18-759: Wireless Networks
Lecture 17: 1G, 2G, and 3G

Peter Steenkiste
Departments of Computer Science and Electrical and Computer Engineering

Spring Semester 2016
http://www.cs.cmu.edu/~prs/wirelessS16/

Outline

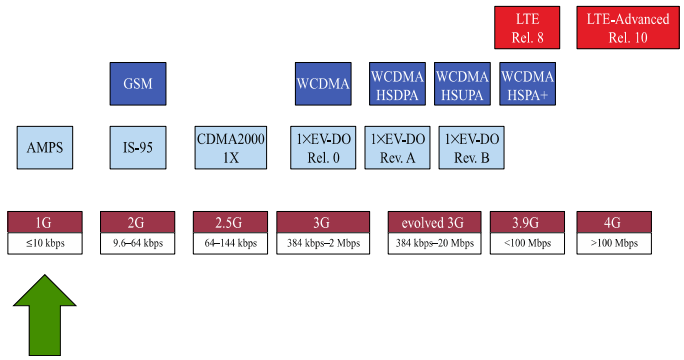
- 1G: AMPS
- 2G: GSM
- 2.5G: EDGE, CDMA
- 3G: WCDMA

Some slides based on material from
"Wireless Communication Networks and Systems"

The Cellular Landscape

FDMA	0.15bps/Hz Max.rate 64Kbps TDMA &CDMA	0.30 bps/Hz Max.rate 2 Mbps TDMA,CDMA, WCDMA	5-10 bps/Hz Max. rate ~ 100Mbps/1Gbs
1G Analog	2G Digital Modulation Convolution coding Power Control	2.6G/3G Hierarchical cell structure Turbo-coding	4G MIMO Adaptive Systems OFDM Modulation
AMPS TACS NMT C-450	PDC GSM HSCSD GPRS IS-54/IS-136 IS-95/IS-95A/IS-95B PHS	EDGE Cdma2000 WCDMA/UMTS 3G 1x EV-DO 3G 1X EV-DV	LTE LTE-Advanced WiMax

Evolution of Cellular Wireless Systems



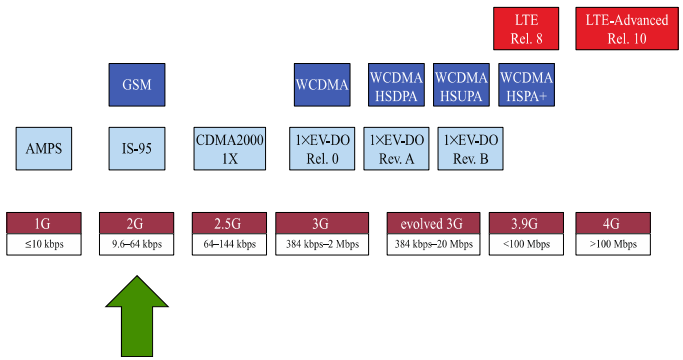
Advanced Mobile Phone Service (AMPS)

- In North America, two 25-MHz bands were allocated (DL: 869-894 MHz, UP: 824-849 MHz)
  - » Deployed since early 80's
  - » Shared by two providers
- Channels are spaced by 30 KHz, allowing for 416 channels (21 control, 395 for voice calls)
  - » Control channels are full duplex data channels at 10 Kbps
  - » Includes preamble, word sync, and Digital Color Code identifying the base station
  - » Can send urgent control in data channels
- Conversations carried in analog using frequency modulation
- Cell size = 2-20Km, frequency reuse is exploited

AMPS Operation

- When unit wakes up, it sends telephone and serial number to MTSO
  - » Both stored in read-only memory
  - » Used for billing purposes and to detect stolen phones
- Steps in placing a call:
  1. User dials in a number – sent to the MTSO
  2. MTSO verifies validity of service request
  3. MTSO notifies user of channels to use for send/receive
  4. MTSO sends ring signal to the called party
  5. MTSO completes circuit when party picks up
  6. When either party hangs up, MTSO releases circuit and wireless channels, and completes billing

Evolution of Cellular Wireless Systems



Differences Between First and Second Generation Systems

- Digital traffic channels – first-generation systems are almost purely analog; second-generation systems are digital
  - » Using FDMA/TDMA or CDMA
- Encryption – all second generation systems provide encryption to prevent eavesdropping
- Error detection and correction – second-generation digital traffic allows for detection and correction, giving clear voice reception
- Channel access – second-generation systems allow channels to be dynamically shared by a number of users

Motivation for Switch from Analog to Digital

- Higher quality
- Compression
- Encryption
- Error Detection and Correction
- Multiplexing channels by different users
  - » I.e. TDMA

Global System for Mobile telecommunication (GSM)

- GSM is a set of ETSI standards specifying the infrastructure for a digital cellular service
  - » European Telecommunications Standards Institute
- The standard is used in approx. 109 countries around the world including Europe, Japan and Australia
- Order 44 million subscribers
  - » For 2G only – 2-3 Billion if you include all versions

Design Requirements for GSM-like 2G Systems

- Degree of multiplexing: at least 8
  - » Not worth the added TDMA complexity otherwise
- Maximum cell radius: ~35km
  - » Needed for rural areas
- Frequency: around 900 MHz
- Maximum speed: 250 km/hr – high-speed train
- Maximum coding delay: 20 msec
  - » Do not want to add too much to network delay (voice!)
- Maximum delay spread: ~10 μsec
- Bandwidth: up to 200 KHz, ~25 kHz/channel

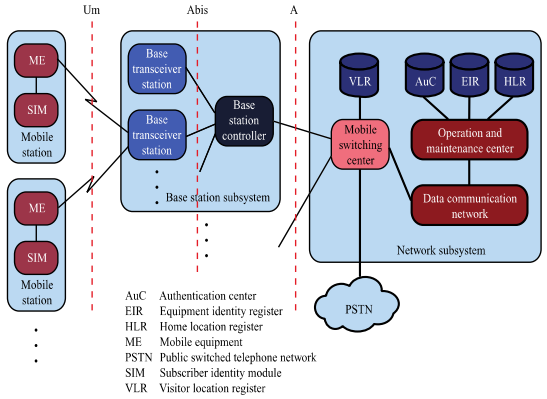
Global System for Mobile Communications (GSM)

- Hybrid FDMA/TDMA approach
- Developed to provide a common second-generation technology for Europe
  - » Over 6.9 billion subscriber units by the end of 2013
- Mobile station communicates across the air interface with base station in the same cell as mobile unit
- Mobile equipment (ME) – physical terminal, such as a telephone or PCS
  - » ME includes radio transceiver, digital signal processors and subscriber identity module (SIM)
- GSM subscriber units generic until SIM is inserted
  - » SIMs roam, but this Is not necessarily the case for subscriber devices

GSM SIM

- Users have a Subscriber Identity Module (SIM) – a smart card
- The user identity is associated with a mobile through the SIM card
- The SIM is portable and transferable
- All cryptographic algorithms (for authentication and data encryption) can be realized in the SIM
- May also store short messages, charging info, ..
- SIM implications:
  - » Equipment mobility and user mobility are not the same
  - » International roaming independent of the equipment and network technology

Global GSM System

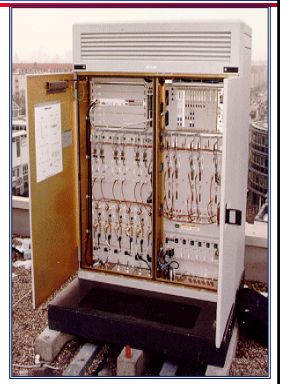


Base Station Subsystem (BSS)

- BSS consists of base station controller (BSC) and one or more base transceiver stations (BTS)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging
- Each BTS defines a single cell
  - » Includes radio antenna, radio transceiver and a link to a base station controller (BSC)

Base Transceiver Station

- Radio transmission/reception management (modulation/demodulation, equalisation, interleaving ...)
- Physical layer management (TDMA transmission, SFH, coding, ciphering ...)
- Link layer management
- Received signal quality and power measurement



Base Station Controller

- Radio resource management:
  - Channel allocation
  - BTS measures processing
  - BTS and MS power control
  - Handover
  - ...
- Interfaces management:
  - With the MSC (gathers the traffic towards the MSC) and
  - With the BTSs

Network Subsystem (NS)

- NS provides link between cellular network and public switched telecommunications networks (PSTN)
  - » Controls handoffs between cells in different BSSs
  - » Authenticates users and validates accounts
  - » Enables worldwide roaming of mobile users
- Central element of NS is the mobile switching center (MSC)

Mobile Switching Center

- Management of the communications between the mobiles and the fixed network
  - Handover management
  - Interconnection with the fixed network (switching features)
  - Management of the visiting users with the VLR
  - *Gateway MSC* (GMSC) function: is the gateway for the calls coming/going towards an external network.