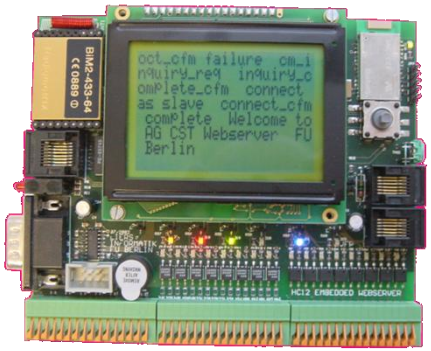
- Possible and/or already existing applications of such systems:
  - in medicine (body area networks, supervision of health condition, ...)
  - in entertainment (the new ICE age, ICE = Information, Communication, Entertainment)
  - in enterprises (fleet management, self maintenance, ...)
  - at home (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)

Evolution of communication : Examples from CST lab



Industry control system

RF,
wired



Wireless embedded
web server

GPRS,
WLAN,
…

Client

Example Application: Habitat Monitoring/Skomer Island UK

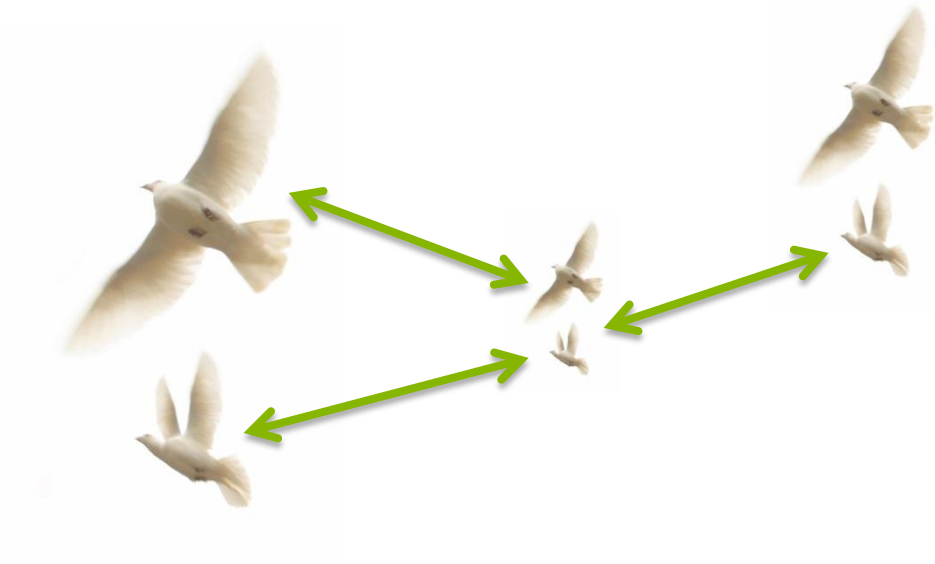
Manx Shearwater

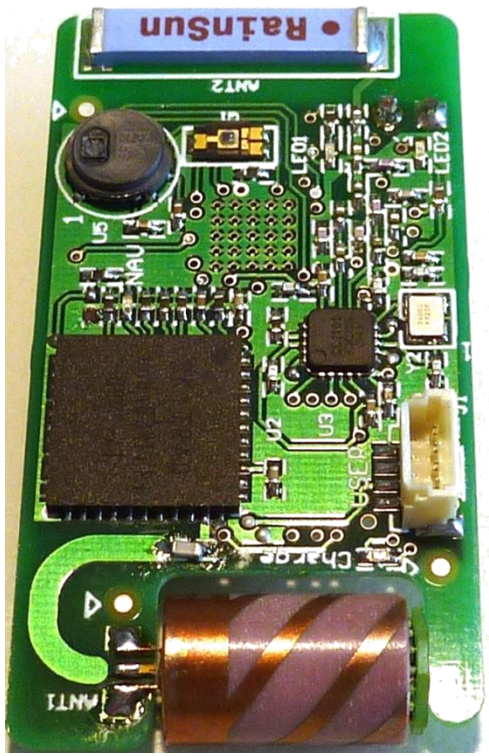
Combination of RFID and ScatterWeb

- Main challenge: robustness, reliability, easy-to-use
- Joint project with Oxford University and MSRC

More information: research.microsoft.com/habitats/

AvianGPS





Core: MSP430F1610 + CC1101
Sensors: GPS, Pressure Sensor, Light Sensor

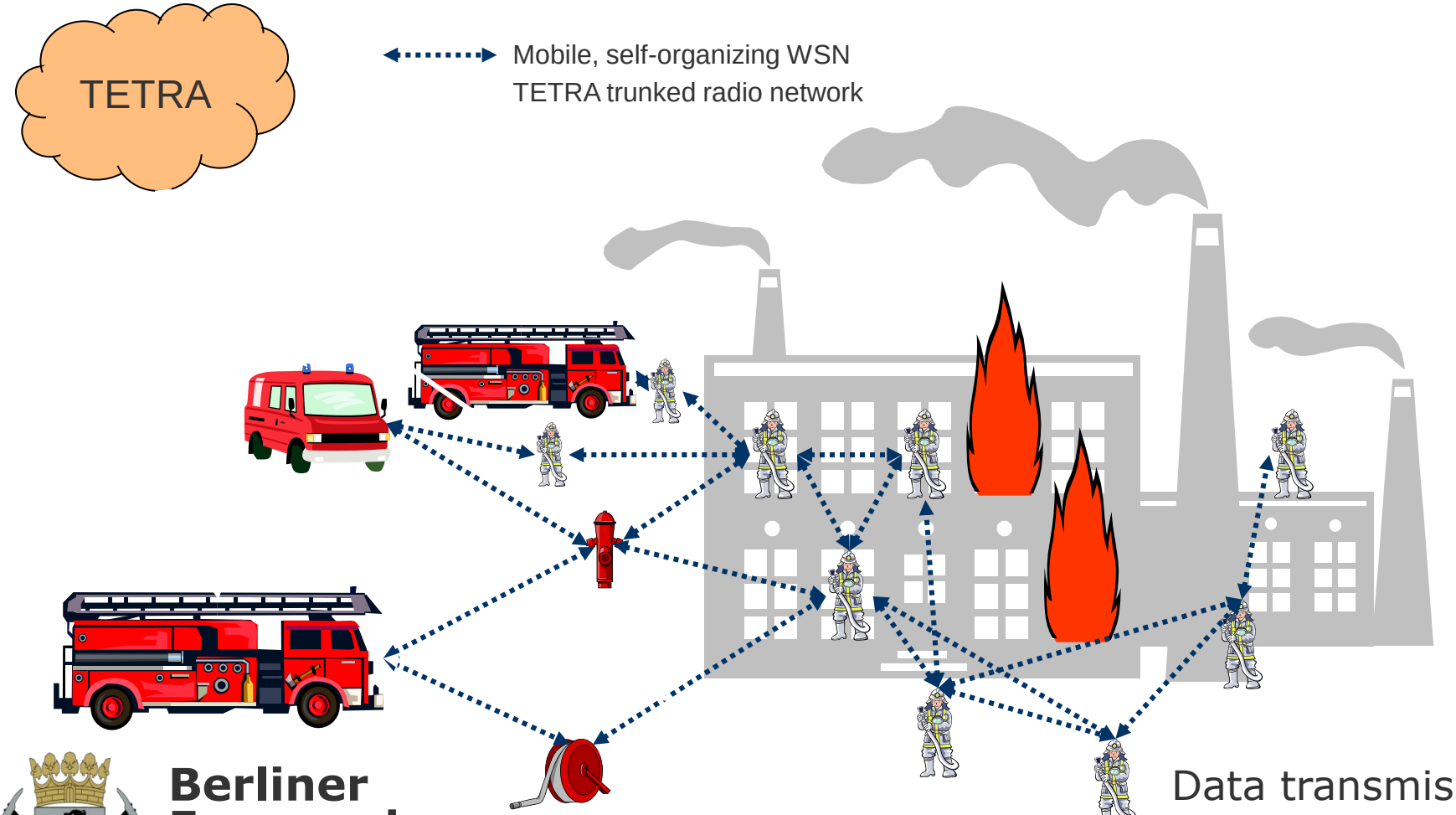
Weight: 7 g (without battery)
Size: 24 mm x 45 mm

Partners: Freie Universität Berlin, University of Oxford, Microsoft Research Ltd.

Challenging application: safety for rescue forces

Localization on the disaster site

Project FeuerWhere – the extreme challenge



Berliner Feuerwehr
4450 fire fighters
300000 incidents/year (8000 fires)

Data transmission & localization

Evolution of communication

From wired to wireless

Evolution of communication

1970

2011

Smartphone, Mobile

VoIP/Video

Email

Blogs

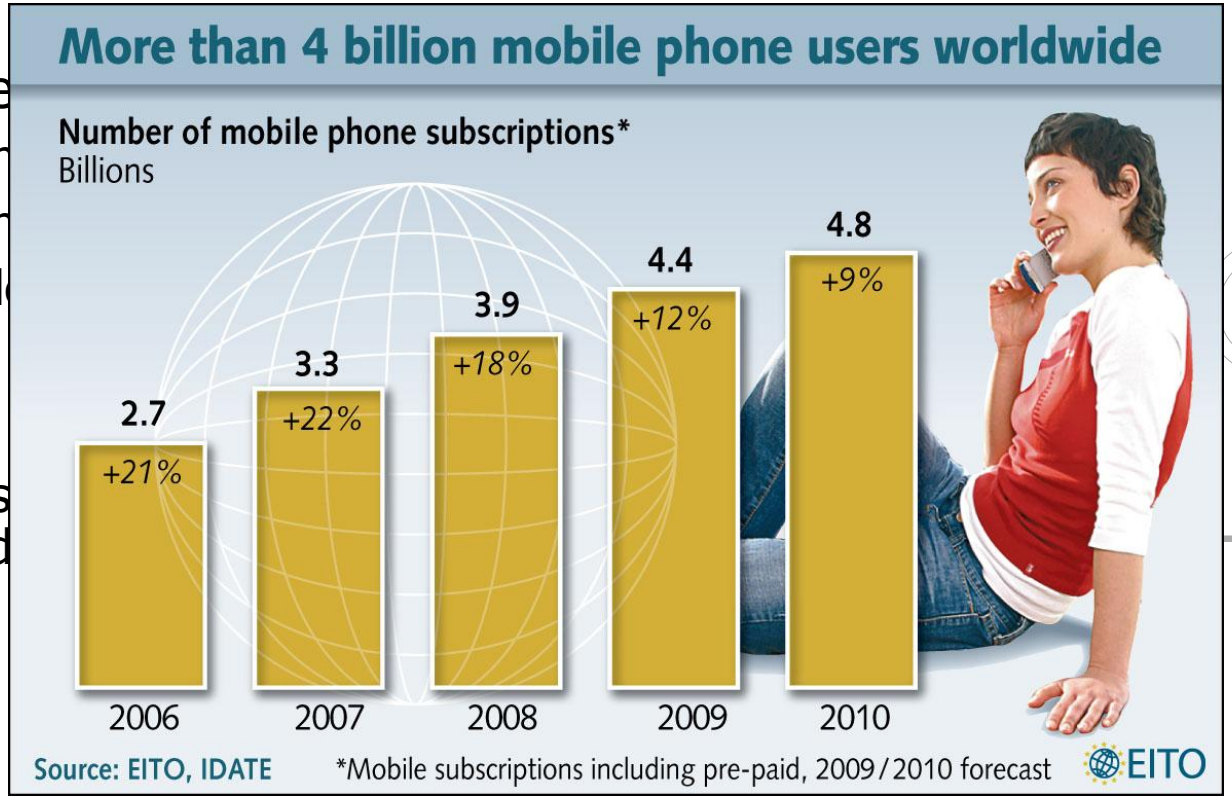
IM

Evolution of communication

- Everybody, at anytime, from anywhere.

anybody, (m)anytime, (m)anywhere

- Trendsette
  - more than
  - more than
  - world-wid
- Goal:
  - Transmiss
    Audio, Vid

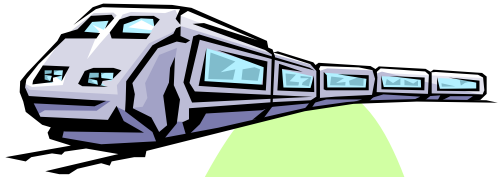


Evolution of communication

LAN, WLAN
780 kbit/s

GSM 57 kbit/s
Bluetooth 500 kbit/s

UMTS, GSM
115 kbit/s

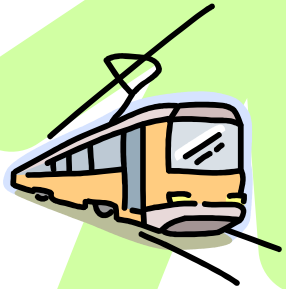


LAN
100 Mbit/s,
WLAN
54 Mbit/s

GSM 384 kbit/s,
WLAN 780 kbit/s

GSM 115 kbit/s,
WLAN 11 Mbit/s

UMTS, GSM
384 kbit/s



UMTS,
DECT
2 Mbit/s

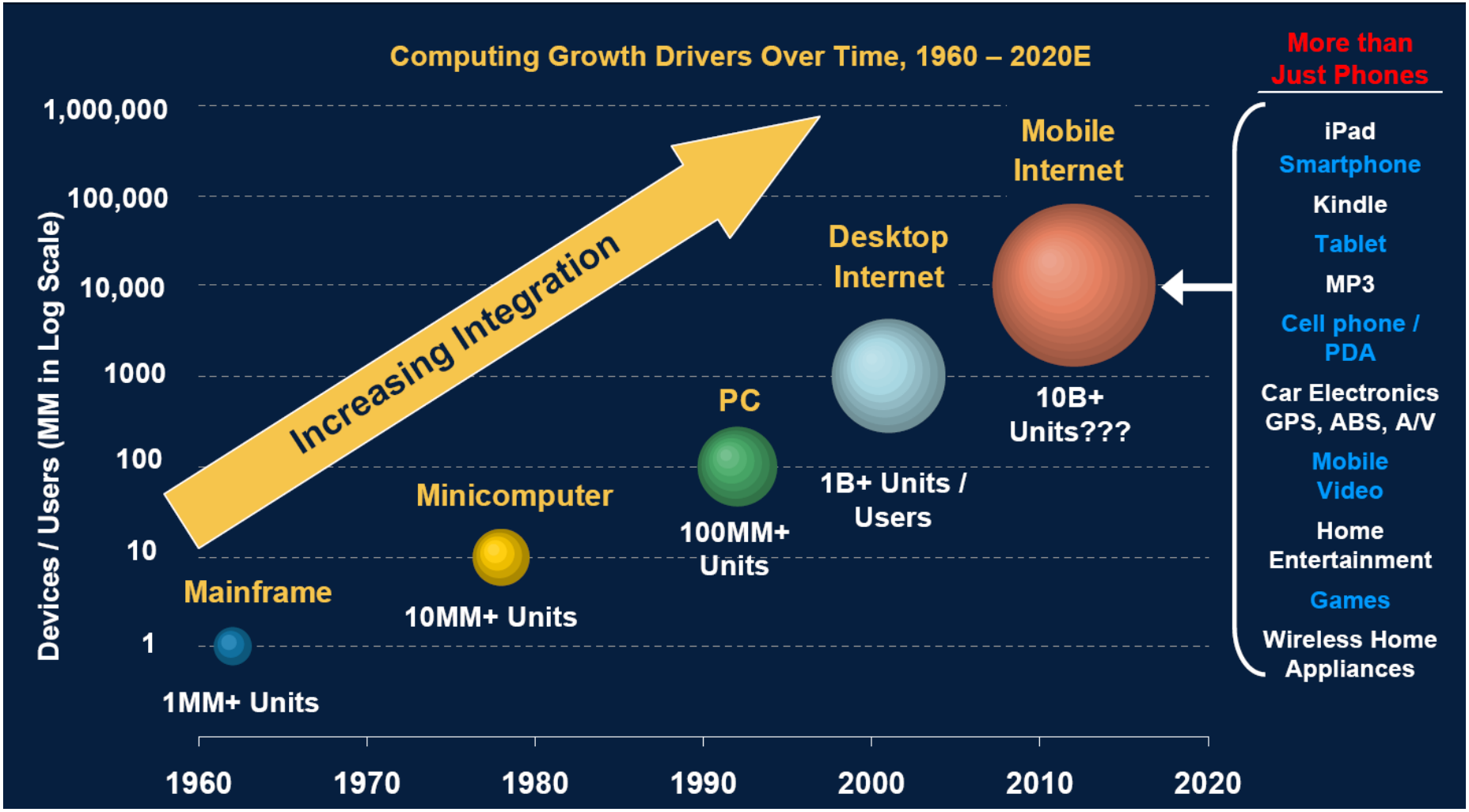
Evolution of communication

Ubiquitous communication

Evolution of communication

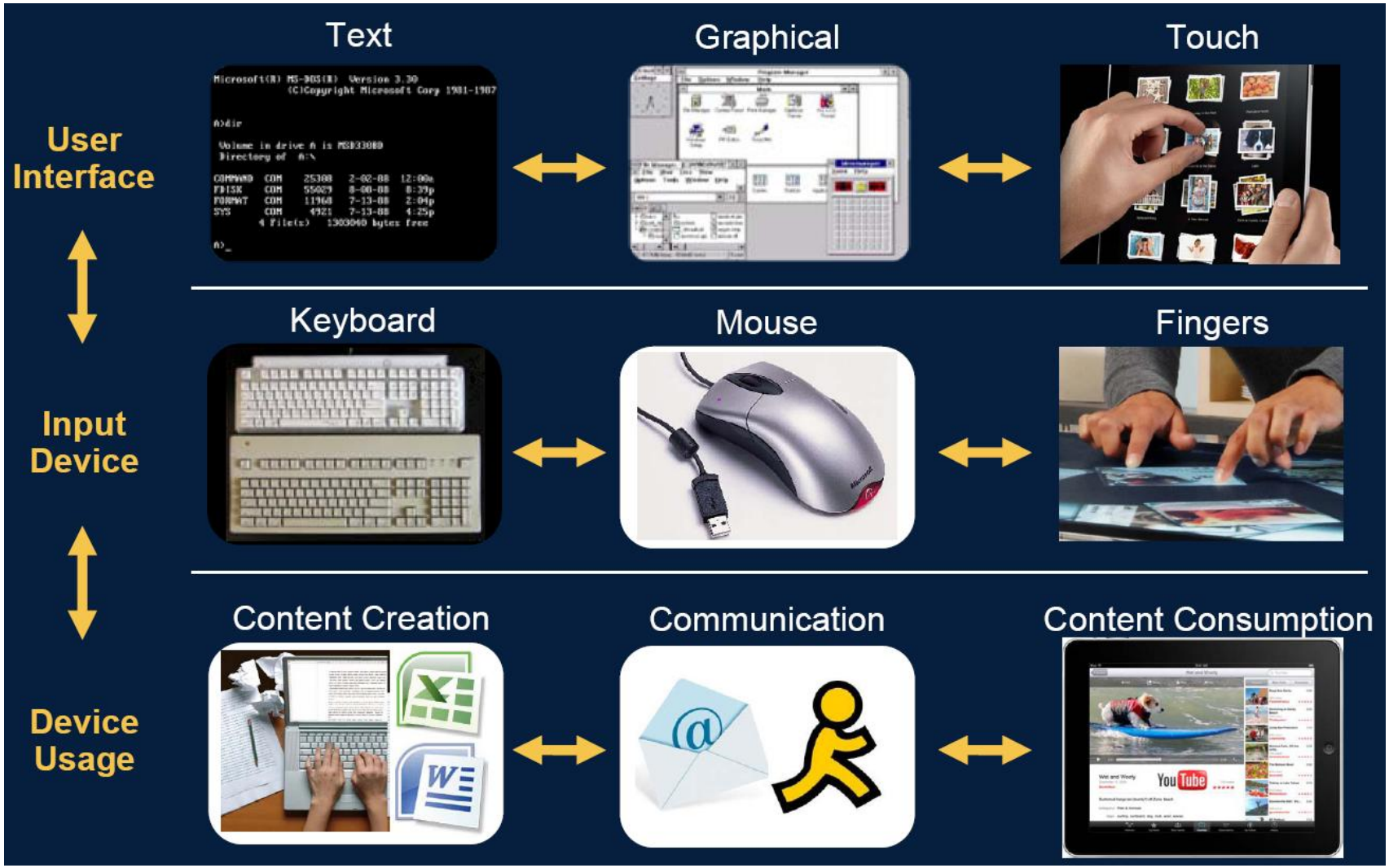
Mainframe Computing 1960s	Mini Computing 1970s	Personal Computing 1980s	Desktop Internet Computing 1990s	Mobile Internet Computing 2000s
		 		 

Evolution of communication



Note: PC installed base reached 100MM in 1993, cellphone / Internet users reached 1B in 2002 / 2005 respectively;
Source: ITU, Mark Lipacis, Morgan Stanley Research.

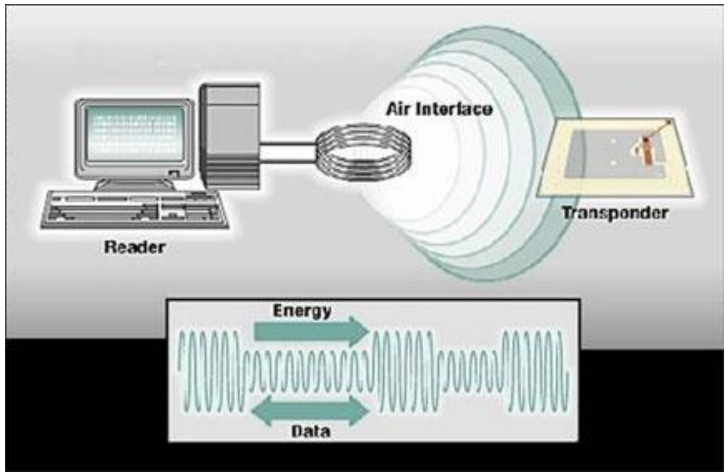
Evolution of communication

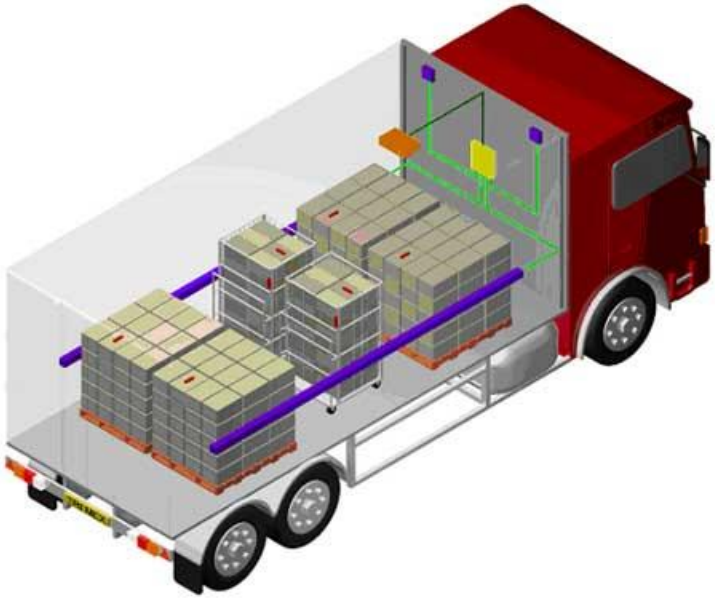


Source: Morgan Stanley Research

Evolution of communication

- 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.





Evolution of communication

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

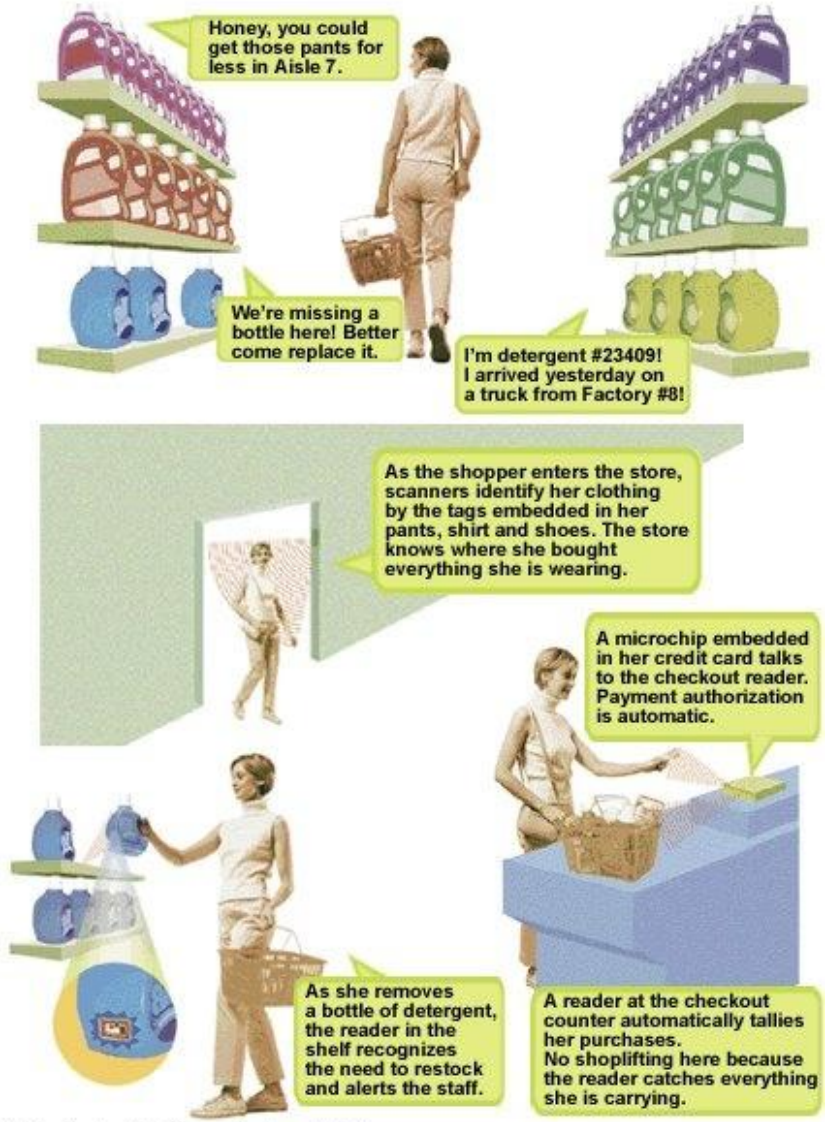
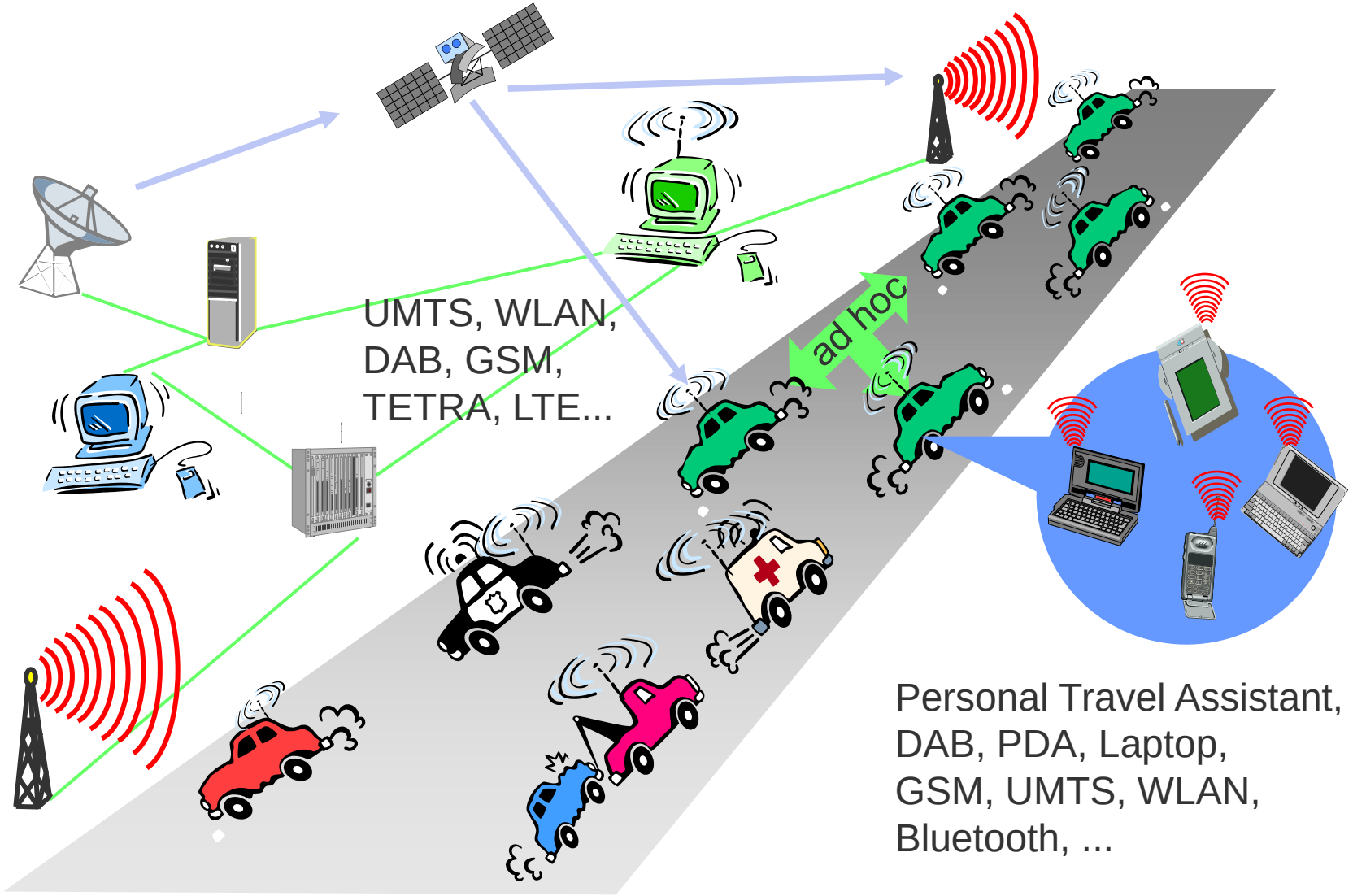


Illustration by Lisa Knouse Braiman for Forbes

Evolution of communication

Evolution of communication: On the road



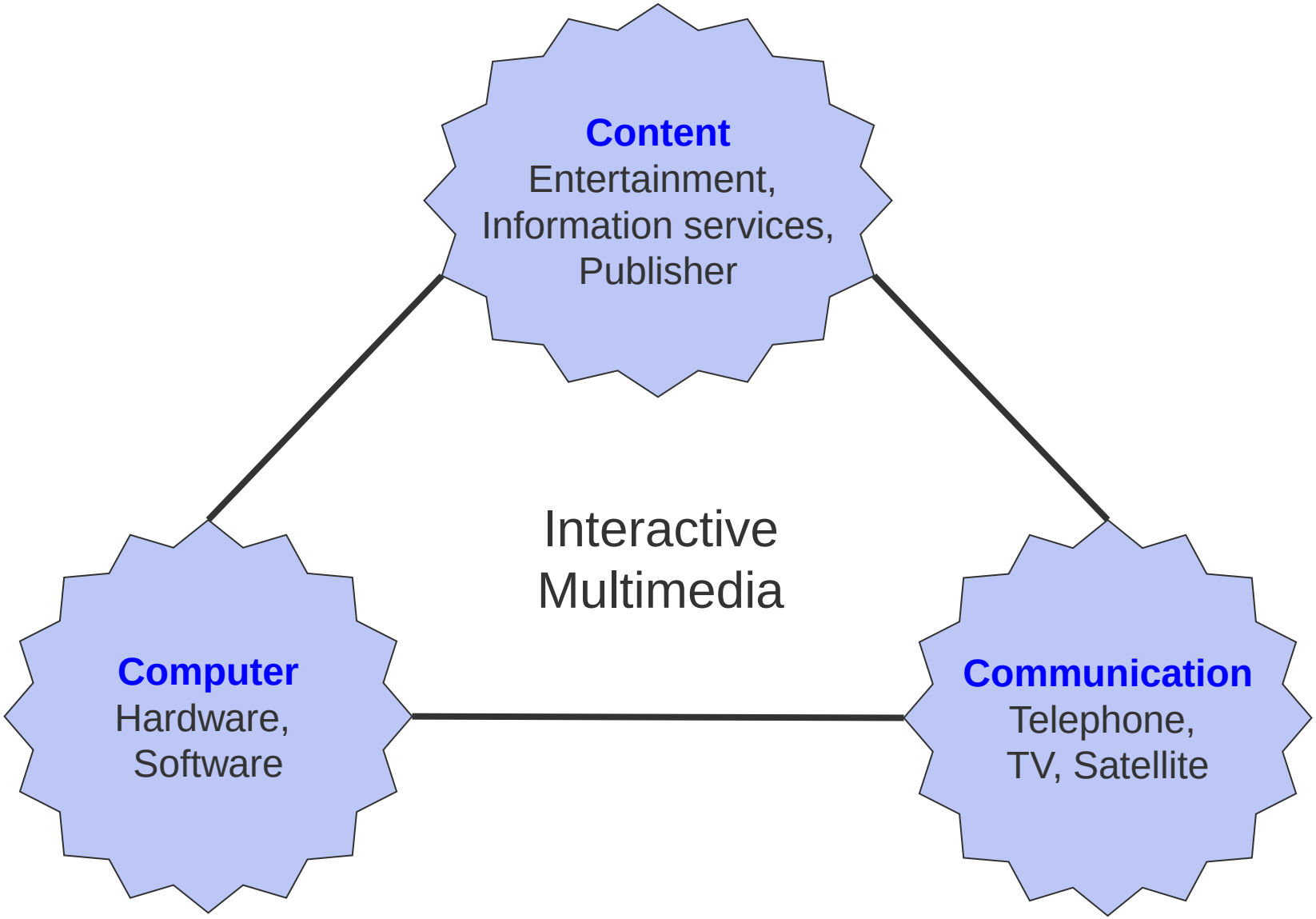
Economic aspects of telecommunications

Economic aspects: Business sectors

- Supplier
  - Produces hard-/software-technologies, e.g., Siemens, Cisco, Nokia, Alcatel, …
- 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!

Economic aspects: Converging industries



Economic aspects: The telecommunications market

ITK-Markt Deutschland	Marktvolumen (in Mrd. Euro)				
	2004	2005	2006	2007	2008
Summe ITK + digitale CE	**137,8**	**142,8**	**145,9**	**147,8**	**150,2**
Digitale CE	**6,8**	**8,7**	**9,8**	**10,5**	**10,9**
Summe ITK	**131,1**	**134,1**	**136,1**	**137,3**	**139,2**
Informationstechnik[1]	**66,3**	**68,1**	**70,1**	**72,5**	**75,0**
Telekommunikation[2]	**64,8**	**66,0**	**66,0**	**64,8**	**64,2**
Summe ITK Hardware u. Systeme[3]	**34,0**	**34,0**	**33,9**	**33,7**	**33,5**
Computer Hardware	17,4	17,1	16,7	16,5	16,3
TK-Endgeräte	5,2	5,2	5,2	5,2	5,2
Bürotechnik	2,7	2,9	3,0	3,2	3,3
Datenkommunikations- u. Netzinfrastruktur	8,7	8,9	8,9	8,8	8,8
Software	**15,4**	**16,1**	**17,0**	**18,0**	**19,0**
IT-Services	**26,7**	**27,9**	**29,1**	**30,5**	**32,0**
Telekommunikationsdienste[4]	**55,0**	**56,1**	**56,1**	**55,1**	**54,7**

[1] Computer Hardware, Bürotechnik, Datenkommunikationshardware, Software, IT-Services
[2] TK-Endgeräte, Netzinfrastruktur, Telekommunikationsdienste
[3] Computer Hardware, TK-Endgeräte, Bürotechnik, Datenkommunikations- u. Netzinfrastruktur
[4] ohne Carrier-to-Carrier Geschäft

Quelle: BITKOM (September 2007)

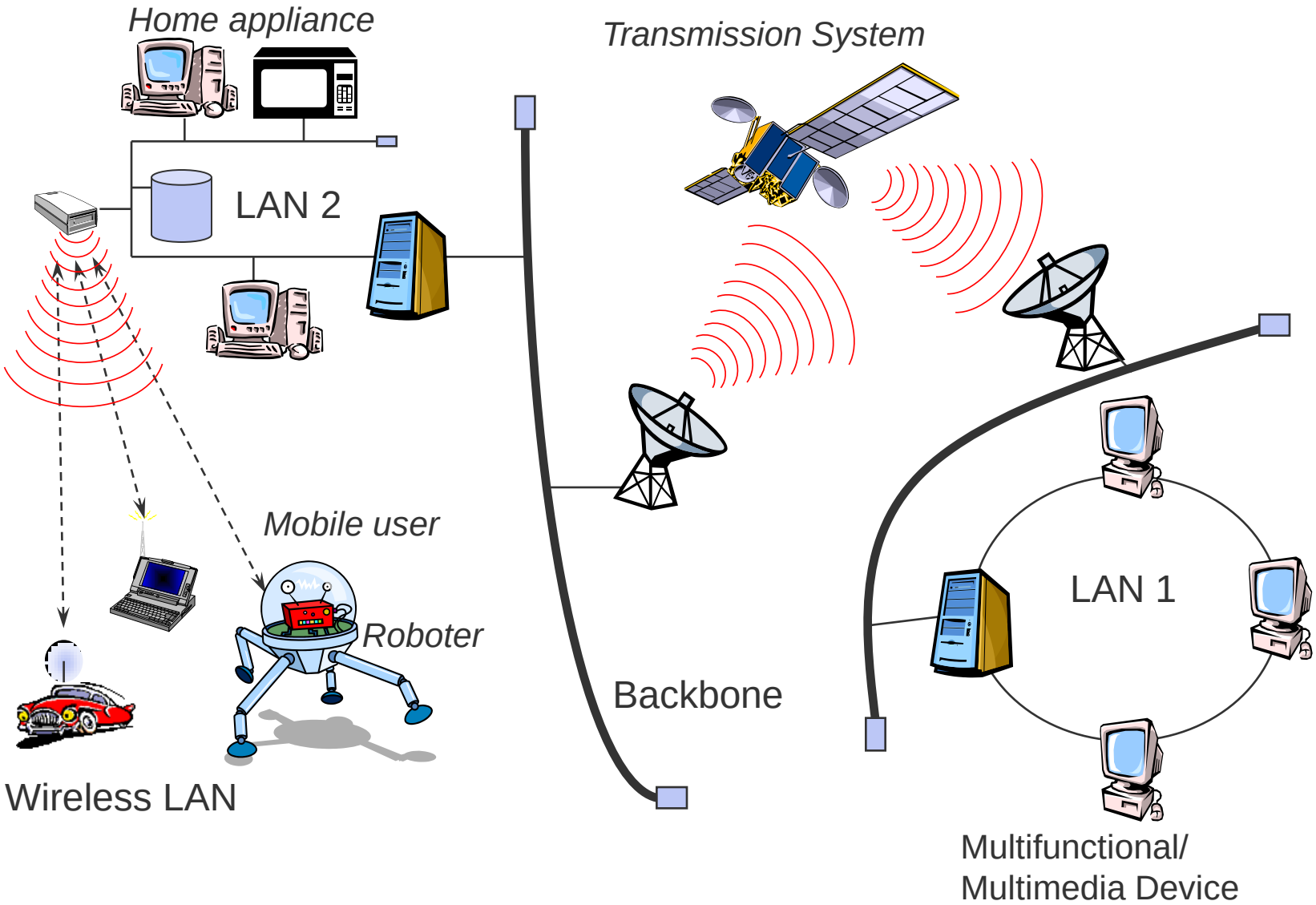
Computer networks

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

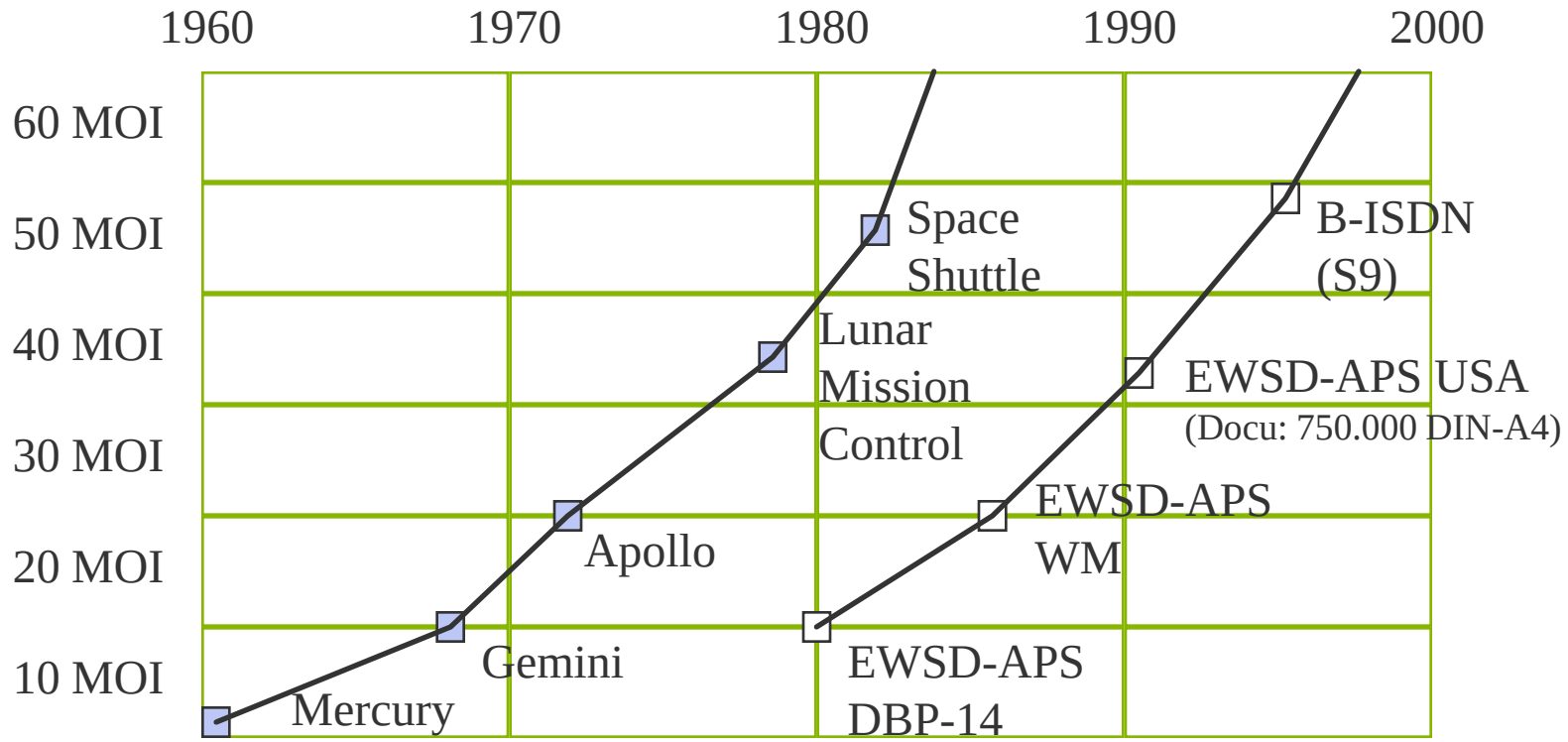
- Basics: Computer-Computer-Communication
  - Digital telecommunication is exclusively based on computers
  - Modern telecommunication networks are **Computer Networks**

Computer networks



Computer networks: Software

- Complexity of software for networks
  - Example: EWSD-System of Siemens
    Elektronisches WählSystem Digital / Electronic Digital Switching System

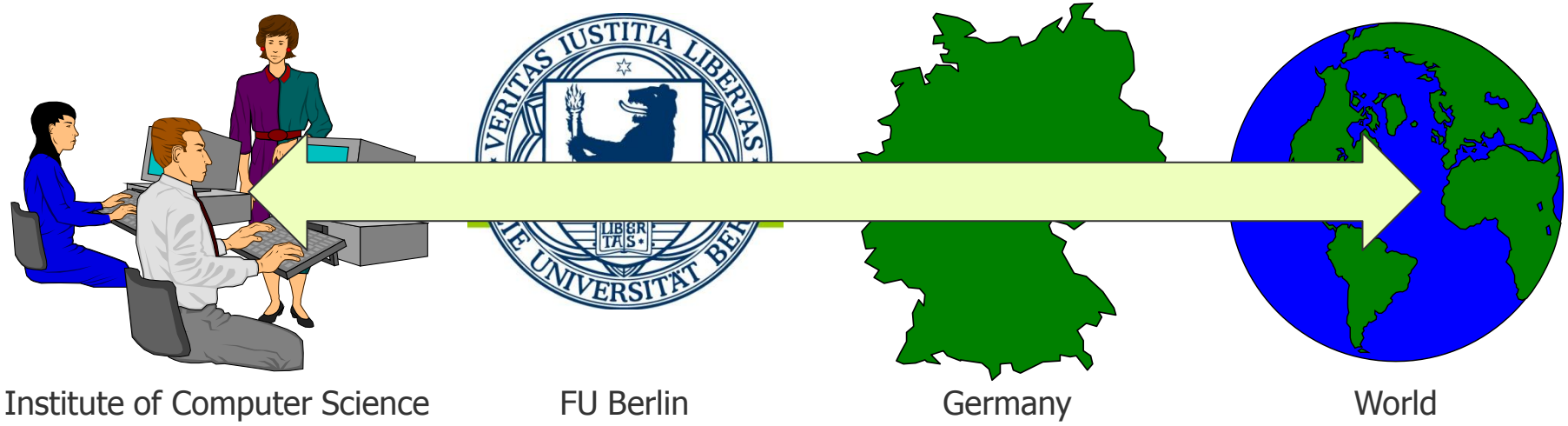


MOI = Million Object-Code-Instructions

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

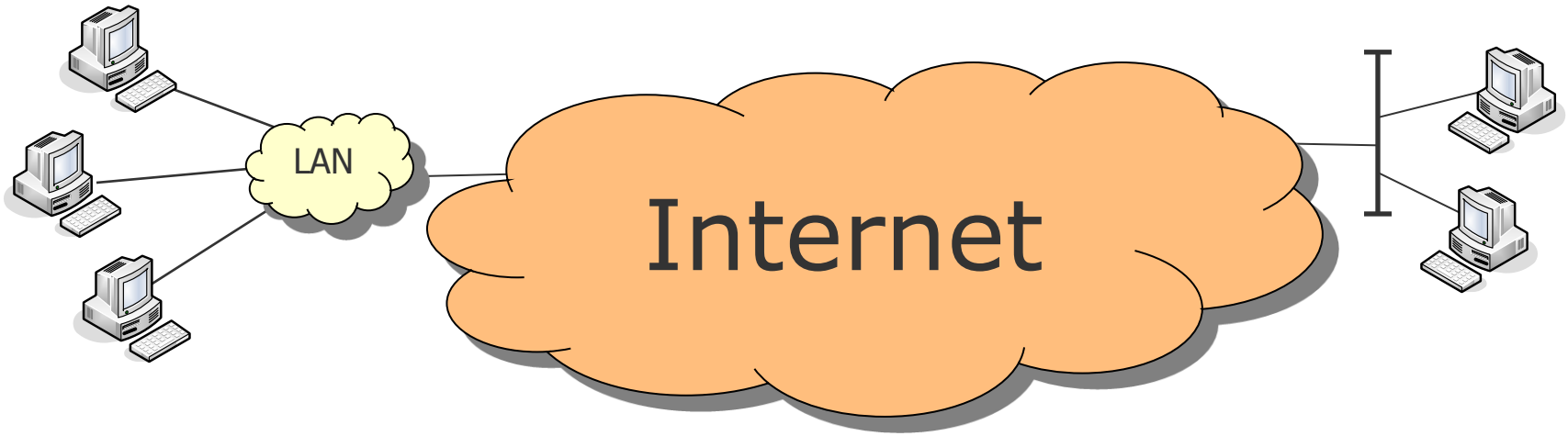


The Internet: Design Principles

- 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

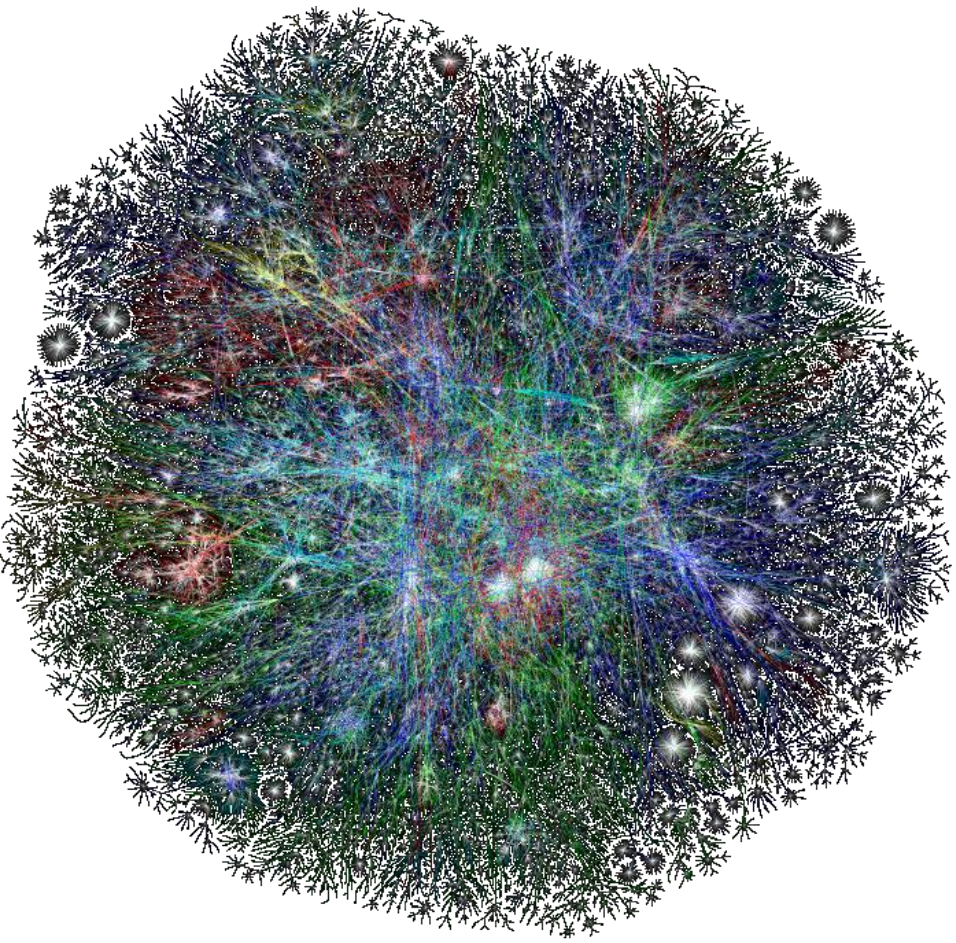
The Internet: Structure

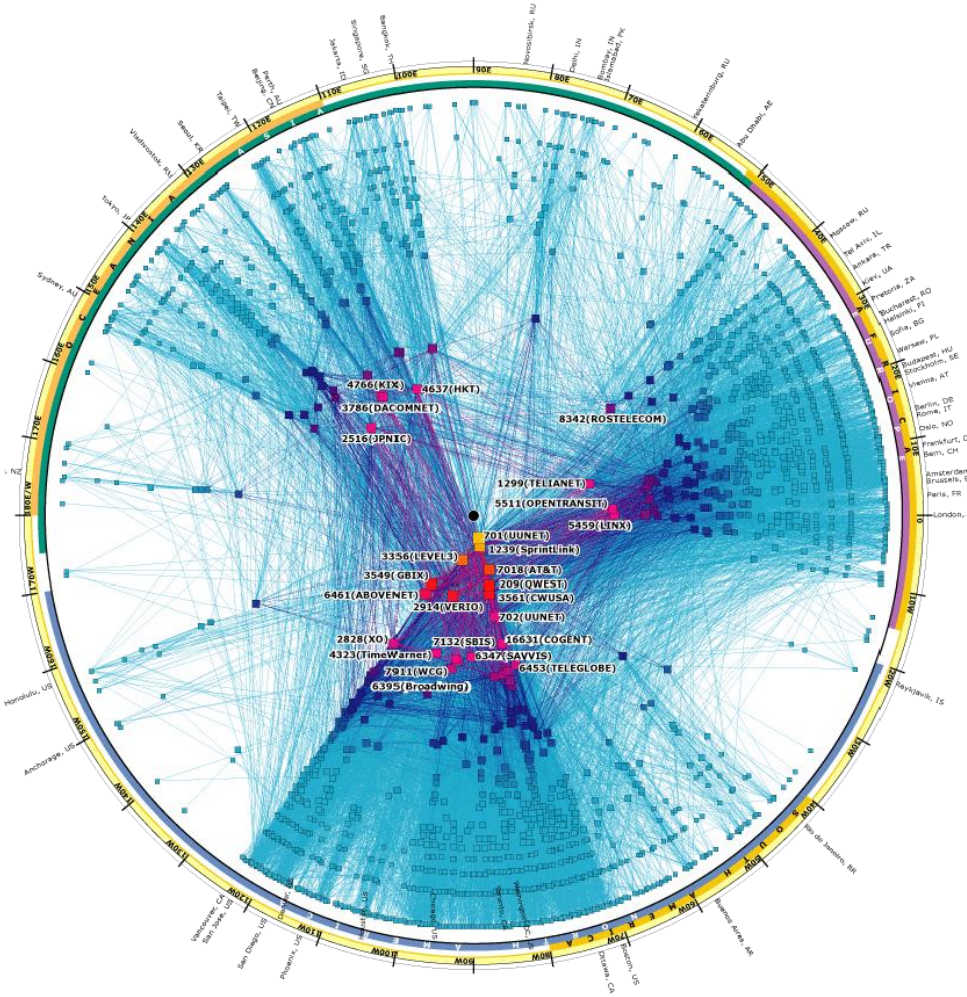
- Goal
  - World-wide communication of heterogeneous computers
- Structure:
  - Interconnection of computers and local networks over and partially interconnected router networks



➡ Definition of a uniform protocol family: TCP/IP

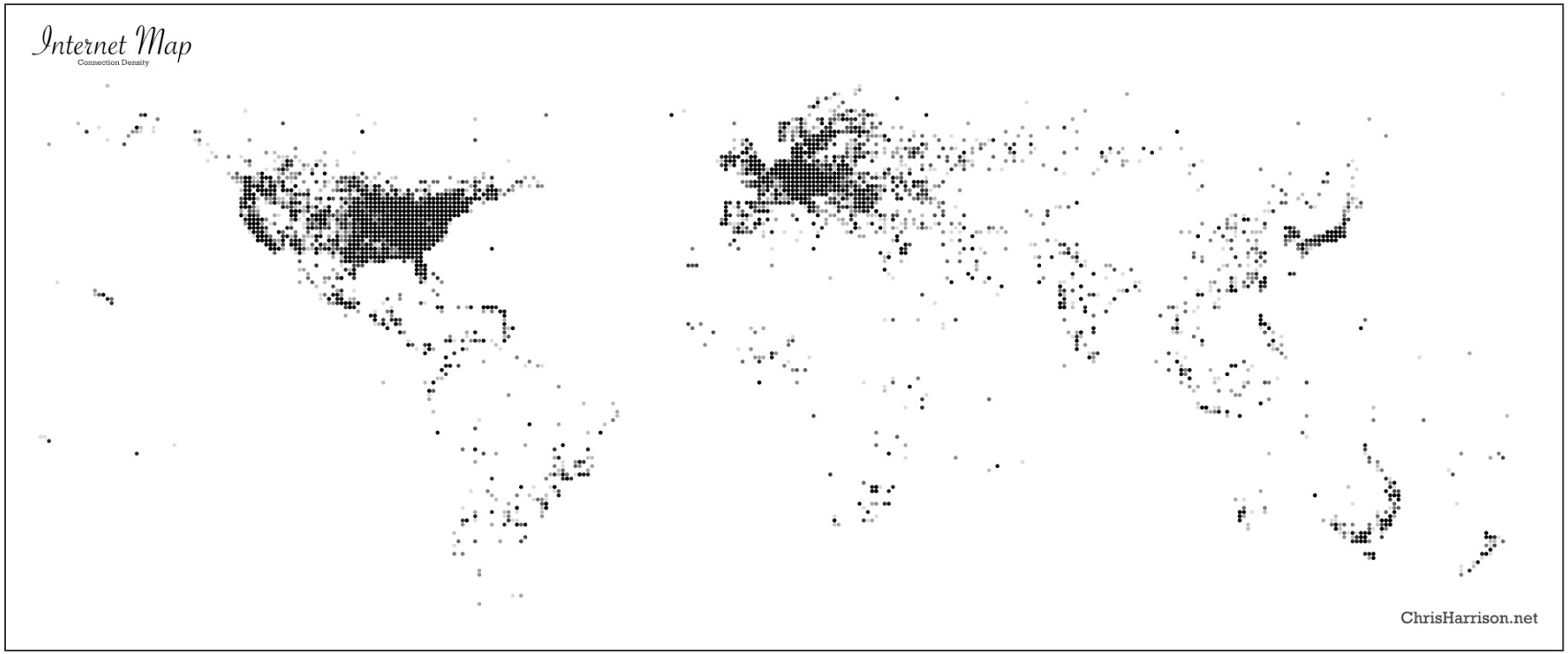
The Internet: The “real” Structure





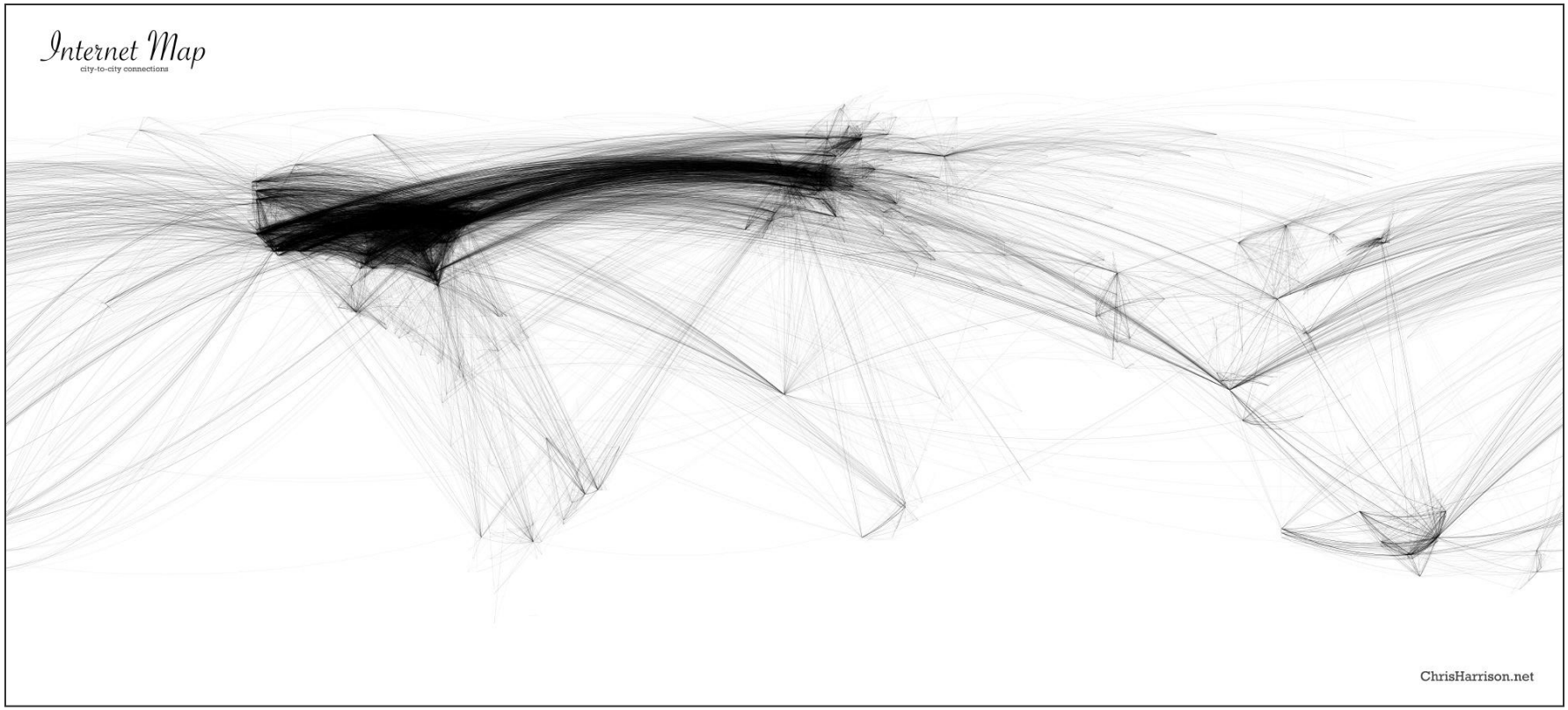
The Internet: The “real” Structure

- World Connection Density, Courtesy of ChrisHarrison.net

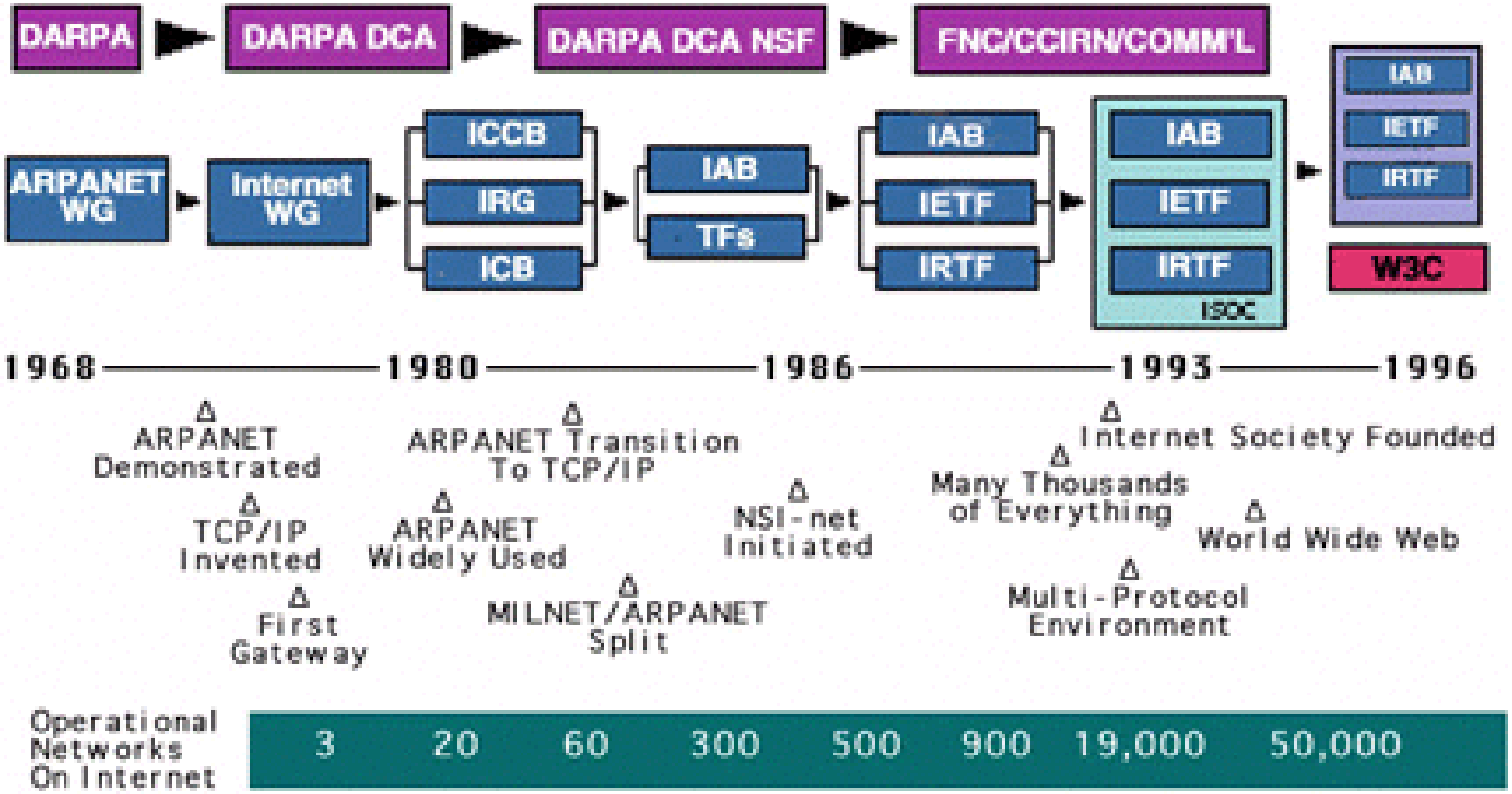


The Internet: The “real” Structure

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



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: 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

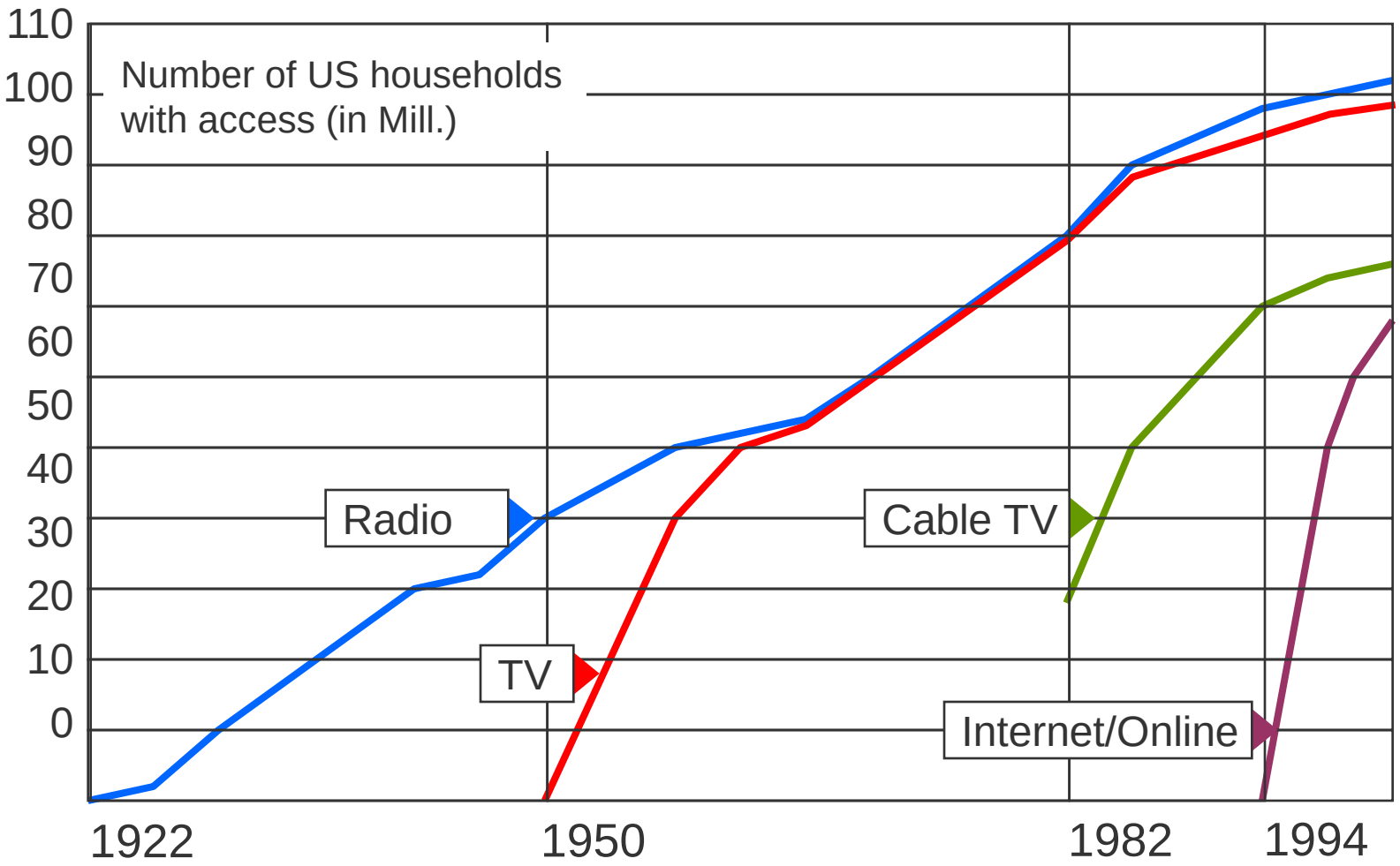
The Internet: The History

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

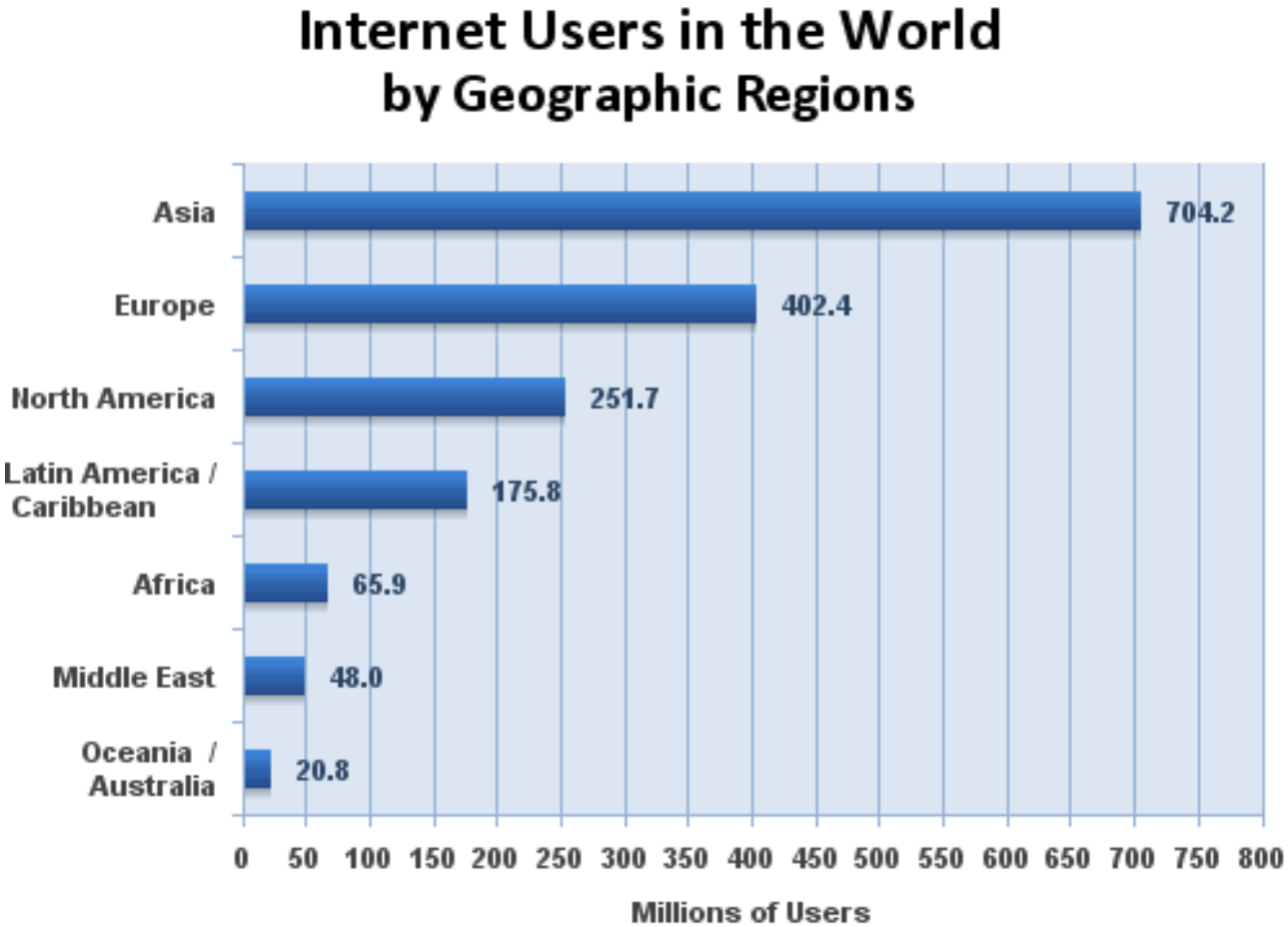
Year	Event
1988	IP-Link to the Internet from Germany over Eunet-IRB Dortmund and XLink (eXtended Lokales Informatik-Netz Karlsruhe)
1989	Number of hosts breaks 100,000.
1991	EBONE: EuropeanBackbone
1992	▪ Internet Society is chartered (www.isoc.org). ▪ World-Wide Web released by CERN. ▪ Number of hosts 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

The Internet: Development



(Source: Bertelsmann)

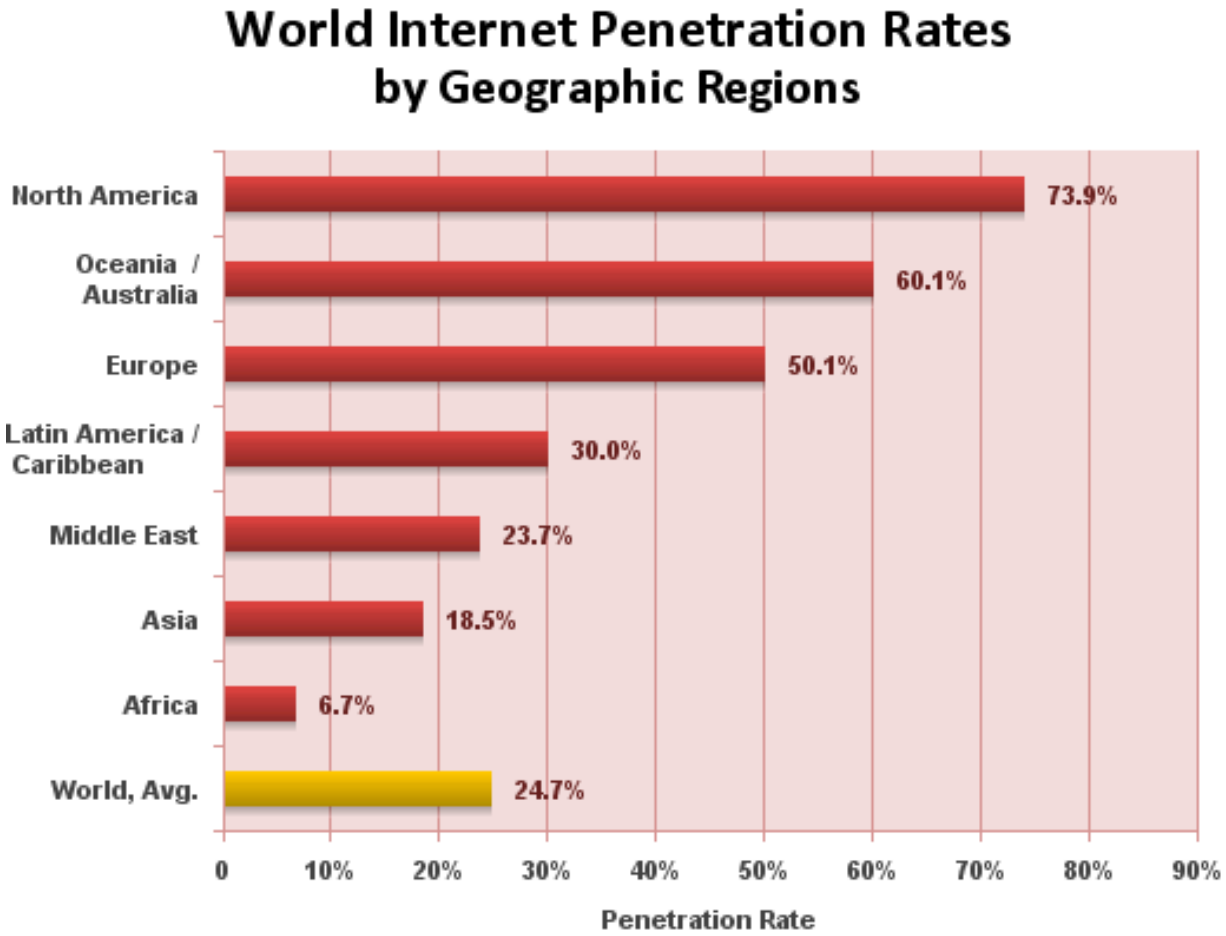
The Internet: User statistics



Source: Internet World Stats - www.internetworldstats.com/stats.htm
Estimated Internet users are 1,668,870,408 for June 30, 2009
Copyright © 2009, Miniwatts Marketing Group

www.internetworldstats.com

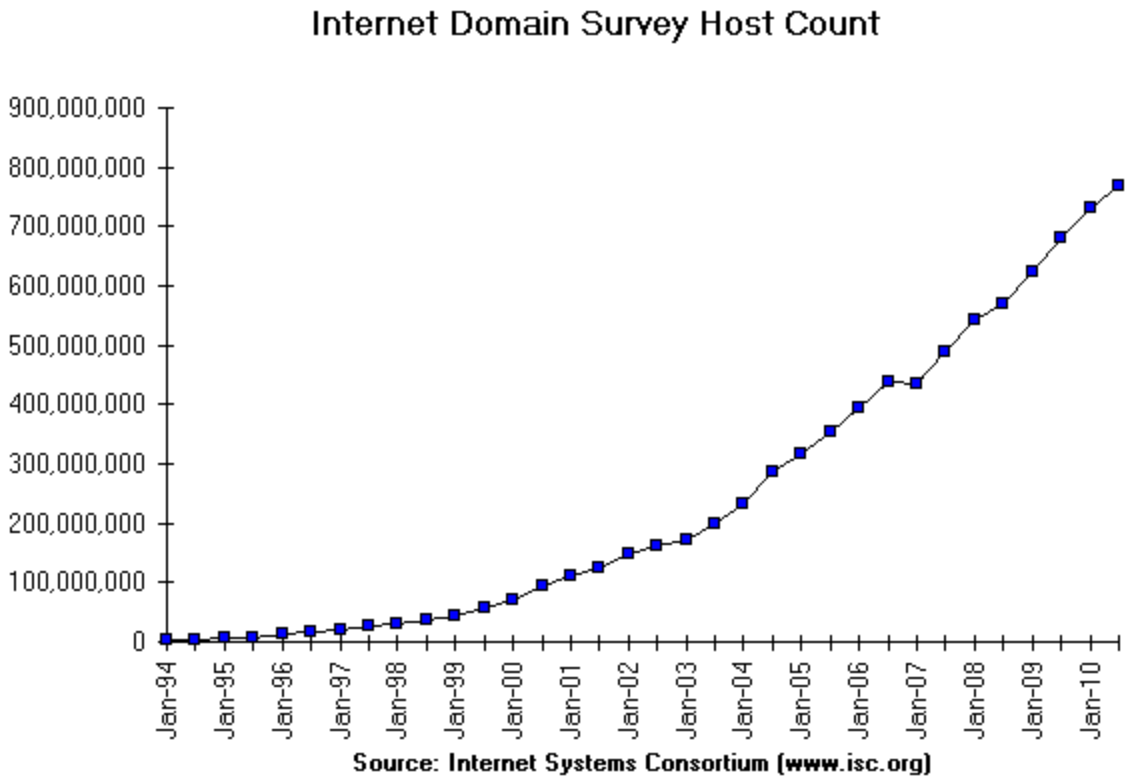
The Internet: User statistics



Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 6,767,805,208 and 1,668,870,408 estimated Internet users for June 30, 2009.
Copyright © 2009, Miniwatts Marketing Group

www.internetworldstats.com

The Internet: Number of Hosts



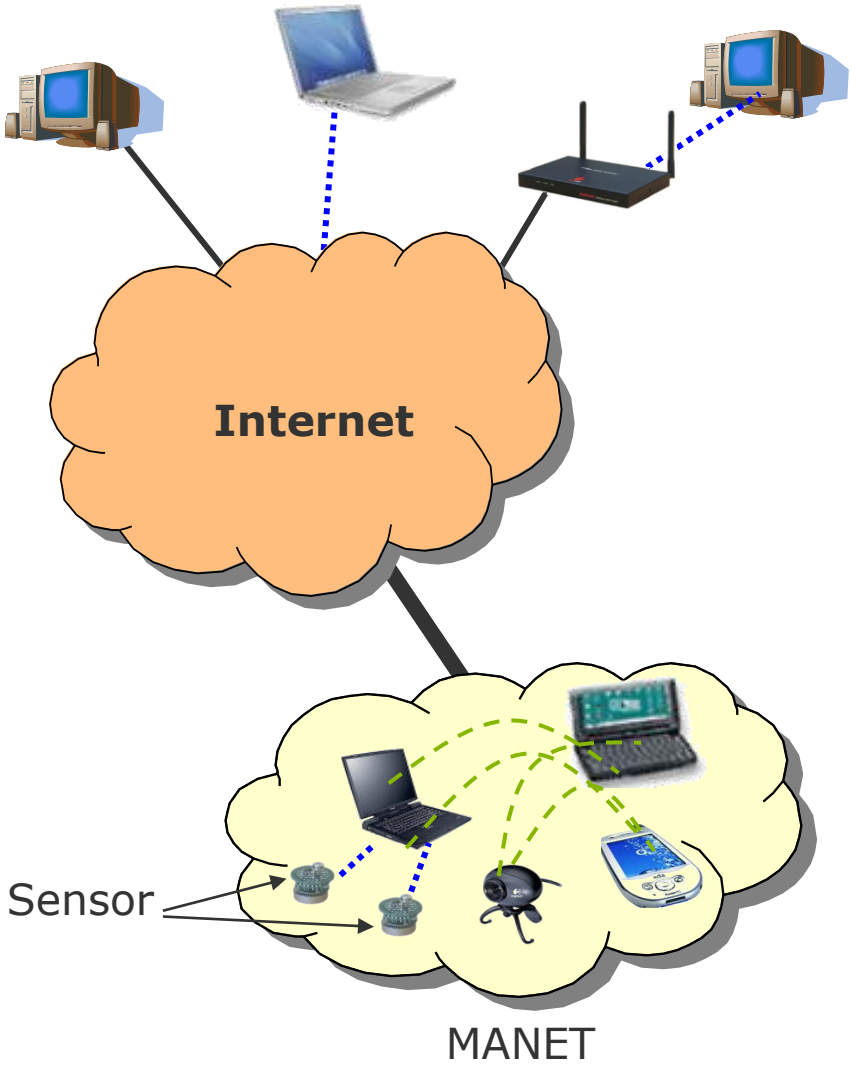
Source: Internet Systems Consortium (www.isc.org)

Why do we teach this course?

Relationship between research and teaching

Research topics

- Network Architectures and Communication Protocols
  - Wired networks
    - Local Area Network (LAN)
    - Wide Area Network (WAN)
    - Internet
  - Wireless networks
    - Wireless Local Area Network (WLAN)
    - Mobile Ad-hoc Network (MANET), Wireless Mesh Network (WMN), Wireless Sensor Network (WSN)
    - GSM, 3GPP
  - Protocols
    - HTTP, TCP/UDP, IP
    - IEEE 802.11a,b,g
  - Internet of Things
    - Anytime, Anywhere, Anything



Research topics

DES-Mesh

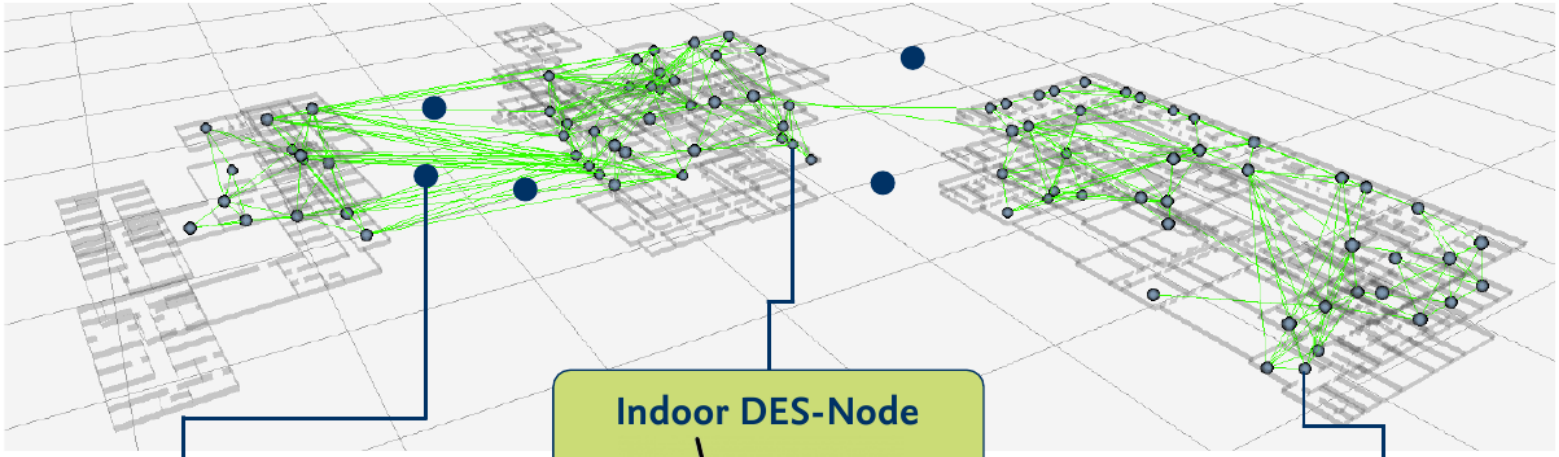
The wireless mesh network DES-Mesh is made up of custom stationary mesh routers, each with at least 3 IEEE 802.11a/b/g radios per node. This setup allows a wide variety of studies of different layers of the network protocol stack.

DES-Testbed

The DES-Testbed is a hybrid wireless multi-hop network. Currently, it consists of a mesh network and a wireless sensor network, each with 100 nodes. The research focus is on real world studies and comparisons of the results to simulations.

DES-WSN

The wireless sensor network DES-WSN consists of 100 custom MSB-A2 sensor nodes. These sensor nodes are equipped with temperature, humidity, pressure, and motion sensors allowing a basic monitoring of environment parameters in the DES-Testbed.



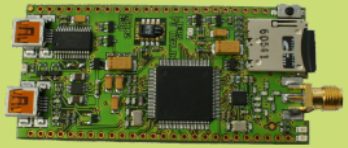
Outdoor DES-Node

- 10 outdoor DES-Nodes
- Improve connectivity between buildings
- Each with 3 IEEE 802.11a/b/g radios

Indoor DES-Node

- 100 indoor DES-Nodes in 3 buildings
- Each with 3 IEEE 802.11a/b/g radios
- Connected to central server

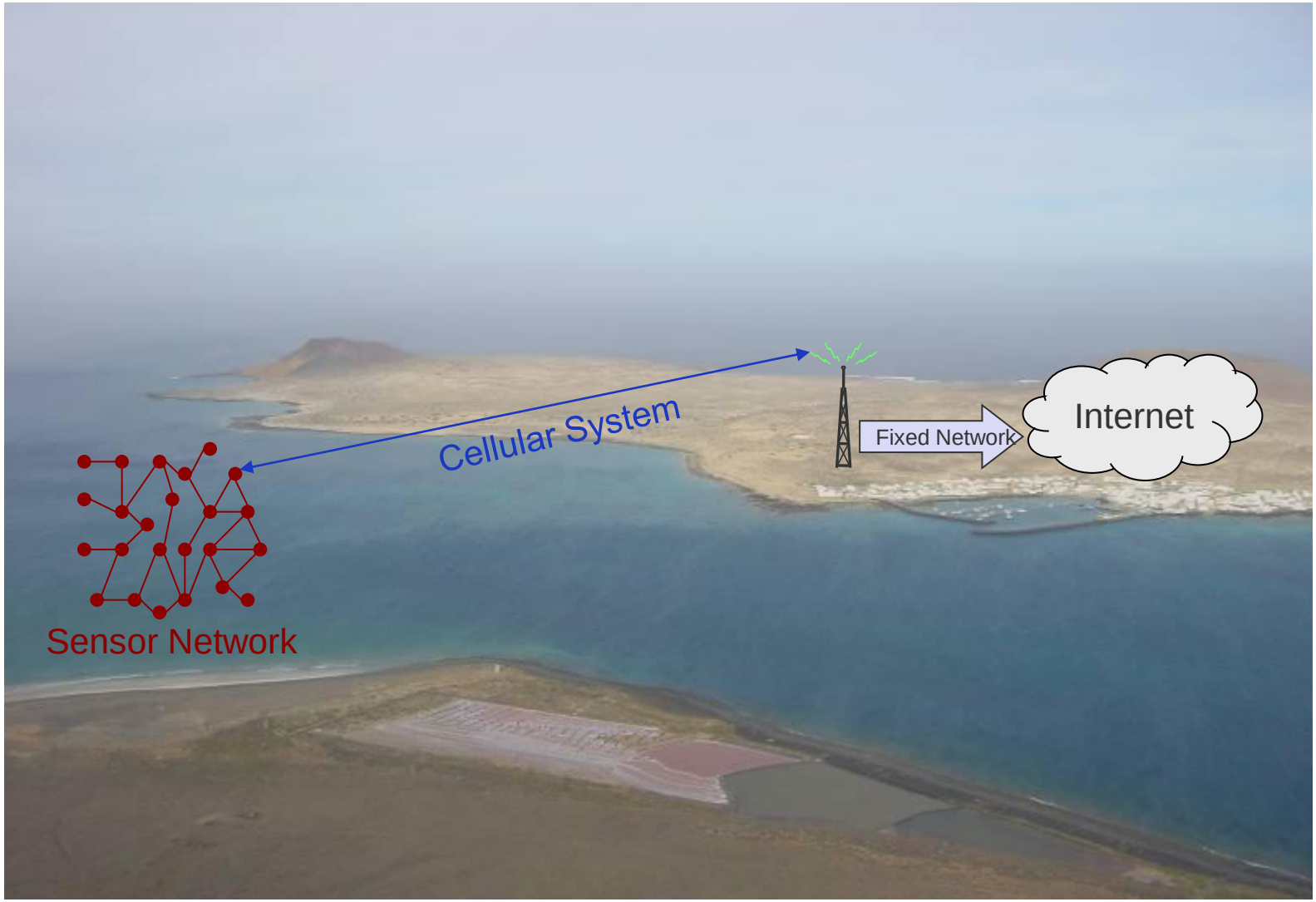
MSB-A2 Sensor Node



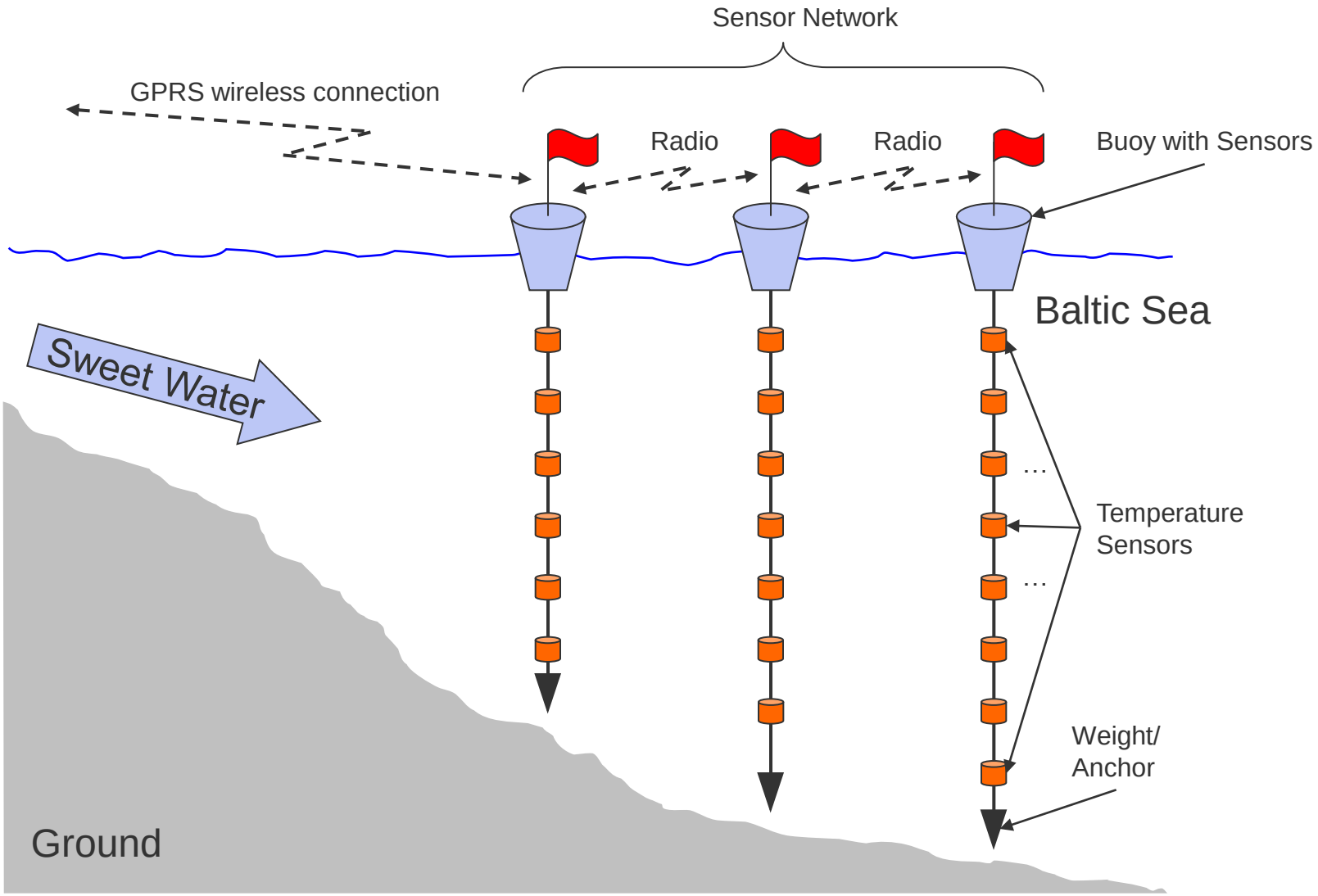
- Based on ARM7 microprocessor
- Chipcon CC1100 868MHz transceiver
- Variety of sensors on board

www.des-testbed.net

Research topics

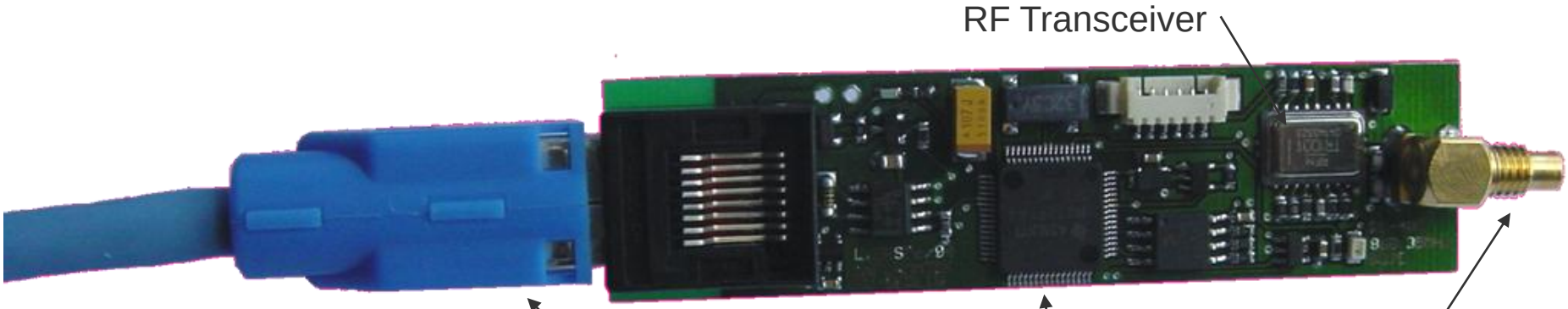


Research topics

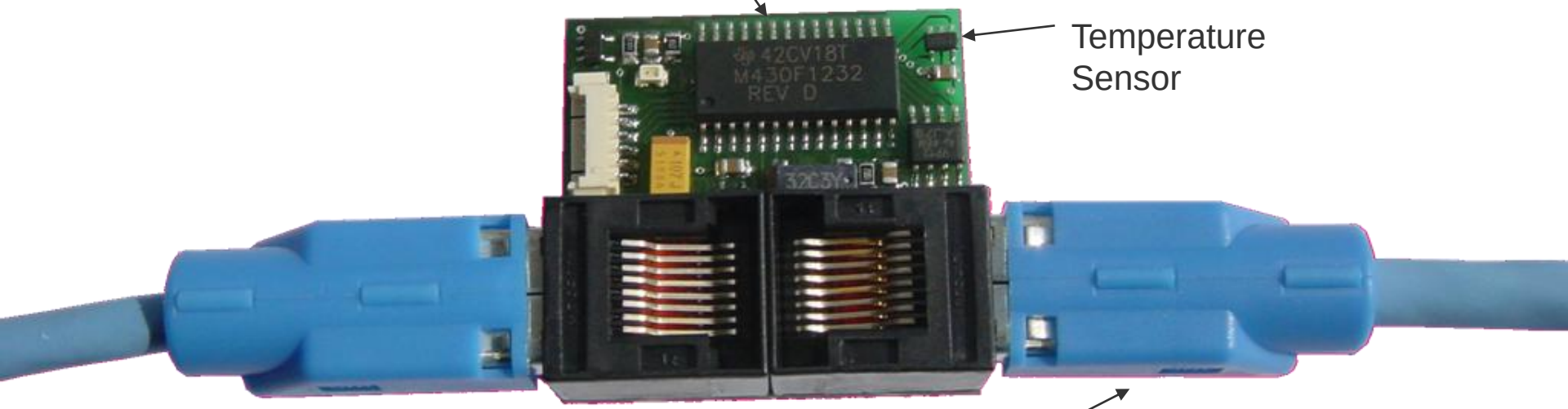


Research topics

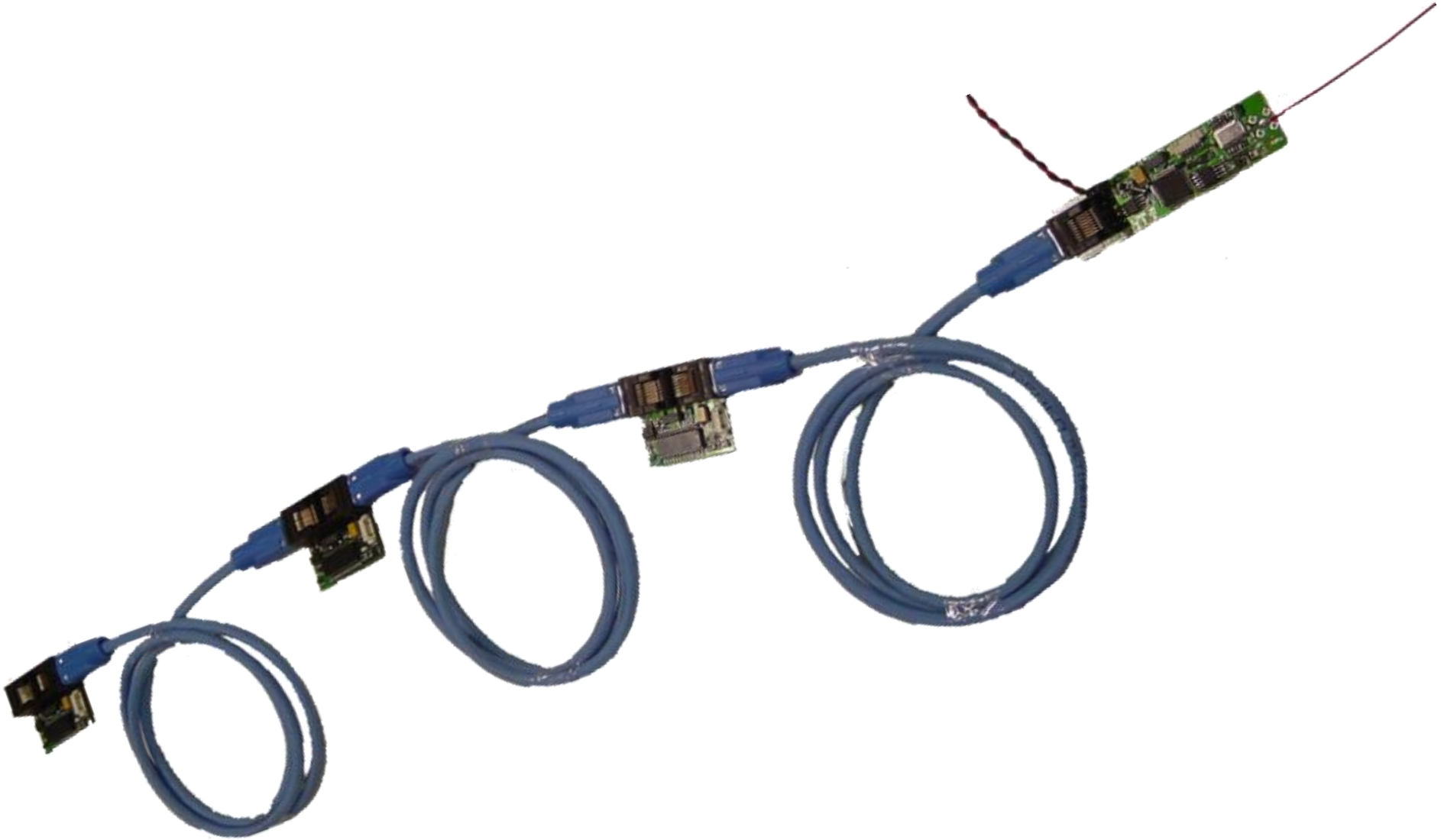
- Sensor node with processor, RF, and sensor



Research topics



Research topics



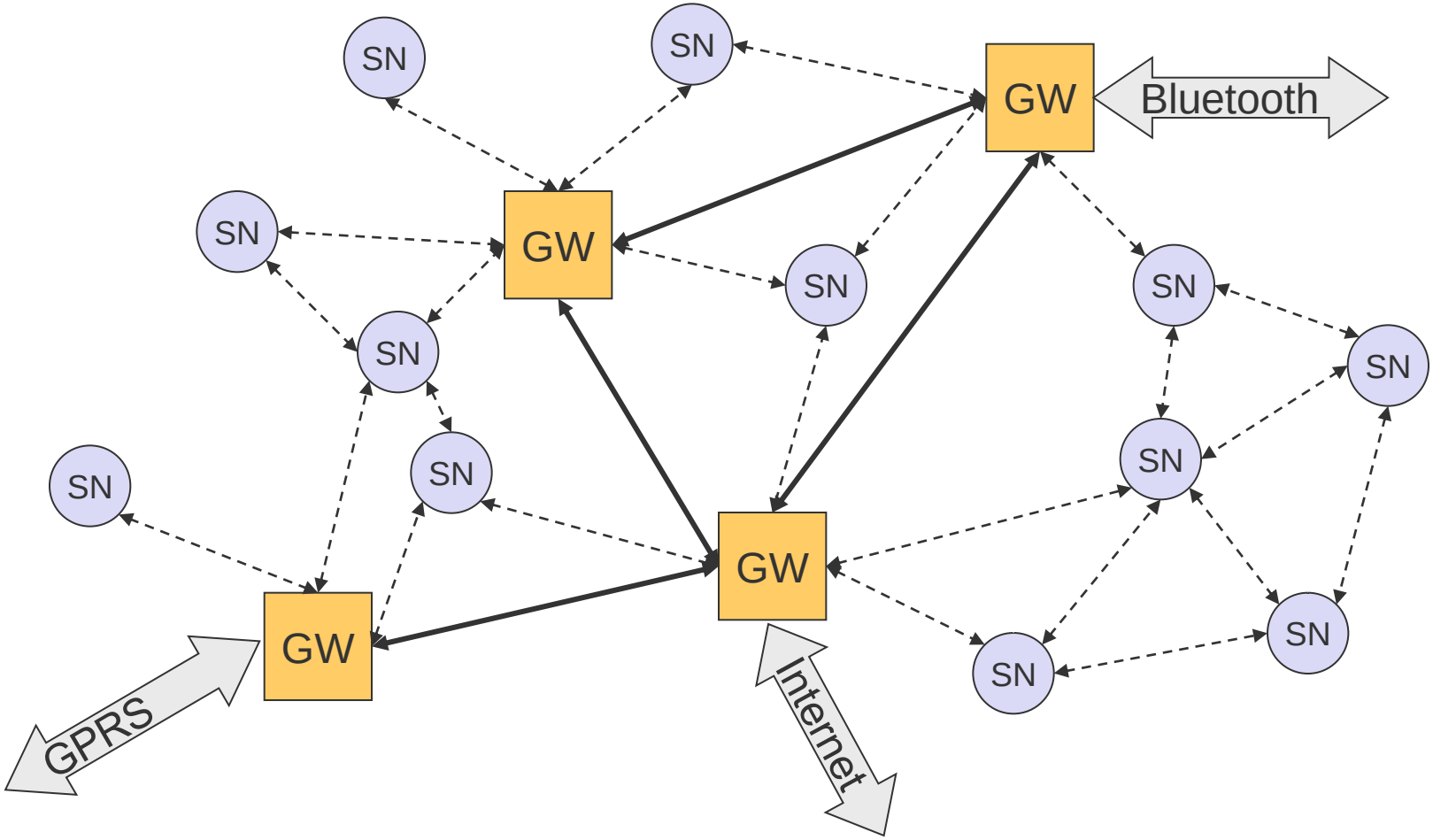
Making WSNs seawater-proof

Chain of Sensors

Protection of nodes
in oil (incl. antenna)

Research topics

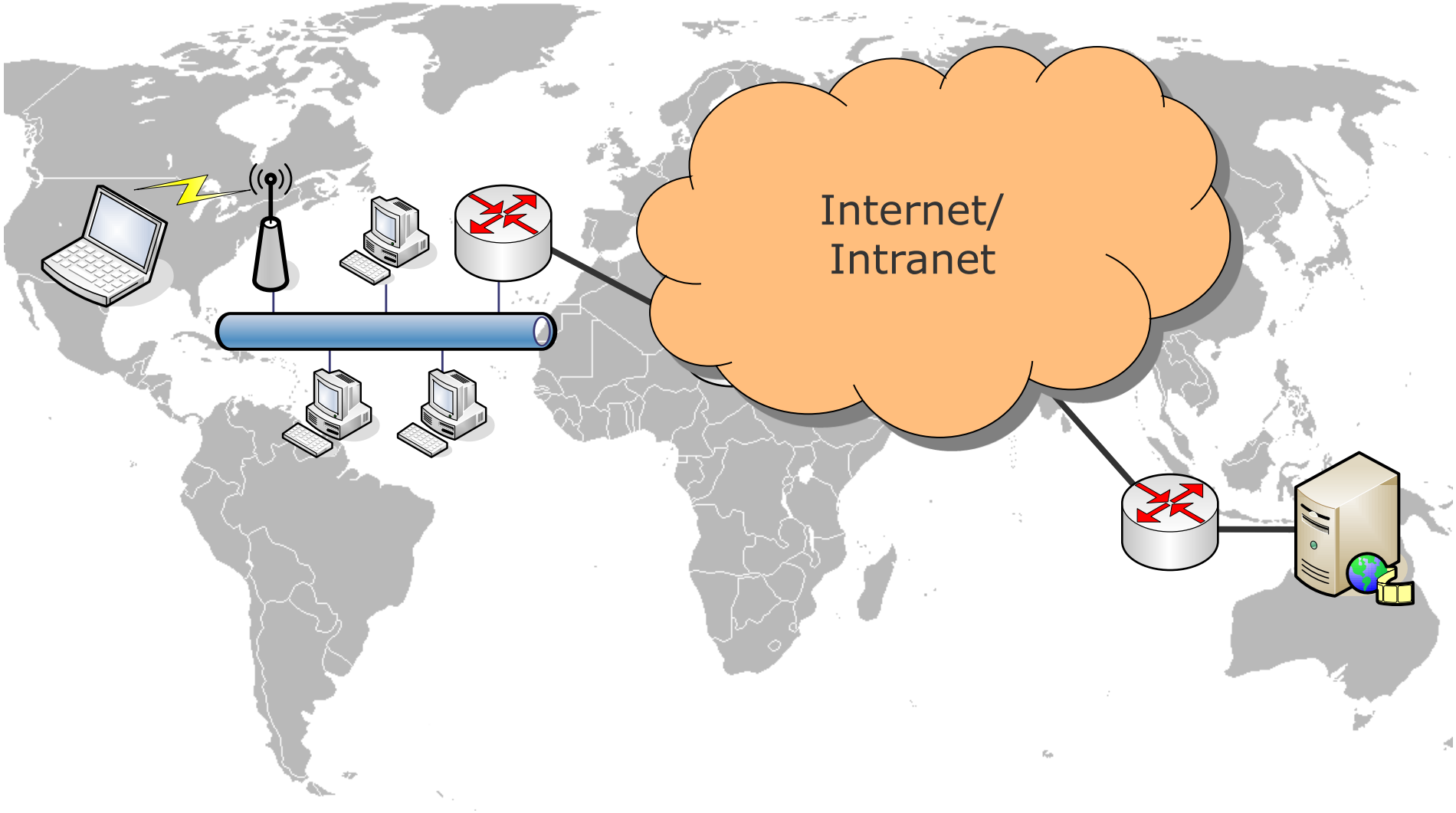
- Interoperation between sensor networks and other networks



Example for the course

Multimedia communication over the Internet

Example: Video Streaming over the Internet



Trends

- Computers do not stay alone anymore
- Communication metaphor evolves from human-to-human communication to everything-to-everything communication
  - Penetration of computer and networking into all aspects of life
  - Internet of the Things
- Existing networks are going to be integrated
  - Telephone networks, mobile networks, computer networks, etc.
- The computer and 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