Wireless Cellular Networks II: 2.5G and 3G

Raj Jain
Professor of Computer Science and Engineering
Washington University in Saint Louis
Saint Louis, MO 63130

Audio/Video recordings of this lecture are available at:
http://www.cse.wustl.edu/~jain/cse574-10/
Overview

- Wireless Generations: 2.5G, 3G
- GPRS, EDGE
- EV-DV, EV-DO
- WCDMA, CDMA2000, TD-SCDMA
- HSDPA
3G Technologies

- Wideband CDMA (W-CDMA): Next Generation GSM. Uses 5 MHz channel width ⇒ 2 Mbps
- CDMA2000: Next Generation CDMA (IS-95)
  - 1.25 MHz Channels ⇒ 144 kbps
  - 3x, 6x, 9x, and 12x in future
  - 3xRTT (Radio Transmission Technology):
    - 3.75 MHz channel ⇒ 2 Mbps
- UWC-136: Next Generation TDMA (IS-136)
  - 200 kHz Channels ⇒ 384 kbps or
  - 1.6 MHz Channels ⇒ 2 Mbps
Developed by Universal Wireless Communications Consortium (UWCC)
Goal: Provide high-speed packet based Voice and Data
3G

- Also known as ITU IMT-2000 Project. Started in 1980.
- Goal: To have one world-wide standard and a common frequency band for mobile networking
- Result:
  - Three frequency bands: Below 1 GHz, 1.7GHz, 2.5GHz
  - Three different technologies: W-CDMA (Europe) CDMA2000 (North America), and TD-SCDMA in China.
WCDMA

- Wideband CDMA
- Proposed by European Telecom Std Inst (ETSI) Alpha group
- WCDMA has 5MHz single carrier system w Freq Div Duplexing and direct sequence (FDD-DS) ⇒ 2 Mbps data
- 3rd Generation Partnership Project (3GPP.org)
- 2.5G:
  - HSCSD (High-Speed Circuit Switched Data)
  - GPRS (General Packet Radio Service)
    - 144 kbps data only
  - EDGE (Enhanced Data for GSM Evolution)
    - 384 kbps data
  - HSDPA (High-speed downlink packet access)
    - Asymmetric. 2 Mbps+ downlink.
CDMA2000

- Proposed by Third Generation Partnership Project 2 (3GPP2.org).
- 3GPP2: Partnership of 5 Telecom standards bodies: ARIB and TTC in Japan, CWTS in China, TTA in Korea and TIA in North America
- Full backward compatibility with IS-95B (CdmaOne)
- CDMA2000 is also known as CDMA-MC (multi-carrier)
- It uses n carriers of 1.2288 MHz each. 1x, 3x, 6x, 9x, 12x
CDMA2000 (Cont)

- 6.25 kHz guard band between carriers
- Single carrier or multi-carriers
- 2.5G: Operators can overlay CDMA2000 1x now over CdmaOne. Also known as CDMA2000 1xEV. Implemented in 2 steps:
  - 1xEV-DO (Evolution data only),
  - 1xEV-DV (Evolution data and voice on one carrier).
TD-SCDMA

- Time Division Synchronous CDMA
- Proposed by China Wireless Telecommunication Standards group (CWTS)
- Uses Time Division Duplex (TDD)
- Synchronous ⇒ All base station clocks are synchronized
- http://www.tdscdma-forum.org/
2.5 G

Data services over 2G networks

- GSM
  - High-speed circuit-switched data (HSCSD)
  - General Packet Radio Service (GPRS)
  - Enhanced Data Rate for GSM Evolution (EDGE)

- CdmaOne:
  - 1xEV-DO
  - 1xEV-DV
HSCSD

- High-Speed Circuit Switched Data (HSCSD)
- First attempt to get high-speed data over GSM
- Allows data users to get 1 to 8 slots
  Data rates up to 115 kbps
- Circuit switched $\Rightarrow$ Constant data rate
  Not suitable for bursty data
  Not widely implemented
  GPRS is more widely implemented
GPRS

- General Packet Radio Service (GPRS)
- Standard GSM has 8 slots per 200 kHz channel
  \[ \Rightarrow 9.6 \text{ kbps data} \]
- GPRS allows any number of slots to a user
  - 4 different codings used depending upon channel condition
  - 9.05 kbps to 21.4 kbps per slot
  - 76-171 kbps using all 8 slots.
- GPRS user can hop channels (as in CDPD). 2.5G Technology

Gi = GSM User
Gpi = GPRS User

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<tr>
<td>Uplink 1</td>
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<td>Uplink 2</td>
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<td>Downlink 1</td>
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<td>GP₁</td>
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<td>G₁</td>
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<td>Downlink 2</td>
<td>GP₁</td>
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<td>GP₂</td>
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GPRS (Cont)

- Supports intermittent and bursty data transfers
  Point-to-multipoint also supported
- Need to add two new elements to GSM networks:
  - Service GPRS support node (SGSN)
    - Security, Mobility, Access control
  - Gateway GPRS support node (GGSN)
    - Connects to external packet switched networks
- Standardized by ETSI
EDGE

- Enhanced Data Rates for GSM Evolution (EDGE)
- Standard GSM uses Gaussian Minimum Shift Keying (GMSK) modulation
- EDGE changes to 8-PSK modulation $\Rightarrow$ 3 bits/Hz
- GPRS+EDGE $\Rightarrow$ 384 kbps
- Need better radio signal quality
## Data Rates

<table>
<thead>
<tr>
<th>Technology</th>
<th>Bandwidth</th>
<th>Data Rate/User (Theory)</th>
<th>Data Rate/User (Realistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM</td>
<td>200 kHz</td>
<td>9.6 kbps</td>
<td>9.6 kbps</td>
</tr>
<tr>
<td>GPRS</td>
<td>200 kHz</td>
<td>172 kbps</td>
<td>40 kbps</td>
</tr>
<tr>
<td>EDGE</td>
<td>200 kHz</td>
<td>474 kbps</td>
<td>100 kbps</td>
</tr>
<tr>
<td>CDMA2000 3x</td>
<td>3.75 MHz</td>
<td>2 Mbps</td>
<td>384 kbps</td>
</tr>
<tr>
<td>WCDMA</td>
<td>5 MHz</td>
<td>2 Mbps</td>
<td>1 Mbps</td>
</tr>
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</table>
HSDPA

- High-Speed Downlink Packet Access for W-CDMA
- Improved spectral efficiency for downlink ⇒ Asymmetric
- Up to 10 Mbps in theory, 2Mbps+ in practice
- Announced by Siemens, then by Ericsson, Alcatel, Fujitsu
- Adaptive modulation and coding (AMC)
- Multi-code (multiple CDMA channels) transmission
- Fast physical layer (L1) hybrid ARQ (H-ARQ)
- Packet scheduler moved from the radio network controller (RNC) to the Node-B (base station)
  ⇒ advanced packet scheduling techniques
  ⇒ user data rate can be adjusted to match the instantaneous radio channel conditions.
1xEV-DV

- 1x Evolution to Data and Voice (1xEV-DV)
- Single 1.25 MHz bandwidth shared between voice and data users
- 3.1 Mbps peak data rate on Forward Packet Data Channel
- Voice users are usually scheduled first
- Dynamic allocation of the unused BS power to data users every slot cycle (1.25 ms)
1xEV-DV vs. 1xEV-DO

- EV-DV uses 1 RF channel for data and voice while EV-DO requires separate carrier frequencies
- Fully compatible with CdmaOne and CDMA2000 allowing all types of handoff between those systems ⇒ economical, incremental deployment; uninterrupted voice and data coverage
- EV-DV provides smooth coexistence between voice and data services
- IS-2000 Rel 0 BS can be upgraded to support EV-DV Rel C by addition of channel card and SW upgrade
- To upgrade the same BS to support EV-DO in addition to 1x, a separate RF path (from antennas through PA’s to channel card) is needed
## Data Rates

<table>
<thead>
<tr>
<th></th>
<th>Down Link</th>
<th>Up Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x</td>
<td>9.6 kbps – 614.4 kbps</td>
<td>9.6 kbps – 460.8 kbps</td>
</tr>
<tr>
<td>1xEV-DV Rel. C</td>
<td>9.6 kbps – 3.09 Mbps</td>
<td>9.6 kbps – 460.8 kbps</td>
</tr>
<tr>
<td>1xEV-DV Rel. D</td>
<td>9.6 kbps – 3.09 Mbps</td>
<td>9.6 kbps – 1.5 Mbps</td>
</tr>
<tr>
<td>1xEV-DO</td>
<td>38.4 kbps – 2.45 Mbps</td>
<td>9.6 kbps – 450.8 kbps</td>
</tr>
<tr>
<td>1xEV-DO Rel. A</td>
<td>38.4 kbps – 2.45 Mbps</td>
<td>9.6 kbps – 1.5 Mbps</td>
</tr>
</tbody>
</table>
3G Deployments

- 3G deployments are finally happening.
- UMTS forum lists statistics (March 2010)
  Ref: http://www.umts-forum.org/
  - Total cell phones 3.3B
  - GSM based 2.6B = 80%
  - HSPA = 216 M
  - WCDMA+HSPA = 507 M
Evolution of Cellular Technologies

NA
- AMPS
- CDMA
- NA-TDMA
- D-AMPS
- 1xEV-DO
- 1xEV-DV
- CDMA2000

Europe
- TACS
- GSM
- GPRS
- EDGE
- WCDMA
- HSDPA

China
- TD-SCDMA

Analog → Digital
FDMA → TDMA → CDMA

Voice 1G | Voice 2G | 2.5G | Voice+Data 3G
Summary

- Three systems for 3G: W-CDMA (ROW), CDMA2000 (NA), TD-SCDMA (China)
- GPRS and EDGE = 2.5 G path for GSM systems
- 1xEV-DO and 1xEV-DV = 2.5G CDMAone systems
- CDMA2000 allows many channel width: 1xRTT, 3x, 6x
- HSDPA provides a high-speed asymmetric data on 3G systems
Homework 15

- Read chapters 1, 4, and 5 from Harte, et al. (on 2 hour reserve in Olin Library) or read the Wikipedia articles
- Draw a diagram showing the constellations of 8PSK modulation used in EDGE systems
Wikipedia References: 2.5G and 3G

Wikipedia References (Cont)

Wikipedia References (Cont)

List of Acronyms

- **3GPP** 3rd Generation Partnership Project
- **AMC** Adaptive modulation and coding
- **ARQ** Automatic Repeat reQuest
- **BS** Base Station
- **CDMA** Code Division Multiple Access
- **CWTS** China Wireless Telecommunication Standards group
- **EVDO** Evolution Data-Only
- **EVDV** Evolution Data and Voice
- **EDGE** Enhanced Data rates for GSM Evolution
- **GAN** Generic Access Network
- **GHz** Giga Hertz
- **GPRS** General Packet Radio Service
- **GSM** Global system for mobile communication
- **HSCSD** High-Speed Circuit Switched Data
- **HSDPA** High-Speed Downlink Packet Access
List of Acronyms (Cont)

- HSOPA  High-Speed OFDM Packet Access
- HSPA  High-Speed Packet Access
- ITU  International Telecommunications Union
- LTE  Long-Term Evolution
- MHz  Mega Hertz
- PSK  Phase-Shift Keying
- TD-SCDMA  Time-Division Synchronous Code-Division Multiple Access
- UMTS  Universal Mobile Telecommunications System
- WCDMA  Wideband Code Division Multiple Access
- $x$RTT  $x$ times Radio Transmission Technology