Telematics
Chapter 1

Motivation

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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

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

[Diagram showing the connection between a man, telephone set, and telephone network with acoustic interface and communication interface.]
In the Past: Too Much Redundancy
Convergence Towards a Single Network

Mobile Networks
- GSM
- GPRS
- UMTS
- LTE

Internet
- FTP
- WWW
- Web2
- P2P
- FTP

Cable Networks
- Broadcast
- VoD
- iTV

Home Networks
- Content Sharing

Enterprise Networks
- PSTN
- ISDN
- DSL
- UMS

One Network
(Everything over IP)

Communities
- WiFi
- WiMax
- 3G/4G
- VoIP
- IPTV
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 wired and sparse to wireless and ubiquitous
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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.

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

- Goals:

<table>
<thead>
<tr>
<th>VoIP/Video</th>
<th>Email</th>
<th>Web surf</th>
<th>IM / social</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="VoIP/Video" /></td>
<td><img src="image2.png" alt="Email" /></td>
<td><img src="image3.png" alt="Web surf" /></td>
<td><img src="image4.png" alt="IM / social" /></td>
</tr>
</tbody>
</table>
Global Mobile Data Traffic Forecast by Region

Source: Cisco and MIT Technology Review
Wireless Performance Gains

1900

• About 10 bit/s/100,000 km²
• About 1000 watt

2013

Smartphone

• 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 384 kbit/s, WLAN 780 kbit/s
- GSM 57 kbit/s, Bluetooth 500 kbit/s
- UMTS, GSM 115 kbit/s
- LAN 100 Mbit/s, WLAN 50 Mbit/s
- UMTS, GSM 384 kbit/s
- GSM 300 kbit/s, WLAN 11 Mbit/s
- GSM 300 kbit/s, WLAN 11 Mbit/s
Worldwide Mobile Devices Sales

WORLDWIDE MOBILE DEVICE SALES
By units sold to end users

2009 1.21 bln
2010 1.60 bln
2011 1.78 bln
2012 1.75 bln

Nokia
440.9 mln
2009
281.1
2010
315.1
2011
333.9
2012

Samsung
235.8
114.2
2009
89.3
2010
315.1
2011
333.9
2012

LG
122.0
49.7
2009
56.9
2010
86.4
2011
67.3
2012

Motorola
58.5
46.6
2009
51.5
2010
43.3
2011
47.3
2012

Sony Ericsson
55.0
41.8
2009
38.6
2010
40.7
2011
34.2
2012

RIM/Blackberry
34.3
2009
29.7
2010
40.3
2011
33.9
2012

Apple
24.9
2009
24.7
2010
TCL
34.0
2011
32.1
2012

ZTE
16.0
2009
13.5
2010
23.8
2011
23.8
2012

Huawei
10.8
2009
10.8
2010
23.8
2011
23.8
2012

Others
199.6
2009
485.5
2010
595.9
2011
587.4
2012

Source: Gartner
Note: Research In Motion (RIM) rebranded itself as BlackBerry. Sony acquired Ericsson’s share in mobile phone venture in Feb. 2012
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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
Environment Automation: Example using RFID

WE WANT TO IMPLANT THIS RFID TAG IN YOU.

THAT VIOLATES MY RIGHTS!

WE WANT TO IMPLANT THIS RFID TAG IN YOU
AND IT'S ALSO A CELLPHONE,
DIGITAL CAMERA, AND
MP3 PLAYER.

← WRONG

COOL!

RIGHT →
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)
- …
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Economic Aspects: Business Sectors

- **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

Global IT Spending

Source: Gartner, Worldwide IT Spending Forecast, 2Q13 Update
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

<table>
<thead>
<tr>
<th>ACCESS LINKS</th>
<th>ACCESS POINTS</th>
<th>SWITCH &amp; ROUTERS</th>
<th>TIER 2 ISP (REGIONAL)</th>
<th>TIER 1 ISP (GLOBAL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wireless Hosts</td>
<td>Cellular</td>
<td>Wifi</td>
<td>Ethernet</td>
<td>ISP A</td>
</tr>
<tr>
<td>Wired Hosts</td>
<td></td>
<td></td>
<td></td>
<td>ISP B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ISP C</td>
</tr>
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So What is the Internet? The Topology Aspect

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

- Wireless Hosts
- Wifi
- Cellular
- Ethernet
- Wired Hosts

Diagram showing different access links, access points, and network topology involving Tier 1 and Tier 2 ISPs.
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<tr>
<td>Cellular</td>
<td></td>
<td>Access points</td>
<td></td>
<td>ISP A</td>
</tr>
<tr>
<td>Wireless Hosts</td>
<td></td>
<td>Wired hosts</td>
<td></td>
<td>ISP B</td>
</tr>
<tr>
<td>Wifi</td>
<td></td>
<td>Ethernet</td>
<td></td>
<td>ISP C</td>
</tr>
<tr>
<td>Data Center</td>
<td></td>
<td></td>
<td>ISP 1</td>
<td>ISP 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ISP 3</td>
<td>ISP 4</td>
</tr>
<tr>
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</tr>
</tbody>
</table>
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
The Internet: Number of Hosts

Source: Internet Systems Consortium (www.isc.org)
Topography: Location of Internet users

- Internet Penetration Rate by Region (source ITU, Jeff Ogden)
## The Internet: The History

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957</td>
<td>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.</td>
</tr>
</tbody>
</table>
| 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

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>15 nodes (23 hosts): UCLA, SRI, UCSB, U of Utah, BBN, MIT, RAND, SDC, Harvard, Lincoln Lab, Stanford, UIU(C), CWRU, CMU, NASA/Ames</td>
</tr>
</tbody>
</table>
| 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. |
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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>1988</td>
<td>IP-Link to the Internet from Germany over Eunet-IRB Dortmund and XLink (eXtended Lokales Informatik-Netz Karlsruhe)</td>
</tr>
<tr>
<td>1989</td>
<td>Number of hosts breaks 100,000.</td>
</tr>
<tr>
<td>1991</td>
<td>EBONE: European Backbone</td>
</tr>
</tbody>
</table>
| 1992 | - Internet Society is chartered ([www.isoc.org](http://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: Incredibly Fast Deployments

Number of US households with access (in Mill.)

1922
1950
1982
1994

Radio

Cable TV

TV

Internet/Online

(Source: Bertelsmann)
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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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