Wireless Mobile Telephony

Arian Durresi

CIS Department
The Ohio State University
Columbus, OH 43210

Durresi@cis.ohio-state.edu

http://www.cis.ohio-state.edu/~durresi/

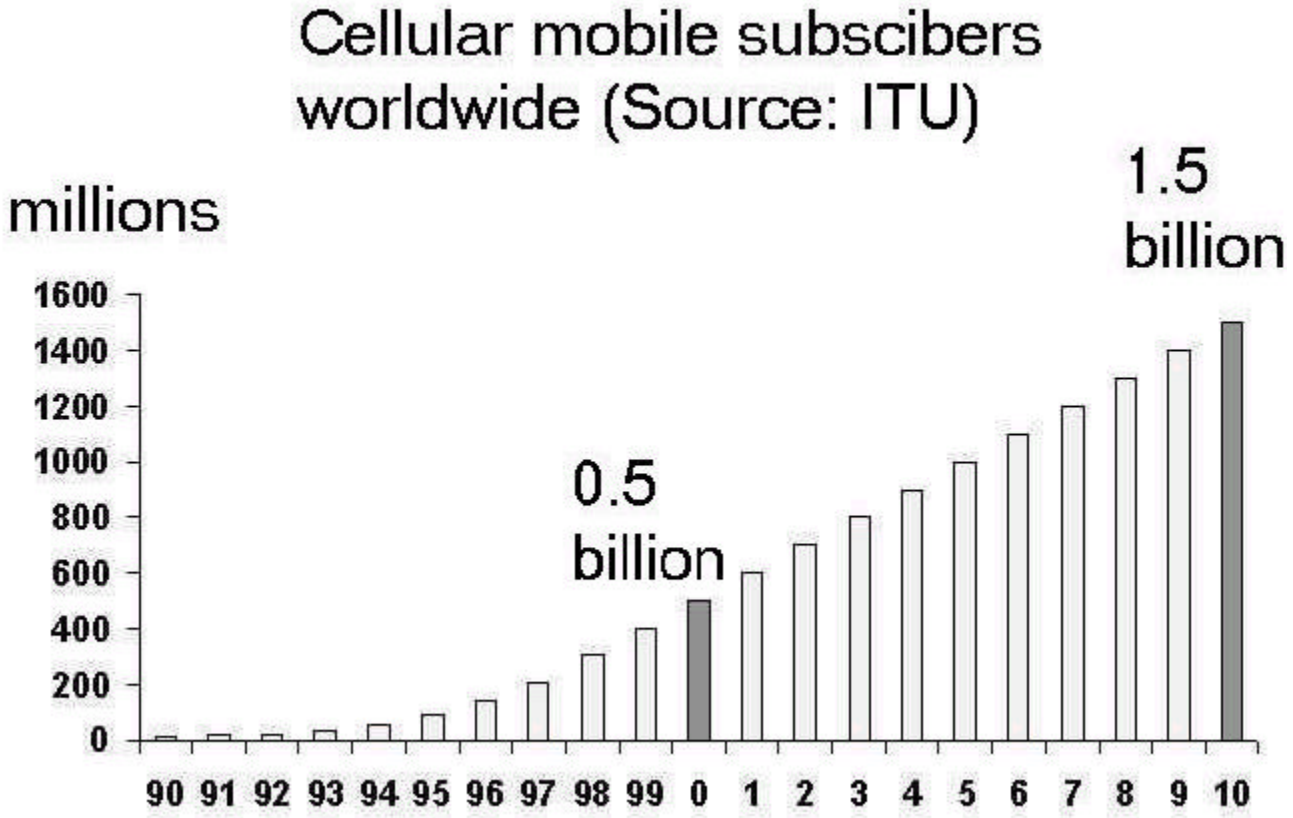
Overview

- Why wireless mobile telephony ?
- First Generation, Analog technologies
- Second Generation, Digital :
  - D-AMPS, GSM, IS-95
- Third Generation: ITU IMT-2000

Why Wireless Mobile Telephony ?

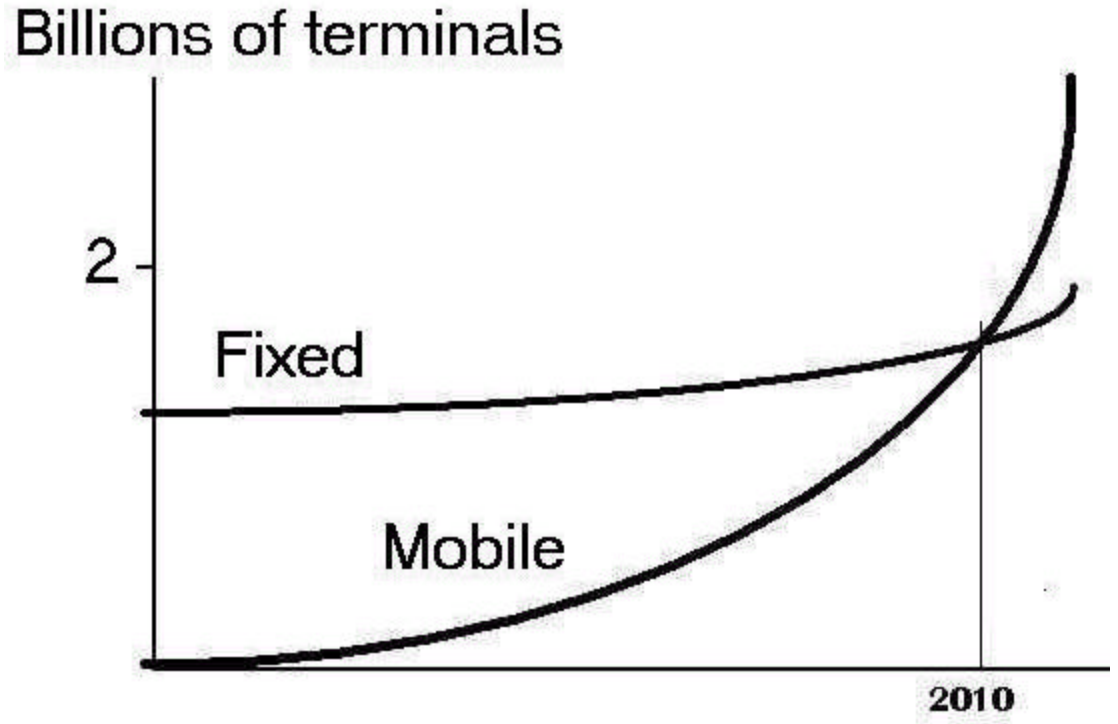
- Negroponte Switch : Personal mobile communications go on Ether, Broadcast communications on cable
- Frequency Spectrum probably the most valuable natural resource
- Progress in microelectronic - very smart mobile terminals
- More open for business opportunities
- Mobile phone the only technology with a growth rate higher than Internet. By the year 2003: 700 millions Internet users and 830 millions mobile phone users

Growth of Cellular Market



Arian Durresi

Fixed & Mobile Growth



Arian Durresi

Mobile Phone First Generation

- First Generation: Analog, 70'-80', Access FDMA
  - Advanced Mobile Phone System (AMPS) 800 MHz, North America
  - Total Access Communication System (TACS) 900 MHz, Europe
  - Nordic Mobile Telephone (NMT) 450 and 900 MHz, Sweden, Norway, Denmark, Finland etc.
  - Good basic service, good territorial coverage.
  - Continue to operate profitably. Will survive for some time

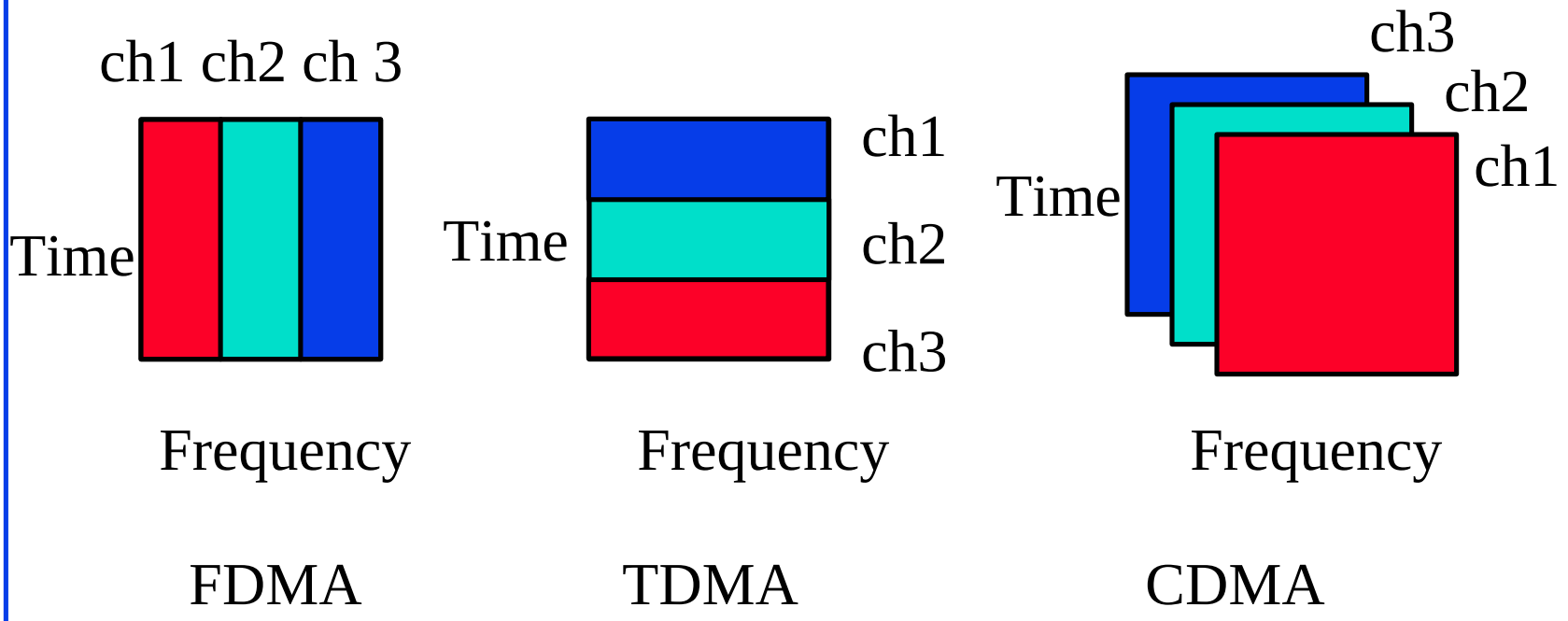
Mobile Phone Second Generation (2G)

- The need for second generation:
  - Capacity. The old systems were almost saturated
  - More services, specially value added
  - Analog system more vulnerable to physical influences and disturbances

2G cont.

- Second Generation. Digital Technology
  - Global System for Mobile Communication (GSM), Europe +, in 120 countries (US too), 97.6 million subscribers, 200 networks, 33% of the world market
  - Digital Advanced Mobile Phone System (D-AMPS): International Standard (IS-136), US +
  - Interim Standard 95 (IS-95): 13million subscribers, 50% of US market, Asia (South Korea), South America.
  - Personal Digital Cellular (PDC): Japan, 33 million subscribers
- Third Generation in development

Multiple Access Schemes



- Multiple access = Supporting more than one communication channel on a radio resource
- Big debate: Who will win TDMA or CDMA?

Arian Durresi

TDMA vs. CDMA

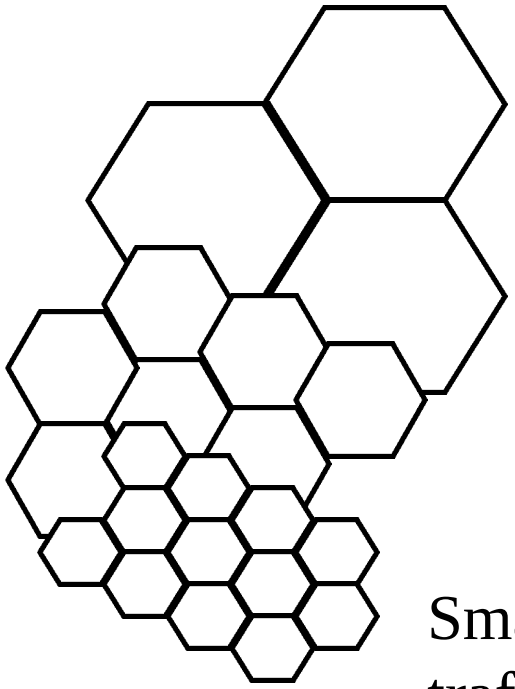
- Spectrum Efficiency: Which multiple access scheme has better bps/Hz.cell ?
- Flexibility: Which access scheme offers better flexibility to handle multi-rate, -cell, -load, and -services ?
- TDMA: some flexibility advantages, but has a spectrum efficiency disadvantage
- CDMA: Less flexibility but has better spectrum efficiency Has
- Actual results depend on standards details

Arian Durresi

TDMA vs. CDMA cont.

- Answer unclear
  - IS-95 is probably superior to IS-54/136
  - IS-95 vs. GSM is unclear
  - IS-95 is clearly more complex
- IS-54/136 is a grossly sub-optimum TDMA system
- GSM is a sub-optimum TDMA system (but pretty good)
- IS-95 is a sub-optimum CDMA system

Cellular System



Large cells for low density traffic areas

Small cells for high density traffic areas

- Cellular structure permits to reuse the frequencies and to distribute the resources depending on the traffic

Arian Durresi

Radio Resource Management

- Cell planning and management quasi online :
  - 1. Simulation of radio propagation using data from satellite about the territory, building, vegetation etc.
  - 2. Optimization of step 1: radio parameters, power.
  - 3. The dimensions of the cells and number of channels are calculated from the traffic foreseen in that area.
  - 4. Frequency distribution among the cells, trying to reduce the interference.
- Specialized personnel, computer system: Operation Support Systems (OSS)

Arian Durresi

IS-136

- Telecommunication Industry Association TIA standard IS-136, November 1994
- IS-136 or D-AMPS is a superset of IS-54, which is a development of AMPS (analog)
- AMPS: Advanced Mobile Phone System
- Access scheme: TDMA
- Frequencies 800MHz, 1.9GHz, Channel bandwidth 300KHz
- D-AMPS worldwide network with over 13 million subscribers, analog + digital 75 million
- Voice is digitized at 8kbps

Arian Durresi

IS-136 cont.

- It is possible to upgrade easily from an analog AMPS network to a digital D-AMPS network
- Digital and analog AMPS channels can co-exist in the same network
- A dual handset can operate in both analog and digital AMPS, in both 800 and 1900 MHz.
- Asynchronous data service, fax, Short Message Service, Sleep Mode capability
- Allow hierarchical cell structures to be implemented
- D-AMPS offers CDPD service
- New: IS-136HS High Speed extended data rate to 384kbps

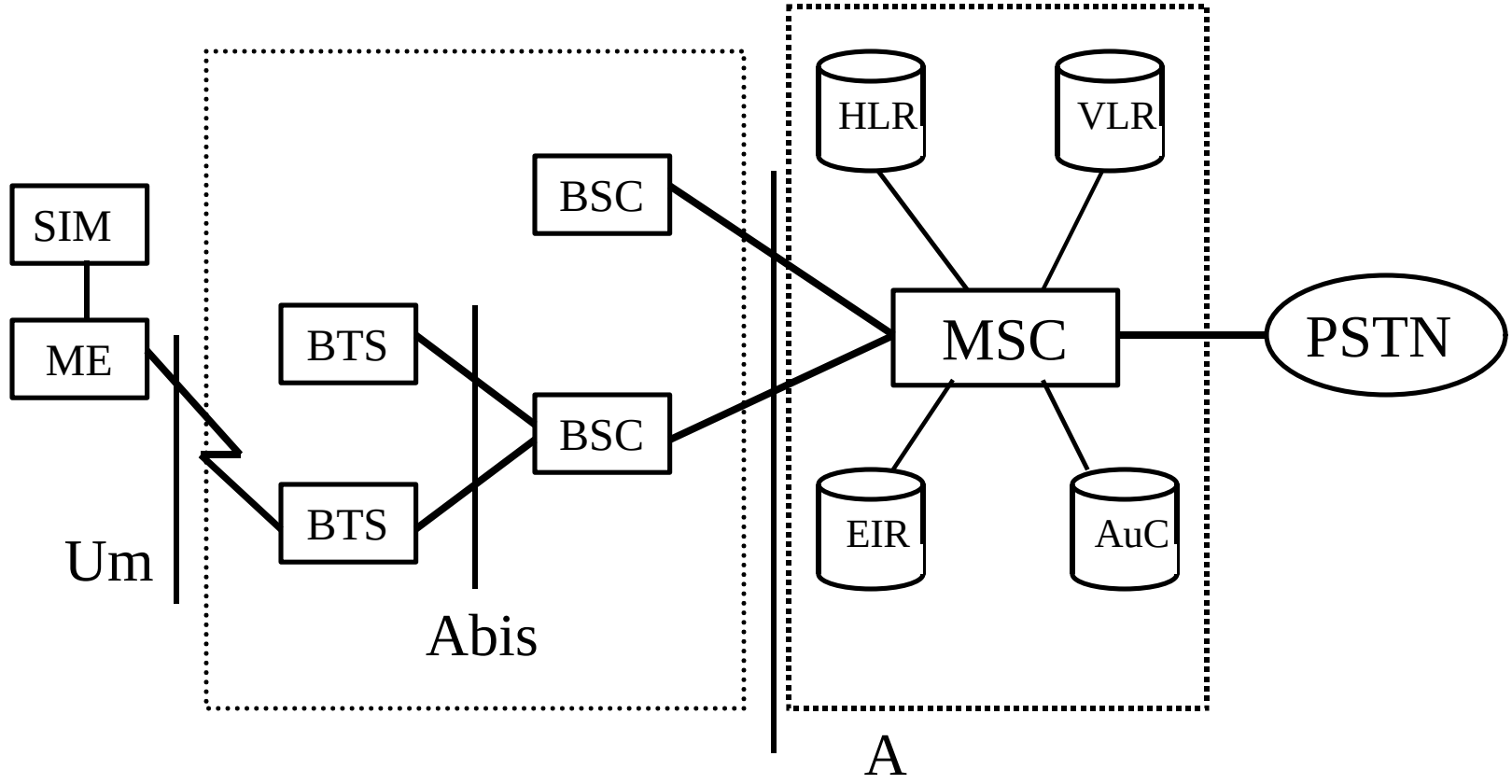
Arian Durresi

GSM

- Global System for Mobile Communication
- 1982 CEPT, 1989 ETSI, standard 8000 pages
- GSM 900 MHz, DCS 1800 MHz, DCS 1900 MHz in US and Canada
- Access scheme: TDMA /FDMA
- Services: Telephony - digitized voice 13kbs, data services up to 9.6bps soon 38.4kbps, group 3 facsimile, Short Message Service (SMS), ISDN, X.25
- International roaming: Subscribers can use the same phone terminal around the world and bill to home. This is a very attractive feature for the users.

Arian Durresi

Architecture of the GSM network



- All the interfaces are standard - this permits a fierce competition among the vendors and a multi vendor network - advantage for the operators

Arian Durresi

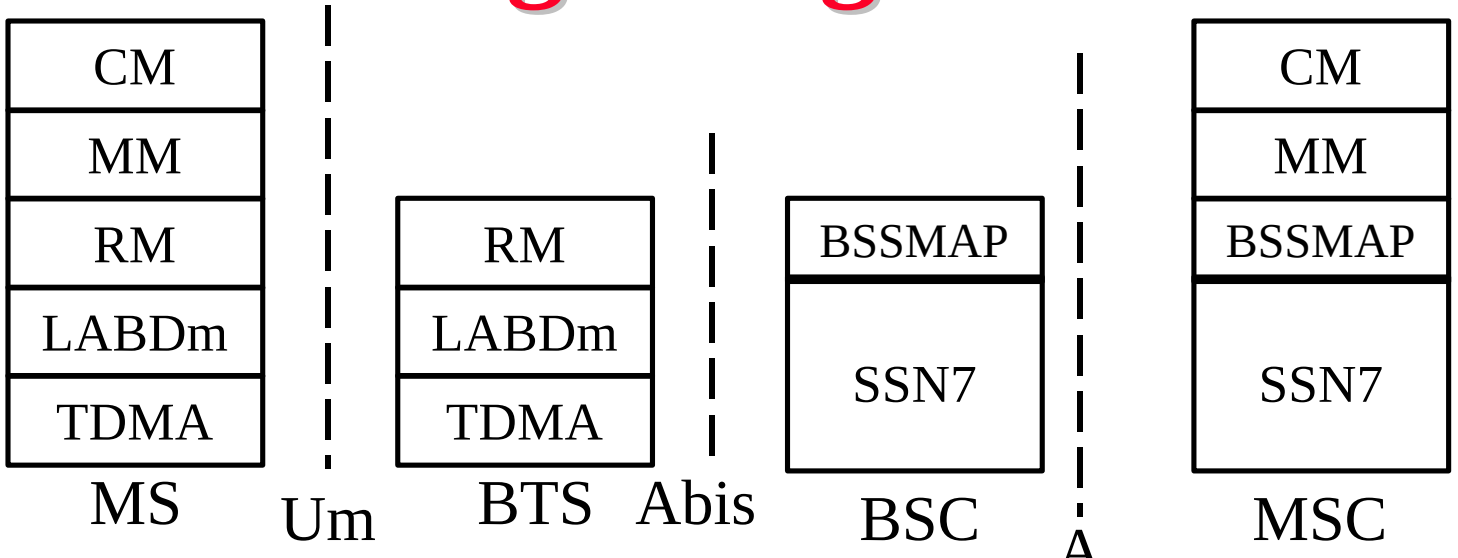
Elements of GSM Architecture

- SIM: Subscriber Identity Module contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication
- ME: Mobile Equipment
- BTS: Base Transceiver Station handles the radio-link protocols with the Mobile Station.
- BSC: Base Station Controller handles radio-channel setup, frequency hopping, and handovers
- HLR: Home Location Register - all the administrative information of each subscriber, and the current location of the mobile

Architecture of GSM network

- VLR: Visitor Location Register contains selected information, for call control and services for mobiles located in its geographic area.
- MSC: Mobile services Switching Center - normal switching node of the PSTN (Public Switched Telephone Network), plus functionality for registration, authentication, location updating, handovers, and call routing to a roaming subscriber.
- EIR: Equipment Identity Register
- AuC: Authentication Center stores a copy of the secret key of each subscriber's SIM card, used for authentication and encryption

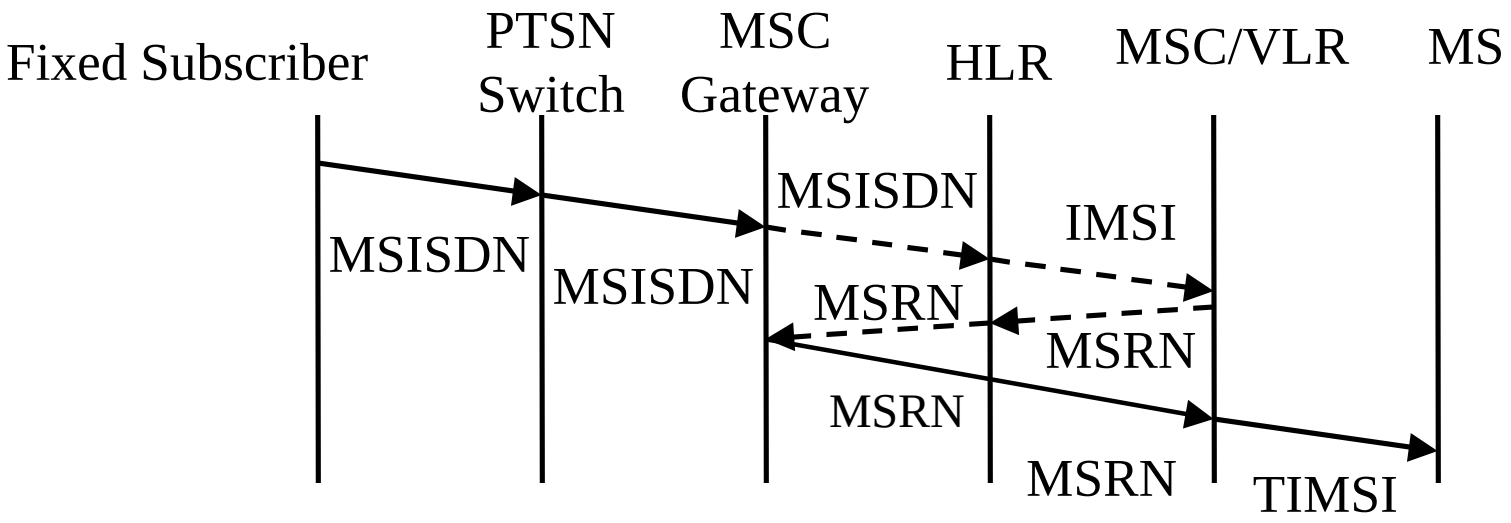
GSM Signaling Protocols



- RM: Radio Resources Management: Controls the setup, maintenance, and termination of radio and fixed channels, including handovers
- MM: Mobility Management: location updating, registration procedures, security and authentication.
- CM:Connection Management: call control.
- MAP: Mobile Application Protocol

Arian Durresi

Call Routing



- MSISDN: Mobile Subscriber ISDN
- IMSI: International Mobile Subscriber Identity
- MSRN: Mobile Station Roaming Number
- TIMSI: Temporary IMSI

Arian Durresi

GSM features

- 124 channel of 200kHz, each channel up to eight logic channels:
  - Traffic (TCH) voice/data, Control (CCH) control and signaling, Cell Broadcast (CBCH)
- Up to eight traffic channels TCH per frequency
- Multipath equalization. The system “studies” the radio channel using a known sequence in every data time slot, than “reacts” constructing an inverse filter.
- Frequency hopping helps to reduce interference
- Automatic Power Control reduces co-channel interference
- Layered signaling protocol

GSM features

- Handover or handoff: Switch an on-going call to a different channel or cell.
- Authentication: Fraud is a problem in mobile phone.
- Security: GSM can encrypt the air transmission
- High Speed Circuit Switched Data (HSCSD): A single user is allocated more than one time slot. Using eight time slots would give a transmission rate of 76.8 kbps
- General Packet Radio Service (GPRS): Packet connection over GSM, 14 kbps over one time slot and 115 kbps over eight.
- Enhanced Data Rates for GSM Evolution (EDGE), IP-based services, 384 kbps

Arian Durresi

IS-95

- Telecommunication Industry Association (TIA) standard IS-95, July 1993, also known as cdmaOne and ANSI-95.
- Developed from Qualcomm's proposal
- Access scheme: narrowband CDMA, Walsh codes - mutually orthogonal
- Frequencies: 800 Mhz, 1.9 GHz. Radio channel bandwidth 1250KHz. The band is divided in 20 full duplex carriers with up to 64 channels each.
- Limited international roaming

IS-95 cont.

- Services: Telephony - digitized voice 8 and 13kbs, data services up to 9.6bps and 14.4kbps, fax.
- The mobile stations add a “pseudo random code” to the useful data, but with different time shift.
- Unique time offsets ⇒ Time synchronized.
- A pilot channel: demodulation reference for initial synchronization and power measurement for handover.
- A Sync channel conveys the timing and system configuration information to the mobile station
- Coverage, quality and capacity are related and must be balanced off of each other to arrive at the desired level of system performance. More difficult to be tuned.

IS-95 cont

- Simplified cell planning through the use of the same frequency in every cell
- Capacity increase, compared to GSM, but at the cost of quality and coverage.
- Automatic power control
- Soft handover: allows the mobile to communicate with multiple base stations simultaneously and chose the best of them.
- Effective fraud control
- Technology with a strong potential

Arian Durresi

Third Generation (3G)

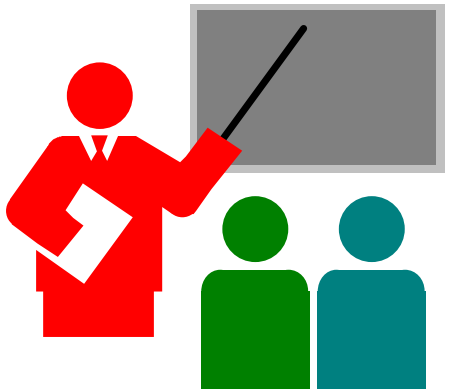
- Goals:
  - Multi-rate: 2Mbps indoor, 384 kbps pedestrian, 144 kbps mobile
  - Multi-service: Mobile Internet, Multimedia, packet and circuit switched services
  - Multi-cell: Seamless coverage across pico-, micro-, and macro-cells
  - Multi-Operator: Easy sharing of band at lowest granularity
  - High spectrum efficiency: Efficient utilization of the frequency spectrum
- Market driven standardization: de facto standards

ITU International Mobile Telecommunication (IMT) 2000

- December 1998: ARIB and TTC (Japan), ETSI (Europe), T1 (USA), and TTA (Korea) launched the "3rd Generation Partnership Project" (3GPP)
- March 1999 Ericsson and Qualcomm agree to harmonize WCDMA and to address the IPR issues
- March 1999 ITU approves key characteristics for the IMT 2000 radio interface.
- Radio interface - Combination of : wideband CDMA (W-CDMA), time division CDMA (TD-CDMA) and SDMA
- GSM network architecture will be integrated.

Arian Durresi

Summary



- Wireless mobile telephony, three generations
- Longtime debate TDMA vs. CDMA
- IS-136, GSM, and IS-95
- Third generation hopefully will be a unique system

Arian Durresi

Key References

- U. Black “Emerging Communications Technologies” Chapter 9
- A very good and concise GSM reference by John Scourias: http://www.gsmdata.com/overview.htm
- CDMA development group: http://www.cdg.org
- IMT 2000 : http://www.itu.int/imt
- D-AMPS, http://www.ericsson.com/systems/d-amps/
- Third Generation, http://www-isl.stanford.edu/groups/SARG/research.html
- GSM, http://www.ericsson.com/systems/gsm/

References (Cont)

- A. D. Hadden “Personal Communications Networks” Artech House 1995
- Th. S. Rappart “ Wireless Communications” Prentice Hall 1996
- V. K. Garg “Wireless and Personal Communications Systems” Prentice Hall 1996
- R. Schneider “Future Talk” IEEE Press 1997
- S. M. Redl “An Introduction to GSM” Artech House 1995

References (Cont)

- I. Brodsky “Wireless: The revolution in personal telecommunications
- Arian Durresi, “Developing IRMA-PS a Cell Planning System for GSM Networks”, BSHT. Nr 2. 1996