# CS 480: MOBILE NETWORKS

Lecture PowerPoints

# INTRODUCTION TO MOBILE COMPUTING, REGULATORY AND STANDARDS BODIES

# Topics Covered

- General Introduction
- Overview of Mobile Computing
- Possible Network Configurations
- Introductory Examples of Application Areas
- Mobile and Wireless Devices
- History of Wireless Communications
- Evolution of Standards and the Main Standards Bodies
- Problems Wireless
- Effects of device portability
- Wireless networks in comparison to fixed networks
- Related Tutorial/Workshop Activities

# Learning Outcomes

**The learning outcomes are the following:**

- To be aware of the standards bodies and competing standards
- Understanding the potential of mobile computing and possible application areas

# General Introduction (1)

- The rapid convergence of voice and data communications and increased consumer demand for devices supporting ubiquitous multimedia computing
  - is leading to a multitude of mobile devices supporting a wide range of functionality operating on top of internet technologies.
- Mobile technologies are becoming an integral part of building and deploying modern distributed computing systems
- There is a proliferation of technologies, architectures, protocols, standards and APIs for building distributed computer systems that include mobile devices and use mobile communications.

# General Introduction (2)

- In this context, as computer professionals you need to be aware of current and emerging technologies
  - and to be able to select appropriate technologies, tools and techniques for the design and development of mobile enabled systems.

# Overview of Mobile Computing (1)

Mobile computing can be defined as

- a generic term describing one's ability to use technology while moving, as opposed to portable computers, which are only practical for use while deployed in a stationary configuration.
- using a computing device while in transit.
- the provision of remote data communication support for sales people, field representatives, and customer service representatives while they are “on the road” and away from urban business offices or telework centers

# Overview of Mobile Computing (2)

- Such workers are always equipped with laptop or notebook computers and portable printers
- Many are outfitted with pagers, personal digital assistants (PDAs) and second or third-generation cellular telephony devices such as “smart phones”
- Mobile workers may connect to corporate networks from customer locations via dialup PSTN or cellular connections or through PCS (Personal Communication Services).
- Such workers may also use the data ports and Internet-access services that are increasingly available at hotels and motels to access the information resources at corporate offices.

# Overview of Mobile Computing (3)

- There are two different kinds of mobility:
  - *User mobility*: refers to a user who has access to the same or similar telecommunication services at different places.
    - i.e. the user can be mobile, and the services will follow him or her.
    - Examples for mechanisms supporting user mobility are simple call-forwarding solutions known from the telephone or computer desktops supporting roaming (i.e., the desktop looks the same no matter which computer a user uses to log into the network)
  - *Device portability*: the communication device moves (with or without a user).
    - Many mechanisms in the network and inside the device have to make sure that communication is still possible while the device is moving.
    - A typical example for systems supporting device portability is the mobile phone system. Here the system itself hands the device from one radio transmitter (base station) to the next if the signal becomes too weak.

# Possible Network Configurations (1)

- A communication device can thus exhibit one of the following characteristics:
  - *Fixed and wired*: This configuration describes the typical desktop computer in an office
    - Neither weight nor power consumption of the device allow for mobile usage.
    - The devices use fixed networks for performance reasons.
  - *Mobile and wired*: Many of today's laptops fall into this category
    - Users carry the laptop from one hotel to the next
    - Reconnecting to the company's network via a telephone network and a modem
  - *Fixed and wireless*: This mode is used for installing networks in certain places
    - In historical buildings to avoid damage by installing wires or
    - At trade shows to ensure a fast network setup.
    - bridging the last mile to customer by new operator that has no wired infrastructure and doesn't want to lease lines from a competitor

# Possible Network Configurations (2)

- Mobile and wireless: This is the most interesting case:
  - No cable restricts the user, who can roam between different wireless networks.
  - Today's most successful example for this category is GSM, with more than 800 million users.

- The evolution of cellular telephony networks and services will help to fuel business use of mobile computing technologies in the years to come.
- Business use of mobile computing is also facilitated by PBX (Private Branch Exchange) interfaces for mobile/wireless phones.
  - A PBX is a switching machine with hundreds or possibly thousands of lines, all of which can be reached by dialing one number.

# Ubiquitous Computing

- The word "ubiquitous" can be defined as "existing or being everywhere at the same time," "constantly encountered," and "widespread.“
- When applying this concept to technology, the term ubiquitous implies that technology is everywhere and we use it all the time.
- Because of the pervasiveness of these technologies, we tend to use them without thinking about the tool. Instead, we focus on the task at hand, making the technology effectively invisible to the user.
- Ubiquitous technology is often wireless, mobile, and networked, making its users more connected to the world around them and the people in it.

# Introductory Examples of Application Areas

- Although many applications can benefit from wireless networks and mobile communications,
  - particular application environments seem to be predestined for their use
- Some of the examples are:
  - Vehicles
  - Emergencies
  - Business
  - Replacement of wired networks
  - Infotainment and more
  - Location dependent services

# Vehicles

- Transmission of news, road condition, weather, music via DAB/DVB-T
- Personal communication using GSM/UMTS
- Position via GPS
- Local ad-hoc network with vehicles close-by to prevent accidents, guidance system, redundancy
- Vehicle data (e.g., from buses, high-speed trains) can be transmitted in advance for maintenance
- Figure 1 shows a typical scenario for mobile communications with many wireless devices.

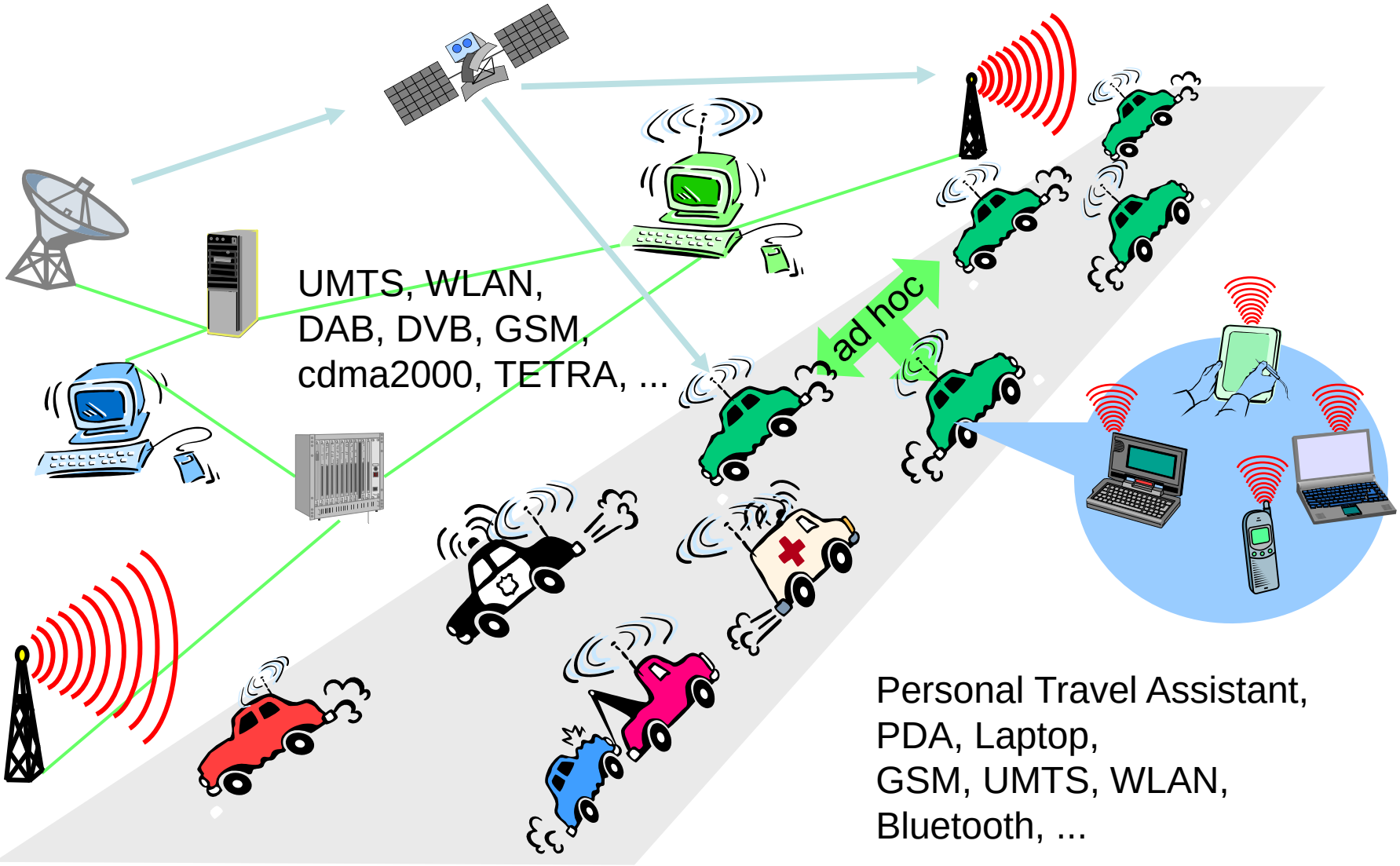



**Figure 1: A typical application of mobile communications: road traffic.**

# Emergencies

- Early transmission of patient data to the hospital, current status, first diagnosis
- Replacement of a fixed infrastructure in case of earthquakes, hurricanes, fire etc.
- Crisis, war, ...

# Business (1)

- Traveling salesmen need instant access to the company's database
  - To ensure that files on their laptop reflect current situation
  - To enable a company to keep track of all activities of travelling employees
  - To keep databases consistent
- Laptop can be turned into true mobile office
  - But efficient and powerful synchronization mechanisms are needed to ensure data consistency
- Figure 2 illustrates what may happen when employees try to communicate off base.
  - At home, a laptop connects via a WLAN or LAN and DSL to the Internet

# Business (2)

- Leaving home requires a handover to another technology, e.g. to an enhanced version of GSM as soon as WLAN coverage ends.
- Data rates drop while cruising at high speeds due to interference.
- Gas stations may offer WLAN hot spots as well as gas.
- Trains already offer support for wireless connectivity
- Several more handovers to different technologies might be necessary before reaching the office.

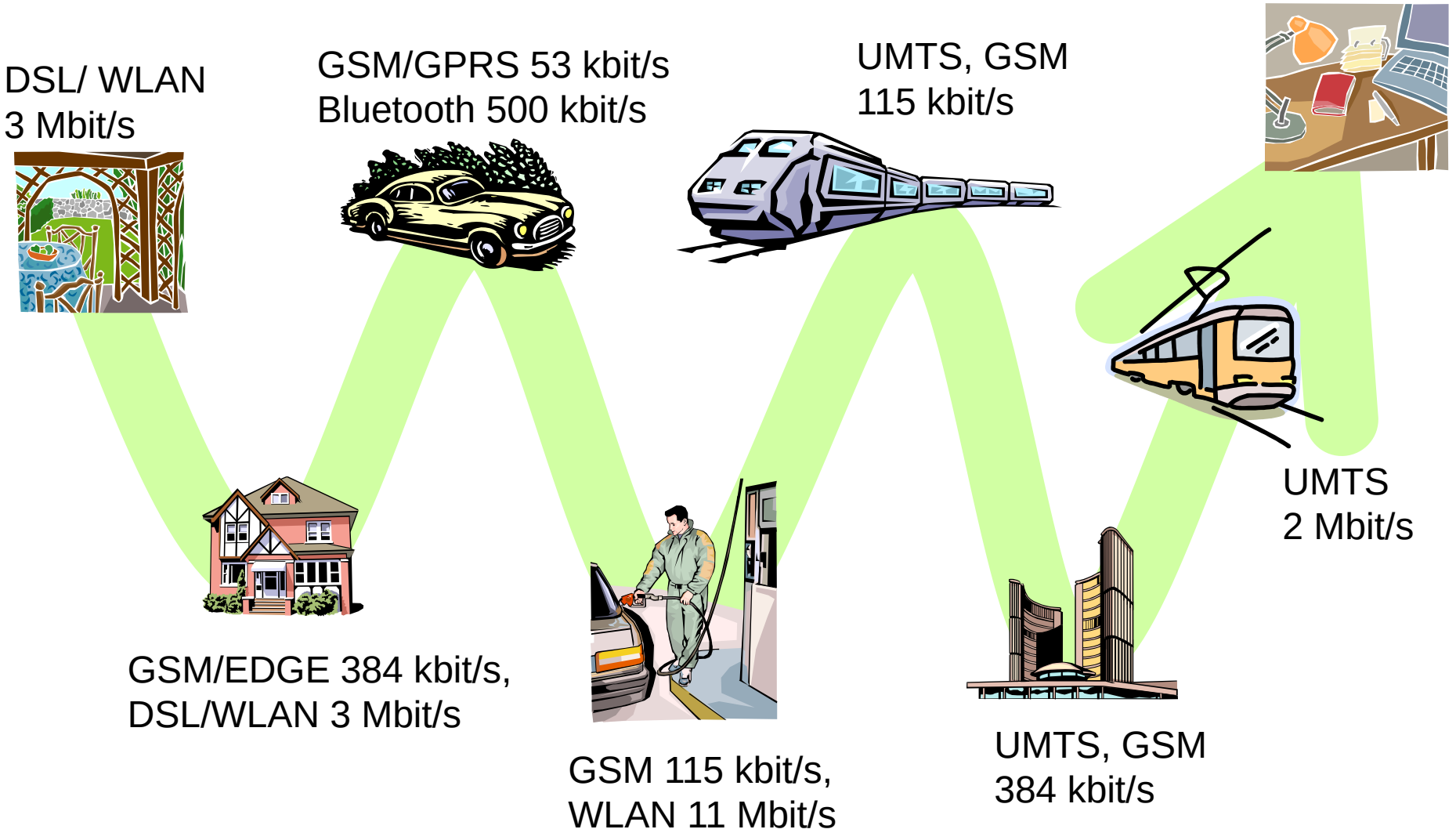



**Figure 2: Mobile and wireless services – always best connected.**

# Replacement of wired networks

- Wireless networks can be used to replace wired networks
  - E.g., Remote sensors, for tradeshows, or in historic buildings
- It is impossible to wire remote sensors for weather forecasts, earthquake detections or to provide environmental information
  - Wireless connections, e.g., via satellite help in this situation
- Trade shows need a highly dynamic infrastructure, but cabling takes long time and proves to be inflexible
  - Many computer fairs use WLANs as replacement for cabling.
- Wireless networks can be used in historical buildings where excess cabling may destroy valuable walls or floors
  - Wireless access points in a corner of a room can be a solution.

# Infotainment and more

- Outdoor Internet access
- Intelligent travel guide with up-to-date location dependent information
- Ad-hoc networks for multi user games

# Location dependent services

- Location aware services
  - what services, e.g., printer, fax, phone, server etc. exist in the local environment
- Follow-on services
  - automatic call-forwarding, transmission of the actual workspace to the current location
- Information services
  - “push”: e.g., current special offers in the supermarket
  - “pull”: e.g., where is the Black Forrest Cheese Cake?
- Support services
  - caches, intermediate results, state information etc. “follow” the mobile device through the fixed network
- Privacy
  - who should gain knowledge about the location

# Mobile and Wireless Devices (1)

Some examples of mobile and wireless devices classified by increasing performance

i.e., based on increase on CPU, memory, display, input devices are briefly outlined below:

- Sensor
  - A simple wireless device is represented by a sensor transmitting state information.
  - An example is a switch sensing the office door.
    - If closed, switch transmits this to mobile phone inside office which will not accept incoming calls
- Embedded controllers
  - Many appliances of already contain a simple or sometimes more complex controller.
  - keyboards, mice, headsets, washing machines, hair dryers, TV sets are examples that contain controllers.
  - An example is where a hair dryer switches off as soon as phone starts ringing, a nice application

# Mobile and Wireless Devices (2)

- Pager
  - a pager is a simple receiver that can only display short text messages, has a tiny display, cannot send messages.
  - Pagers can be integrated into watches
  - Mobile phones have made pagers virtually redundant, short messages replaced paging.
  - The situation is different for emergency services where it is necessary to page a large number of users reliably within short time.
- Mobile phones
  - Traditionally, only had a black and white text display and could only send/receive voice or short messages
  - Today mobile phones migrate more toward PDAs
  - Mobile phones with a color display, touch screen and internet browser are easily available.

# Mobile and Wireless Devices (3)

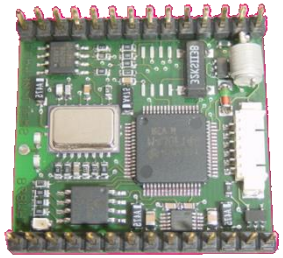
- Personal digital assistant
  - PDAs typically accompany a user and offer simple versions of office software (calendar, note-pad, mail)
  - The typical input device is a pen, with built-in character recognition translating hand-writing into characters.
  - Web browsers and many other software packages are available with these devices.
- Pocket computer
  - Pocket computers offer tiny keyboards, color displays, and simple versions of programs found on desktop computers (text processing, spreadsheets etc)
- Notebook/laptop
  - Laptops offer more or less the same performance as standard desktop computers, they use the same software
  - If operated via a sensitive display (touch sensitive), they are also known as notepads or tablet PCs.

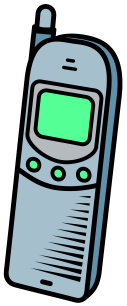
Pager
- receive only
- tiny displays
- simple text messages

PDA
- graphical displays
- character recognition
- simplified WWW

Laptop/Notebook
- fully functional
- standard applications

Sensors, embedded controllers





Mobile phones
- voice, data
- simple graphical displays

Smartphone
- tiny keyboard
- simple versions of standard applications

**performance**

No clear separation between device types possible
(e.g. smart phones, embedded PCs, …)

**Figure 3: Mobile and wireless devices**

# History of Wireless Communication (1)

The history of wireless communication below is intended to help one appreciate today's wireless systems and developments

- 1794: invention of optical telegraph by Claude Chappe
  - long-distance wireless communication as well as optical telegraph was possible with technical means
- 1831: Michael Faraday  demonstrated electromagnetic induction
- James C Maxwell (1831 -79): laid theoretical foundations for electromagnetic fields (1864)
- 1843: Wired communication started with the first commercial telegraph line between Washington and Baltimore

# History of Wireless Communication (2)

- 1876: Alexander Graham Bell's invention and marketing of the telephone
- 1881: In Berlin, a public telephone service was available
- 1886: Heinrich Hertz first demonstrated the wave character of electrical transmission through space
  - Proving Maxwell's equations
- 1856-1943: Nikola Tesla increased the distance of electromagnetic transmission
- 1895: Guglielmo Marconi gave a first demonstration of wireless telegraphy using long wave transmission with very high transmission power (>200kw))
  - most closely connected with success of wireless communication

# History of Wireless Communication (3)

- 1901: First transatlantic transmission
- 1907: Commercial transatlantic connections were set up
  - Huge base stations using up to thirty 100m high antennas were needed on both sides of the Atlantic ocean
- 1915: Wireless voice transmission set up between New York and San Francisco
- 1920: First commercial radio station; sender and receiver still needed huge antennas and high transmission power
- 1920: Discovery of short waves by Marconi
  - Were capable of being reflected at the ionosphere, a technique still used today
  - It was then possible to send short radio waves around the world bouncing at the ionosphere.
  - Smaller sender and receiver, possible due to the invention of the vacuum tube (1906, Lee DeForest and Robert von Lieben)

# History of Wireless Communication (4)

- 1926: First telephone in a train was available on the Berlin–Hamburg line
  - Wires parallel to the railroad track worked as antenna
- 1927: First car radio was commercially available
- 1928: Trials for television broadcasting
  - John L. Baird transmitted TV across the Atlantic and demonstrated colour TV
- First tele-teaching from the CBS station
  - Up until then all wireless communication used amplitude modulation, which offered relatively poor quality due to interference.
- 1933: Invention of frequency modulation by Edwin H. Armstrong.
  - Both schemes are still used for today's radio broadcasting with frequency modulation resulting in a much better quality.

# History of Wireless Communication (5)

- 1958: First analog network (A-Netz) using a carrier frequency of 160 MHz in Germany
  - Connection set-up was only possible from mobile station, no handover, i.e., changing of base station, was possible
  - had 80% coverage, 1971 11000 customers
- 1972: B-Netz in Germany
  - Analogue, 160MHz, connection setup from the fixed network too (but location of the mobile station has to be known)
  - available also in Austria, Netherlands and Luxembourg, 1979 13000 customers in Germany
- 1979: The northern European countries of Denmark, Finland, Norway, and Sweden (Scandinavian countries) agreed upon the Nordic Mobile Telephone (NMT) system
  - Used 450 MHz carrier and still used for mobile communication in some very remote places.

# History of Wireless Communication (6)

- By the early 1980s Europe had more than a handful of different, completely incompatible analog mobile phone standards.
- 1982: European countries decided to develop a pan-European mobile phone standard (GSM specification)
  - In accordance with the general idea of the European Union
  - The new system aimed to use a new spectrum at 900 MHz, allow roaming throughout Europe, be fully digital, and offer voice and data service
- 1983: The US system Advanced Mobile Phone System (AMPS); an analog mobile phone system working at 850 MHz started
- 1984: Telephones at home went wireless with the standard Cordless Telephone (CT1)

# History of Wireless Communication (7)

- 1986: Nordic Mobile Telephone (NMT) at 900 MHz followed
- 1990s: Marked the beginning of fully digital systems
- 1991: European Telecommunications Standards Institute (ETSI) adopted the standard digital European cordless telephone (DECT) for digital cordless telephony
  - DECT works at a spectrum of 1800-1900 MHz with a range of 100-500m.
  - DECT has been renamed Digital Enhanced Cordless Telecommunications for marketing reasons and to reflect its capabilities to transport multimedia data streams.
  - GSM was standardised and its first version was now called Global System for Mobile Communication working at 900 MHz and using 124 full-duplex channels

# History of Wireless Communication (8)

  - GSM offers full international roaming, automatic location services, authentication, encryption on the wireless link, efficient interoperation with ISDN systems, relatively high audio quality, a short message service with up to 160 alphanumeric characters, fax group 3, and data services at 9.6 kbits/s have been integrated.
- US used the analog AMPS while Europe used the digital GSM at 900 MHz
- In US no new spectrum was allocated for a new system, in Europe a new frequency band at 1800 MHz was chosen

# History of Wireless Communication (9)

- 1996: Standardization of HiperLAN (High Performance Radio Local Area Network)
  - ETSI (European Telecommunications Standards Institute), standardization of type 1: 5.15 - 5.30GHz, 23.5Mbit/s
  - Recommendations for type 2 and 3 (both 5GHz) and 4 (17GHz) as wireless ATM-networks (up to 155Mbit/s)
- 1997: Wireless LAN – IEEE 802.11
  - Winner of local area networks
  - IEEE standard, 2.4GHz and infrared, 2Mbit/s
  - Already many (proprietary) products available in the beginning
- 1998: Specification of GSM successors
  - UMTS (Universal Mobile Telecommunication System) as European proposals for IMT (International Mobile Telecommunications)-2000
  - Iridium: 66 satellites (+6 spare), 1.6GHz to a mobile satellite phone

# History of Wireless Communication (10)

- 1999 - Standardization of additional wireless LANs
  - IEEE standard 802.11b, 2.4-2.5GHz, 11Mbit/s
  - Bluetooth (a short range technology to set up wireless personal area networks) for piconets, 2.4Ghz, <1Mbit/s
  - Decision about IMT-2000
  - Several “members” of a “family”: UMTS, cdma2000…
  - Start of WAP (Wireless Application Protocol) and i-mode in Japan
  - Access to many (Internet) services via the mobile phone
- 2000 - GSM with higher data rates and packet-oriented transmission
  - HSCSD (High Speed Circuit Switched Data) offers up to 57,6kbit/s
  - First GPRS (General Packet Radio Service) trials with up to 50 kbit/s (packet oriented!)

# History of Wireless Communication (11)

- 2001 - Start of 3G systems
  - Cdma(Code Division Multiple Access)2000 in Korea, UMTS in Europe, Foma (almost UMTS) in Japan
- Since 2002 – Standardization of high-capacity wireless networks
  - IEEE 802.16 as WMAN – Wireless Metropolitan Area Networks,
  - IEEE 802.20 as WWAN –Wireless Wide Area Networks,
  - IEEE 802.22 as WRAN – Wireless Regional Area Networks

# Effects

- In US different companies developed different new, more bandwidth-efficient technologies to operate side-by-side with AMPS in the same frequency band
- This resulted in three incompatible systems namely:
  - The analog narrowband Advanced Mobile Phone System [AMPS] (IS-88, (TIA, 1993a))
  - Two digital systems:
    - Time Division Multiple Access [TDMA] (Interim Standard [IS]-136, (TIA, 1996))
    - Code Division Multiple Access [CDMA] (IS-95, (TIA,1993b))
- These are some of the problems caused by lack of industry wide standards that hold the technologies back from delivering ubiquitous access to data.
- GSM is one of the few examples where the approach via standardization worked.
  - For this reason, while Europe has one common standard, and roaming is possible, the US still struggles with many incompatible systems

# Evolution of Standards and the Main Standards Bodies (1)

- Many proprietary wireless local area network systems already existed when European Telecommunications Standards Institute (ETSI) standardized the High Performance Radio Local Area Network (HIPERLAN) in 1996
  - This was a family of standards and recommendations.
- HIPERLAN type 1 should operate at 5.2 GHz and should offer data rates of up to 23.5 Mbit/s with type 4 going up to 155 Mbits/s at 17 GHz.
- The IEEE standard 802.11 was the most popular for local area networks
  - It works at the licence-free Industrial, Science, Medical (ISM) band at 2.4 GHz and infrared offering 2 Mbit/s

# Evolution of Standards and the Main Standards Bodies (2)

- Although HIPERLAN has better performance figures,
  - no products were available while many companies soon offered 802.11 compliant equipment
- The year 1998 marked the commencement of mobile communication using satellites with the Iridium system.
  - Up to this time, satellites basically worked as a broadcast distribution medium or could only be used with big and heavy equipment
  - Iridium marked the beginning of small and truly portable mobile satellite telephones including data service.
  - Iridium consists of 66 satellites in low earth orbit and uses the 1.6 GHz band for communication with the mobile phone.

# Evolution of Standards and the Main Standards Bodies (3)

- In 1998, the Europeans agreed on the Universal Mobile Telecommunications System (UMTS) as the European proposal for the International Telecommunication Union (ITU) IMT-2000 (International Mobile Telecommunications)
  - In initial stages, UMTS integrates GSM network technology with more bandwidth-efficient Code Division Multiple Access (CDMA) solutions.
- The year 1999 saw several more powerful WLAN standards.
  - IEEE published 802.11b offering 11 Mbit/s at 2.4 GHz.
- The ITU dropped the plan of a single worldwide standard for third generation mobile phone systems and decided on the IMT-2000 family concept
  - that includes such technologies as UMTS, cdma2000, DECT etc.

# Evolution of Standards and the Main Standards Bodies (4)

- The Wireless Application Protocol (WAP) started at the same time as i-mode in Japan.
- While WAP did not succeed in the beginning, i-mode soon became a tremendous success.
- The year 2000 came with higher data rates and packet-oriented transmission for GSM (HSCSD,GPRS).
- Third generation of mobile communication started in 2001 in Japan with the FOMA service, in Europe with several field trials, and in, e.g., Korea with cdma2000
- IEEE released a new WLAN standard, 802.11a operating at 5 GHz and offering gross data rates of 54 Mbit/s.
  - This standard uses the same physical layer as HiperLAN2 does, the only remaining member of the HIPERLAN family.

# Evolution of Standards and the Main Standards Bodies (5)

- In 2002 new WLAN developments followed
  - Examples are 802.11g offering up to 54 Mbit/s at 2.4 GHz and many new Bluetooth applications (headsets, remote controls, wireless mice, wireless keyboards etc)

# Mobile computing regulatory and standards bodies

- Federal Communications Commission (FCC)
- Office of Communications (Ofcom)
- International Telecommunication Union Telecommunication sector (ITU-T)
- Institute of Electrical and Electronics Engineers (IEEE)

# Federal Communications Commission (FCC) (1)

- The Federal Communications Commission regulates interstate and international communications
  - by radio, television, wire, satellite and cable in all 50 states, the District of Columbia and U.S. territories.
- It was established by the Communications Act of 1934
  - and operates as an independent U.S. government agency overseen by Congress.
- The commission is committed to being a responsive, efficient and effective agency
  - capable of facing the technological and economic opportunities of the new millennium. In its work,
- The agency seeks to capitalize on its competencies in:
  - Promoting competition, innovation, and investment in broadband services and facilities;

# Federal Communications Commission (FCC) (2)

- Supporting the nation's economy by ensuring an appropriate competitive framework for the unfolding of the communications revolution;
- Encouraging the highest and best use of spectrum domestically and internationally;
- Revising media regulations so that new technologies flourish alongside diversity and localism;
- Providing leadership in strengthening the defense of the nation's communications infrastructure.

- Leadership and Organization
  - The agency is directed by five commissioners who are appointed by the President of the United States and confirmed by the U.S. Senate.
  - The president also selects one of the commissioners to serve as chairman.

# Office of Communications (Ofcom)

- Independent communications regulator and competition authority for the UK communications industries.
- Ofcom regulates the TV and radio sectors, fixed line telecoms, mobiles, postal services,
  - plus the airwaves over which wireless devices operate.
- It makes sure that people in the UK get the best from their communications services and are protected from scams and sharp practices,
  - while ensuring that competition can thrive.
- Ofcom operates under the Communications Act 2003.
  - The Act says that Ofcom's general duties should be to further the interests of citizens and of consumers.

# International Telecommunication Union Telecommunication sector (ITU-T) (1)

- ITU's role as creator of the world's most universally-recognized infocommunications standards dates back as far as the organization itself.
  - Since its inception in 1865, the Union has been brokering industry consensus on the technologies and services that form the backbone of the world's largest, most interconnected man-made system.
- In 2007 alone, ITU's Telecommunication Standardization Sector (ITU-T) produced over 160 new and revised standards (ITU-T Recommendations),
  - covering everything from core network functionality and broadband to next-generation services like IPTV.
- ITU-T Recommendations are defining elements in information and communication technologies (ICTs) infrastructure.

# International Telecommunication Union Telecommunication sector (ITU-T) (2)

- Today's work extends well beyond the traditional areas of telephony to encompass a far wider range of information and communications technologies.
- Today priority work areas include
  - ensuring the needs of developing countries are taken into account in the development of global ICTs accessibility
  - adopting international standards to ensure seamless global communications and interoperability for next generation networks (NGN)
  - building confidence and security in the use of ICTs
  - emergency communications to develop early warning systems
  - to provide access to communications during and after disasters
  - the reduction of the impact of ICTs on climate change as well as create better understanding of how ICTs can mitigate its effects.
  - the reduction of the impact of ICTs on climate change as well as create better understanding of how ICTs can mitigate its effects.

# Institute of Electrical and Electronics Engineers (IEEE)

- IEEE is the world’s largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity.
- IEEE and its members inspire a global community through IEEE's highly cited publications, conferences, technology standards, and professional and educational activities.

# Problems Wireless

- A number of challenges can be identified with wireless communication. The most common are
  - **Interference**: wireless transmission cannot be protected against interference using shielding as in the case of cables.
  - **Regulation and spectrum**: frequencies have to be coordinated, unfortunately only a very limited amount of frequencies are available.
  - **Low bandwidth**: transmission rates are still very low for wireless devices compared to desktop systems.
  - **High delay, large delay variations**: in link characteristics applications must therefore be tolerant and use robust protocols
  - **Shared medium**: radio access is always realized via a shared medium. As it is impossible to have a separate wire between a sender and each receiver, different competitors have to “scramble” for the medium.

# Effects of device portability

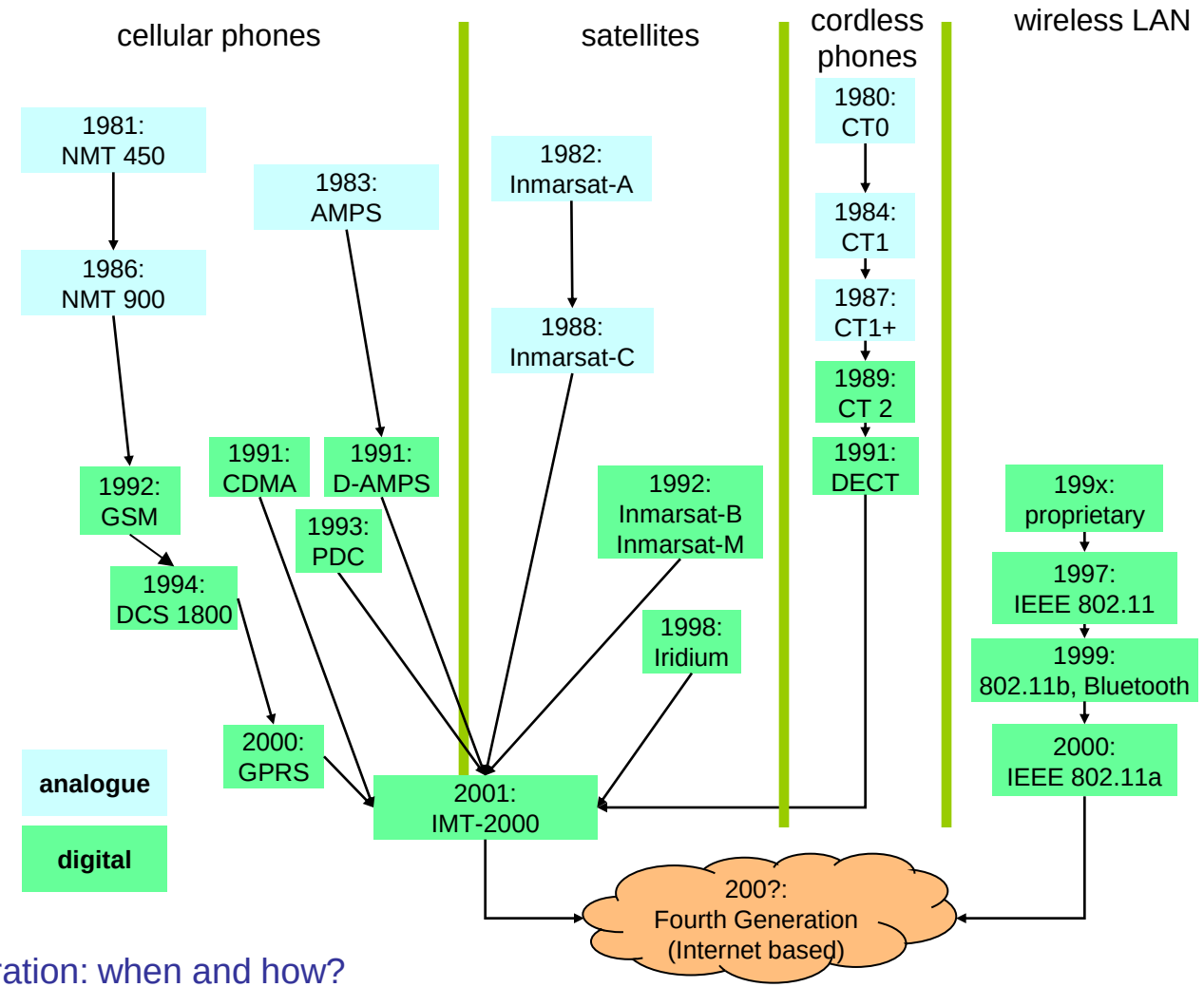
- Power consumption
  - limited computing power, low quality displays, small disks due to limited battery capacity
  - CPU: power consumption ~ $CV^2f$
    - C: internal capacity, reduced by integration
    - V: supply voltage, can be reduced to a certain limit
    - f: clock frequency, can be reduced temporally
- Loss of data
  - higher probability, has to be included in advance into the design (e.g., defects, theft)
- Limited user interfaces
  - compromise between size of fingers and portability
  - integration of character/voice recognition, abstract symbols
- Limited memory (always in relation to e.g. PCs)
  - limited usage of mass memories with moving parts
  - flash-memory or others as alternative

# Wireless networks in comparison to fixed networks

- Higher loss-rates due to interference
  - emissions of, e.g., engines, lightning
- Restrictive regulations of frequencies
  - frequencies have to be coordinated, useful frequencies are almost all occupied
- Lower transmission rates
  - local some Mbit/s, regional currently, e.g., 53kbit/s with GSM/GPRS or about 150 kbit/s using EDGE
- Higher delays, higher jitter
  - connection setup time with GSM in the second range, several hundred milliseconds for other wireless systems – soon in ms range with LTE
- Lower security, simpler active attacking
  - radio interface accessible for everyone, base station can be simulated, thus attracting calls from mobile phones
- Always shared medium
  - secure access mechanisms important

# Related Tutorial/Workshop Activities

- You are required to relate the issues in the lecture to your own personal experience of mobile computing and discuss the limitations of current systems, which you have experienced, and the possible reasons for these limitations.
- You are required to study Figure 4: Overview of some wireless communication systems.
- You are also required to review the IEEE LAN standards outlined in pages 368-371 as well as Table 8.6 ( page 364) of "**Business Data Communications**", sixth Edition by David A Stamper and Thomas L Case.
- In addition, review the material on **standards** outlined on pages 4-6 of "Data Computer Communications" seventh edition by William Stallings publisher PHI.
- Review a section on **Regulations** in **Mobile Communications** by Jochen Schiller.




4G – fourth generation: when and how?

**Figure 4: Overview of some wireless communication systems**