3G: HSPA, cdma 2000

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2700 Slides 12

Third Generation Standards

- ITU approved suite of four 3G standards
- EDGE (Enhanced Data rates for Global Evolution)
  - TDMA standard with advanced modulation and combined timeslots
  - Provides unification of NA-TDMA and GSM
  - Only meets some of the 3G requirements (2.75G?)
- UMTS (Universal Mobile Telephone Service) also called WCDMA (wideband CDMA)
  - Dominant standard outside of US and leading standard for 3G worldwide
  - Viewed as 3G migration path for GSM/GPRS/EDGE systems
- CDMA 2000
  - Also called (3X and cdma three): competes directly with W-CDMA up to 2 Mb/s
  - Evolutionary path for IS-95 which is the dominant standard in the US
- TD-SCDMA: Stand alone standard developed in China
Evolution Path to 3G

2G systems → EDGE

IS-95 CDMA → GPRSA IS-95 CDMA → GPRSA

CDMA 2000 1x-RTT → EDGE

GPRS → EDGE

CDMA 2000 1xEVDO → UMTS (WCDMA)

3G systems

HIGH SPEED DOWLINK PACKET ACCESS (HSDPA)

- HSDPA ≈ 3.5G system upgrade of UMTS
- Standardised in 3GPP Release 5
- Objective is to support delay-tolerant services in low mobility scenarios with enhanced resource efficiency and service quality
  - support for background, interactive and (to some extent) streaming services
  - low mobility
  - enable downlink peak rates of 8-10 Mbits/s >> 3G requirements
  - lower resource consumption per transferred delay-tolerant bit
HIGH SPEED DOWLINK PACKET ACCESS

- HSDPA upgrade of UMTS similar to EDGE
  - upgrade of GPRS
  - completely backwards compatible
  - no new spectrum needed
  - reuse existing infrastructure and 5MHz channels
    - primarily software and minor hardware upgrades
  - coexistence of HSDPA- and non-HSDPA-enabled terminals
  - coexistence of HSDPA- and non-HSDPA-enabled NODE-Bs
    - data flows on HS-DSCH moving from non-HSDPA-cell to HSDPA-cell are automatically switched to a supported transport channel, e.g. DCH
    - gradual hot-spot-based network upgrades possible
  - cost-effective

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HSDPA Architecture

- Upgrade UMTS downlink channels to a HS version:
  - higher-order modulation: QPSK and 16-QAM
  - fast link adaptation: adaptive modulation and coding
  - fast channel-aware scheduling: centered at the Node B
  - fast hybrid ARQ on downlink: combines FEC and selective ARQ
  - reduced TTI of 2 ms: to facilitate better tracking of channel variations
  - HS channels typically transmit at relatively fixed power
NEW PHYSICAL CHANNELS

- **HS-PDSCH** downlink SF 16 data only (up to 15 streams to a user)
- **HS-SCCH(s)** downlink MAC-hs signalling, H-ARQ, etc.
- **HS-DPCCH** uplink SF 256 CQI, (N)ACK

PHYSICAL LAYER PROCESSING

- Physical Layer Processing
  - Turbo encoding
  - Rate matching
  - Interleaving
  - Modulation (series → parallel)
  - Mapping on code tree
  - Spreading
  - Complex scrambling
  - Gain
  - Other channels

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ADAPTIVE MODULATION AND CODING

- LINK ADAPTATION: channel-dependent AMC
  - typically more efficient for services that tolerate short-term data rate variations
  - with only power-controlled channels, it is difficult to exploit all resources
  - AMC can exploit resources better, at the cost of transfer rate jitter
  - Fixed spreading factor SF but variable number of streams and bits per channel symbol

<table>
<thead>
<tr>
<th>MODULATION</th>
<th>SPREADING FACTOR</th>
<th>TURBO CODE RATE</th>
<th>BITS/ BLOCK/CODE</th>
<th>DATA RATE (15 CODES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>16</td>
<td>1/4</td>
<td>240</td>
<td>1.8 Mbps</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>1/2</td>
<td>470</td>
<td>3.6 Mbps</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>3/4</td>
<td>711</td>
<td>5.3 Mbps</td>
</tr>
<tr>
<td>16-QAM</td>
<td>16</td>
<td>1/2</td>
<td>950</td>
<td>7.2 Mbps</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>3/4</td>
<td>1440</td>
<td>10.8 Mbps</td>
</tr>
</tbody>
</table>

HSDPA Upgrades

- Infrastructure
  - NODE-B
    - a new MAC sublayer (MAC-hs) is standardised and needs to be implemented in the NODE-B
    - depending on the legacy NODE-B capabilities, this update may be done via remote software downloads or may possibly require hardware upgrades as well
  - RNC is largely maintains the UMTS Release '99 functionality
    - a software-only upgrade is required, e.g. to enable assignment of data flows to the HS-DSCH (~ channel switching)
  - no substantial impact on the CORE network is expected
- New Mobile Terminals
  - Support physical interface, higher data rates and H-ARQ
- HSDPA deployments began 2006 in Europe, Canada, etc. Over 100 deployments
HSUPA

- High Speed Uplink Packet Access
- Similar to HSDPA – advanced coding and modulation techniques with hybrid ARQ to improve data rate on uplink channel in UMTS
- Now called Enhanced Uplink (EUL) (3GPP)
- Data rates from .73Mbps – 5.76Mbps, 11.5Mbps being tested
- Uses new Enhanced versions of Signaling and physical channels
- Focus of UMTS now on IP in the backhaul

3GPP IP Reference Architecture

The 3GPP IP reference architecture – all traffic IP - with QoS Classes
UMTS

- UMTS is most popular 3G technology
  - Upgrade path from GPRS/EDGE – primarily in air interface to WCDMA standard
  - Now called 3GSM
  - WCDMA – variable power/spreading cdma
  - Provides standard benefits of cdma technology (frequency reuse factor 1, soft handoff, etc.)
  - Deployed throughout the world
  - Upgrade path to HSPDA and HSUPA and all IP in the core defined - over 62.5 million HSPA users

cdma2000

- cdma2000
  - Goal: provide 2.5G and 3G services over TIA/EIA-41 systems which include IS-95a, b, cdmaone systems
  - Evolutionary path
    - cdma2000-1xRTT uses multiple codes on same 1.25 MHz carrier of IS-95 and slight change to the modulation to provide packet data – up to 78 Kbps (basically 2.5G standard)
    - cdma2000-1x-EVDO – a 1.25 MHz radio carrier is dedicated to data only (DO) more Walsh codes per carrier (256) – high data rates – 646 kbps
    - Cdma 2000 1x-EV-DV – carriers supports both data and packetized voice voice, all IP backhaul network
  - CDMA 2000 3x RTT called multi-carrier mode CDMA
    - Extension of IS-95 – uses multiple x 1.25Mhz IS-95 channels
    - On hold until market demands it.
  - IS-41 or GSM MAP signalling in core
CDMA2000 1x Network

- BTS - Base Transceiver Station
- BSC - Base Station Controller
- MSC - Mobile Switching Center
- HLR - Home Location Registry
- SMS-SC - Short Message Service - Serving Center
- STM – Synchronous Transfer Mode
- PDSN – Packet Data Serving Node
- AAA – Authentication, Authorization, and Accounting
- Home Agent – Mobile IP Home Agent
- A10 – Bearer interface between BSC (PCF) and PDSN for packet data
- A11 – Signaling interface between BSC (PCF) and PDSN for packet data

2G System IS-95 (cdmaone)

- CDMAone
- 2G system
- Voice 14.4 Kbps or variable rate 9.6 Kbps
- Data 14.4 Kbps
- 1.25 MHz carrier
- 64 Walsh codes per carrier
### Packet Data Serving Node (PDSN)

- **PDSN** – similar to SGSN in GPRS
- Establish, maintain, and terminate PPP sessions with mobile station
- Support simple and mobile IP services
  - Act as mobile IP Foreign Agent for visiting mobile station
- Handle authentication, authorization, and accounting (AAA) for mobile station
  - uses RADIUS protocol
- Route packets between mobile stations and external packet data networks
- Collect usage data and forward to AAA server
AAA Server and Home Agent

- **AAA server**
  - Authentication: PPP and mobile IP connections
  - Authorization: service profile and security key distribution and management
  - Accounting: usage data for billing

- **Mobile IP Home Agent**
  - Track location of mobile IP subscribers when they move from one network to another
  - Receive packets on behalf of the mobile node when node is attached to a foreign network and deliver packets to mobile’s current point of attachment

1xEVDO -- Data Only on some carriers

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### Multicarrier CDMA (CDMA2000 – 3x)

- Deployed in the same frequency spectrum as IS-95
- 144 Kbps – 384 Kbps high-mobility access
- 2048 Kbps limited coverage
- Uplink: Single wideband carrier with chip rate 3.6864 Mcps
- Downlink: Multiple (up to 12) narrow band carriers (1.2288 Mcps)
- Same architecture at cdma2000 1XEVDO – requires base station and MS equipment changes

#### Downlink

\[ N \times 1.25 \text{ MHz} \]

#### Uplink

\[ 3.75 \text{ MHz} \]
### CDMA2000 Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel bandwidth</td>
<td>1.25, $N \times 1.25$ MHz, UL = 3.75 MHz</td>
</tr>
<tr>
<td>Channel structure</td>
<td>Direct spread spectrum or multicarrier spread spectrum</td>
</tr>
<tr>
<td>Chip rate</td>
<td>$3.6864$ Mcps for direct spread, $n \times 1.2288$ Mcps ($n = 1, 3, 6, 9, 12$) for multicarrier</td>
</tr>
<tr>
<td>Frame length</td>
<td>20 ms for data and control, 5 ms for control information on the fundamental and dedicated control channel</td>
</tr>
<tr>
<td>Handover</td>
<td>Soft handover and interfrequency handover</td>
</tr>
</tbody>
</table>

### 3GPP2 IP Architecture Model

The 3GPP2 IP architecture model supporting mobile IP:

- **VLR**
- **Virtual AAA**
- **PDN (FA)**
- **AAA**
- **HA**
- **Legacy (2G) networks**
- **PCF**
- **SDU**
- **IP-based Radio access network**

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Wireless Access Provider Network
## Systems Comparison

<table>
<thead>
<tr>
<th></th>
<th>CDMA 2000</th>
<th>UMTS</th>
<th>GSM</th>
<th>IS-95</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Channel</strong></td>
<td>1 to N x 1.25 MHz channels DL, UL 3.75 MHz</td>
<td>5 MHz</td>
<td>200 kHz</td>
<td>1.23 MHz</td>
</tr>
<tr>
<td><strong>Modulation</strong></td>
<td>OQPSK</td>
<td>QPSK</td>
<td>GMSK</td>
<td>OQPSK</td>
</tr>
<tr>
<td><strong>Channel rate</strong></td>
<td>N x 1.288 Mcps in downlink, 3.6864 Mcps uplink</td>
<td>3.84 Mcps</td>
<td>270.833kbs</td>
<td>1,228.8kcps</td>
</tr>
<tr>
<td><strong>Modulation Efficiency (br/Hz)</strong></td>
<td>1</td>
<td>.768</td>
<td>1.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### CDMA 2000 - UMTS - GSM - IS-95

#### Power Control
- **CDMA 2000**: 800 Hz up and down link
- **UMTS**: 1500 Hz up and down link
- **GSM**: 2 Hz
- **IS-95**: 800 Hz uplink

#### Base Station Synch
- **CDMA 2000**: Yes using GPS
- **UMTS**: No
- **GSM**: No
- **IS-95**: Yes, using GPS

#### Load Based Scheduling
- **CDMA 2000**: Somewhat with coding and multiple carriers
- **UMTS**: Yes variable spreading and coding, TDD mode
- **GSM**: Voice only
- **IS-95**: Voice only

#### System standard
- **CDMA 2000**: Air only at this time
- **UMTS**: Complete System
- **GSM**: Complete System
- **IS-95**: Air only

#### Security
- **CDMA 2000**: Spread Spectrum + AAA IP (eventually)
- **UMTS**: F1-F9 algorithms + USIM card
- **GSM**: A3, A5, A8 algorithm + SIM card
- **IS-95**: Spread Spectrum + optional CAVE
Pros and Cons

- **CDMA2000**
  - Pros: Better migration story from 2G to 3G
    - cdmaOne operators don’t need additional spectrum
    - 3x promises higher data rates than UMTS, i.e. W-CDMA
  - Cons: CDMA2000 core network less mature
    - cdmaOne interfaces were vendor-specific
    - hopefully CDMA2000 vendors will comply w/ 3GPP2

- **UMTS/3GSM**
  - Pros: Largest market share
    - First to market with new equipment/phones
    - All the advantages of CDMA
    - Higher data rates with HSPA
  - Cons: Need new/more spectrum (5MHz channels)
    - Expensive to implement