

## 18-759: Wireless Networks

### Lecture 8: Cellular Networks

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<http://www.cs.cmu.edu/~prs/wireless09/>

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## What is a Survey?

- Not a set of summaries
- “big picture” using the papers as examples
- We generally expect that you will have to consult additional material
- You can consult pretty much any material as long as you cite the source.
- You **cannot** copy text from other papers or the web. That is called plagiarism.

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## Deliverables

- 20 minute presentation, allowing for 10 minutes of questions.
- 2 page description of the survey

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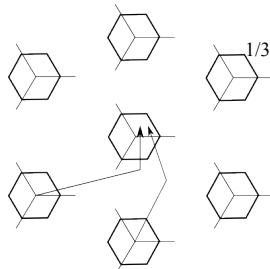
## Surveys

Monday Feb 16	Submit team information	3 students per team – 2 if needed
Friday Feb 20	List of proposed topics due	
Wednesday Feb 25	Instructors announce topics	
March – April	In class presentations	
10 days before presentation	Submit draft slides for feedback from instructors	Earlier is always better
Wednesday April 24	Survey documents due	

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## Cell sectoring

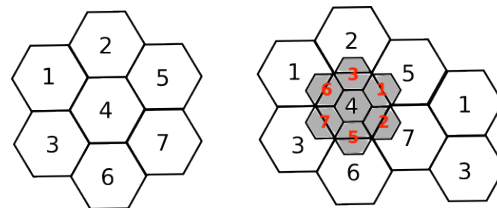


Two interferers in first ring per sector (3 sector)  
 One interferer in first ring per sector (6 sectors)

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## Cell splitting



Radius of small cell half that of the original

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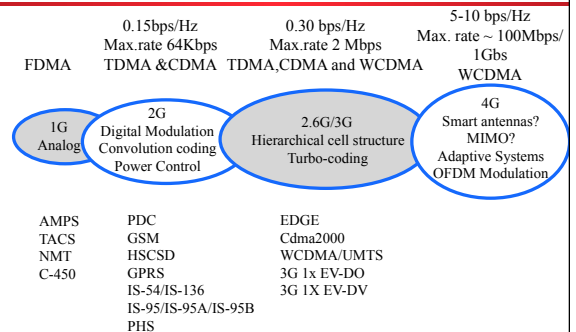
## Overview

- Cellular landscape
- GSM
- CDMA

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## The cellular landscape



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## Cellular Standards

- **2G systems: digital voice**
  - » GSM - FDMA/TDMA, most widely deployed, 200 countries, a billion people
  - » IS-95 - first CDMA-based cellular standard, developed by Qualcomm
  - » IDEN - TDMA, Nextel, merged with Sprint, being phased out for CDMA2000
  - » IS-136 - uses FDMA/TDMA, North America, Cingular and US Wireless, being phased out for GSM, CDMA2000
- **2.5G systems: voice and data channels**
  - » GPRS - evolved from GSM, packet-switched, 170 kbps (30-70 in practice)
  - » CDMA2000 1xRTT - evolved from IS-95, 144 kbps

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## Cellular Standards

- **2.75G - almost 3G in speed**
  - » EDGE - another enhancement of GSM, 384 kbps, 2.75G
  - » Thanks to new modulation scheme (8PSK) – may coexist with GMSK
- **3G: voice (circuit-switched) and data (packet-switched)**
  - » UMTS - W-CDMA, successor to GSM networks, 384 kbps - 2 Mbps, European, some Japan, Cingular in U.S.
  - » CDMA2000 1xEV - CDMA2000 with high data rates - 3.1 Mbps up, 1.8 Mbps down, U.S., Japan, Korean, Canada – Verizon, Sprint
- **4G: 10 Mbps and up, seamless mobility between different cellular technologies, mesh, etc.**

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## Advanced Mobile Phone Service (AMPS)

- In North America, two 25-MHz bands were allocated (DL: 869-894 MHz, UP: 824-849 MHz)
- Shared by two providers
- Channels are spaced by 30 KHz, allowing for 416 channels (21 control, 395 for calls)
- Conversations carried in analog using frequency modulation
- Cell size = 2-20Km, frequency reuse is exploited

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## From analog to digital

- Compression
- Encryption
- Error Correction
- Multiplexing

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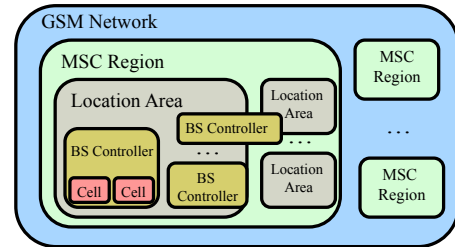
## Global System for Mobile telecommunication (GSM)

- GSM is a set of ETSI standards specifying the infrastructure for a digital cellular service
- The standard is used in approx. 109 countries around the world including Europe, Japan and Australia
- Almost 44 million subscribers - check

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## GSM System Hierarchy



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## 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, etc.

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## Implications of SIM

- Equipment mobility and user mobility are not the same
- International roaming independent of the equipment and network technology

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## Equipment Identifier

- International Mobile Station Equipment Identity (IMEI) uniquely identifies the mobile equipment internationally
- Allocated by manufacturer and registered by the network operator in the Equipment Identity Register (EIR)
- IMEI allows the detection of obsolete, stolen and non functional equipment

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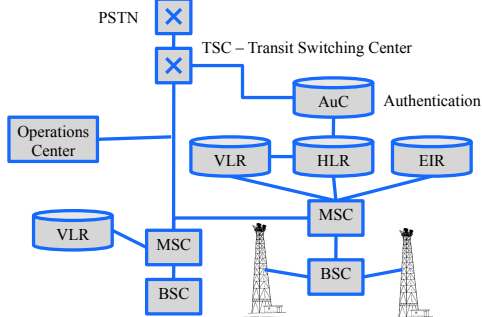
## Mobile Stations

- "Fixed" terminals installed in cars – maximum power 20W
- GSM portable terminals can also be installed in vehicles – maximum power 8W
- Handheld terminals – up to 2W and decreasing to 0.8W

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## GSM phone system



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## Home Location Register

- 1 per Public Land Mobile Network (OLMN)
- Contains entries for every subscriber and every mobile ISDN number that is homed in the respective network
- Permanent subscriber data and relevant temporary information
- Current MS location
- All administrative activities of the subscriber happen here!

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## Visitor Location Register

- 1 per MSC
- Stores data on all mobile stations which are currently in the administrative area of the respective MSC
- 1 VLR could be responsible for more than 1 MSC
- A roaming MS may be registered in a VLR of its home network or the foreign network depending on its location
- MS registers upon entering a LA. The MSC passes the identity of the MS and LAI to VLR

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## Channels

- Traffic Channels (TCH)
  - » For transmission of user payload (data, speech). No control information
  - » Communication may be circuit or packet switched
- Signaling Channels
  - » Broadcast Channel (BCH) – radio channel configuration, synchronization, registration identifiers (LAI, etc.)
  - » Common Control Channel (CCCH) – assignment of dedicated channel and paging
  - » Dedicated/Associated Control Channel (DCCH/ACCH)
  - » Frequency Correction Channel (FCCH)
  - » Synchronization Channel (SCH) – BS identification, frame synchronization of the MS

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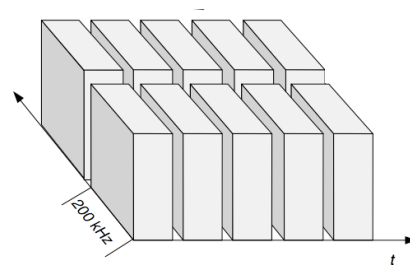
## GSM Multiple Access

- Combination of FDMA and TDMA
- 890-915 MHz for uplink
- 935-960 MHz for downlink
- Each of those 25 MHz bands is sub divided into 124 single carrier channel of 200 KHz
- In each uplink/downlink band there is a 200 KHz guard band
- Each 200 KHz channel carries 8 TDMA channels
- The TDMA frames of the uplink are transmitted with a delay of 3 time slots

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## FDMA/TDMA



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## GSM Services

- Telephony
- Facsimile group 3 (E1)
- Emergency calls
- Short Message Service – messages up to 160 alphanumeric characters
- Fax mail
- Voice mail

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## Disadvantages of GSM

- Each radio channel uses a **frequency guard band** (inefficient)
- **Complex frequency planning** needed to avoid CCI and ACI
- Certain radio channels unavailable due to interference
- Each time slot needs a **time guard band** (inefficient)
- A time slot is occupied even when there is a **pause**

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## What was the target of 3G?

- Greater system capacity both in terms of users and bandwidth
- Good support for mobility at high data rates at high speeds
- cdma2000 (Qualcomm) vs. W-CDMA

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## Code Division Multiple Access (CDMA)

- CDMA uses codes to convert between analog voice signals and digital signals.
- It then uses codes to divide voice and control data into data streams called “channels”

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## CDMA Signal Generation

- Analog to digital conversion (Pulse Code Modulation)
- Vocoding
- Encoding and Interleaving
- Channelization
- Conversion of the digital signal to a RF signal (modulation)

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## Variable Rate Vocoder

- Human speech is full of pauses (thinking, waiting to hear back, etc.)
- CDMA vocoder varies compression of the voice signal into one of four data rates, based on the user’s speech activity
- The four rates are: Full, 1/2, 1/4, 1/8
- Full rate when the person talks very fast
- 1/8 when the person is silent or nearly so

(built in BTS and phones)

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## Vocoder Types

- CDMA systems can use either a 8 Kbps or a 13 Kbps vocoder.
- Extended Variable Rate Coding (EVRC) vocoder produces the quality of the 13 Kbps vocoding, with a 8 Kbps rate

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## Encoding and Interleaving

- Builds redundancy into the signal to recover information loss
- Encoding relies on **convolutional encoding**
- Simplified scheme is the repetition code: every bit is repeated three times
- The encoded bits are called symbols
- The decoder at the receiver uses a majority logic rule
- Combat burst errors (built in BTS and phones)

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## Interleaving

- Reduce the effect of burst errors and recover lost bits
- Symbols are said to be interleaved or scrambled in a pattern that the receiver knows
- De-interleaving at the receiver unscrambles the bits, spreading any burst errors that occur during transmission



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## Channelization

- The encoded voice is further encoded to separate it from other encoded voice data
- The encoded symbols are spread over the entire bandwidth of the CDMA channel
- The receiver knows the code and uses it to recover the data

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## Two types of codes

- **BTS to mobile**
  - » Walsh codes
  - » Nearly "orthogonal" codes
  - » Unique enough that the voice data can only be recovered by a receiver applying the same Walsh code
- **Mobile to BTS**
  - » Pseudorandom Noise (NS) codes
  - » Appears to be random but is not
  - » 4.4 trillion combinations of code for CDMA
  - » Less computationally intensive
  - » (assigned during setup, hardwired set of codes for discovery)

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## At the receiver...

- RF to digital signal
- Despreading of the signal
- De-interleaving and decoding
- Voice decompression
- Digital to Analog voice recovery

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## Code channels in CDMA

- Code channel is a stream of data designated for a specific use of person
- This channel may be voice data or overhead control data
- Channels are separated by codes
- The forward and reverse links use different types of channels

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## Forward Link Channels

- Pilot
  - » The BTS constantly transmits here. The mobile uses this channel to acquire the system. It then uses the pilot signal to monitor and adjust its power
- Sync
  - » The BTS constantly transmits here. The mobile uses this channel for time synchronization – system time and identification number of the cell site. The mobile ignores the sync channel after it is synchronized.

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## Forward Link Channels

- Paging
  - » CDMA uses up to seven paging channels
  - » It transmits overhead information such as commands and pages to mobiles
  - » Traffic channel assignment during call set-up
  - » Mobile ignores paging channel after a traffic channel is established
- Traffic
  - » CDMA uses 55-61 forward traffic channels to send both voice and overhead control data during a call
  - » When the call is completed, the mobile tunes back into the paging channel

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## Reverse Link Channels

- Access
  - » Register with the network
  - » Originate calls
  - » Respond to pages and commands
  - » Transmit overhead messages
- Traffic
  - » Only used when there is a call
  - » Transmits voice data to the BTS
  - » Transmits the overhead control information during the call

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## Call processing stages

- Initialization
  - » Acquires the system via the Pilot code channel
  - » Synchronizes with the system via the Sync code channel
- Idle mode
  - » Mobile and base station communicate over the access and paging code channels
  - » The mobile obtains overhead information via the paging code channel
- Access mode
  - » Call origination
  - » Use of access and paging channels for call set up until a traffic channel has been established

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## Call Overhead Messaging

- Uses “Dim and Burst” or “Blank and Burst” signaling, which replaces part of the voice traffic with system messages
- Strong data recovery schemes prevent the user from detecting this

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## cdma2000 vs W-CDMA

	cdma2000	W-CDMA
Chip Rate	3.6864 Mbps	4.096 Mbps
Downlink Pilot for Channel Estimation	CDM common pilot	TDM dedicated Pilot
Antenna Beamforming	Aux. Pilot	TDM dedicated Pilot
BS Synchronization	Synchronous	Asynchronous
BS Acquisition and Detection	Synchronization thru time shifted PN correlation	3 step parallel code search

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## cdma2000/W-CDMA similarities

- Coherent forward link (FL) and reverse link (RL)
- Fast power control in FL and RL
- Variable length orthogonal Walsh sequences for FL channelization
- Complex QPSK spreading on FL and RL
- Identical Polynomials for Convolutional Codes
- Parallel turbo codes for higher data rates

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## cdma2000/W-CDMA similarities

- Variable spreading factors for higher data rates
- Mobile assisted inter-frequency handoff procedures
- Variable rate operation with blind rate estimation for simple services (voice)
- Continuous reverse link operation

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## What's Next?

- OFDM
- WiMAX
- Long Term Evolution
- Cellular Landscape

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## References

- <http://www.youtube.com/watch?v=EDDEsX7vall>
- [http://www.youtube.com/watch?v=bur9hq\\_abog](http://www.youtube.com/watch?v=bur9hq_abog)

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