3G WCDMA

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Multiple Access Technologies

- CDMA – Code Division for Multiple Access.
- Each user is allocated a certain “code” sequence on which he transmits his data.
- The codes of different users are orthogonal.
CDMA Cocktail Party

• CDMA Communication is analogous to a “Cocktail party” scenario.

• Imagine several conversations going on in a room but softly.
  – Different groups are talking in different language

• Unless you know the language, you cannot understand the conversation
  – This is the principle of code

• Rest of the conversations will appear as noise
  – This is interference
Introduction 3G UMTS
UMTS Overview

• 2G Wireless Systems.
  – GSM, CDMA One (IS-95).
  – Wireless voice communications, SMS, Basic Data (EDGE, GPRS)

• UMTS (Universal Mobile Telecommunication System).
  – WCDMA (Wideband CDMA) is the air interface for UMTS.
UMTS Overview

• Created by 3GPP (3rd Generation Partnership Project).

• Designed for Multimedia Communication.
  – High quality images and video.
  – Access to information and services.
UMTS History

  – Identified frequencies around 2GHz for 3G.
• Original target – Single 3rd generation air interface.
• In 1998 ETSI adopted WCDMA.
• First commercial networks – Japan ‘01, Europe ‘02.
UMTS Timeline

• UMTS Development and Deployment timeline.

3GPP Release 99
CDMA Air Interface

3GPP Release 4

3GPP Release 5
IMS/HSDPA

3GPP Release 6
HSUPA
MBMS


Deployed in Japan

Commercial Deployment in Europe

3GPP Release 7
HSPA+ VOIP

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Cellular Data Rate Evolution

- **3GPP R99**: 0.4 Mbps
- **3GPP R5**: 14 Mbps
  - DL Peak Rate: 14 Mbps
  - UL Peak Rate: 0.4 Mbps
- **3GPP R6**: 5.7 Mbps
  - DL Peak Rate: 14 Mbps
  - UL Peak Rate: 0.4 Mbps
- **3GPP R7**: 11 Mbps
  - LTE: 28 Mbps
  - HSPA: 5.7 Mbps
- **3GPP R8**: 50 Mbps
  - LTE: 160 Mbps
  - HSPA: 42 Mbps

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UMTS Peak Data Rate Evolution

• R99 in theory enabled 2 Mbps, but in practice gave 384 Kbps.

• HSPA in Release 5 and Release 6 pushes the peak rates to 14 Mbps in downlink and 5.7 Mbps in uplink.

• HSPA evolution in Release 7 brings a maximum 28 Mbps in downlink and 11 Mbps in uplink.

• LTE will then further push the peak rates beyond 100 Mbps in downlink and 50 Mbps in uplink.
  – It employs a 20 MHz bandwidth.
Salient features of WCDMA

• Bit rates up to 2 Mbps.
• Variable bit rate to offer bandwidth on demand.
• Multiplexing of speech, video, data on a single link.
• Capability to handle variable delay requirements.
  – From delay sensitive to best effort packet data.
• Variable quality requirements.
  – 10% FER to $10^{-6}$ BER.
Salient features of WCDMA

- Coexistence of 2G and 3G with inter-system handovers for enhanced coverage.
  - Backward compatibility
- High spectrum efficiency.
- Support of asymmetric uplink and downlink.
  - For asymmetric apps such as web browsing.
- Coexistence of FDD and TDD modes.
# WCDMA vs. GSM Air Interfaces

<table>
<thead>
<tr>
<th></th>
<th><strong>WCDMA</strong></th>
<th><strong>GSM</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier spacing</td>
<td>5 MHz</td>
<td>200 KHz</td>
</tr>
<tr>
<td>Frequency reuse factor</td>
<td>1</td>
<td>1-18</td>
</tr>
<tr>
<td>Frequency diversity</td>
<td>Multipath diversity with Rake combining.</td>
<td>Frequency hopping.</td>
</tr>
<tr>
<td>Packet data</td>
<td>Load based packet scheduling.</td>
<td>Time slot based scheduling with GPRS.</td>
</tr>
<tr>
<td>Downlink transmit diversity</td>
<td>Supported.</td>
<td>Not supported.</td>
</tr>
</tbody>
</table>

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## WCDMA vs IS-95 Air Interfaces

<table>
<thead>
<tr>
<th></th>
<th>WCDMA</th>
<th>IS-95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier spacing</td>
<td>5 MHz</td>
<td>1.25 MHz</td>
</tr>
<tr>
<td>Base station synchronization</td>
<td>Not needed.</td>
<td>Yes, obtained via GPS.</td>
</tr>
<tr>
<td>Efficient radio resource</td>
<td>Yes, provides QOS.</td>
<td>Not needed for speech only</td>
</tr>
<tr>
<td>management algorithms</td>
<td>For voice and video</td>
<td>networks.</td>
</tr>
<tr>
<td>Packet data</td>
<td>Load based packet</td>
<td>Packet data transmitted</td>
</tr>
<tr>
<td></td>
<td>scheduling.</td>
<td>on circuit switched calls.</td>
</tr>
<tr>
<td>Downlink transmit</td>
<td>Supported.</td>
<td>Not supported.</td>
</tr>
<tr>
<td>diversity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Services and Applications
Introduction

• 2\textsuperscript{nd} Generation systems like GSM, were originally designed for efficient delivery of voice services.

• UMTS networks are, on the contrary, designed from the beginning for flexible delivery of any service.
  – High bit rates theoretically up to 2 Mbps in 3GPP Release ’99.
  – Beyond 10 Mbps in 3GPP Release 5.
  – Practical bit rates are up to 384 kbps initially, and beyond 2 Mbps with Release 5.
  – Low delays with packet RTTs below 200 ms.
Types of Services

• Services are divided into

• Person-to-Person
  – Peer-to-peer or intermediate server based connection between two persons or a group of persons.
  – Example: AMR Speech, Push-To-Talk etc.
Types of Services

• Content-to-Person
  – Characterized by the access to information or download of content – UDP Based.
  – Example: Audio/Video Streaming.

• Business/Enterprise Connectivity
  – Laptop (Data Cards) access to internet or intranet using WCDMA as the radio modem.
Images and Multimedia

• The end user performance requirements for the real time video sharing service are that
  – Image quality and update rates should be high enough to enable ‘scanning’ the environment with the camera.
  – Delay between taking a picture and showing it to the other side is low enough to enable true interactivity.
Evolution of P-to-P video service

Person to Person video service evolution

- No CS Component 2-Way PS Video Telephony
- CS Voice Call + PS real time 1-Way video sharing
- CS Voice call + PS MMS still pictures and videos

Packet switched delay requirements

- <400 ms e2e delay Conversational requirements
- <5 second video delay. Streaming requirements
- <1 minute MMS delivery Background delay requirements.

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Content-to-person Services
Audio and Visual Streaming

• Streaming applications are very asymmetric.
  – Withstand more delay than conversational services.
  – Jitter has to be smoothed out.

• Web broadcast
  – Usually target very large audiences that connect to a media server
  – Offer their core products for 28.8 kbps market.

• Video streaming on demand.
  – Video clips or lectures to a server connected to a higher bandwidth local intranet.
  – Bandwidth variation sensitive. Streaming in the 100 Kbps to 7.300 Mbps intranet market
Radio Access Network Architecture
System Architecture

• Network elements are grouped into
  – User Equipment (UE) that interfaces with the user.
  – UMTS Terrestrial RAN (UTRAN) that handles all radio-related functionality.
  – Core Network responsible for switching and routing calls and data connections to external networks.
System Architecture

UMTS High Level System Architecture

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Sub-Networks based modular UMTS

Network elements in a PLMN

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UMTS Architectural Elements

• User Equipment (UE) consists of two parts:
  – Mobile Equipment (ME)
    • The terminal used for radio communication.
    • Communicates over the air interface.
  – UMTS Subscriber Identity Module (USIM)
    • Smartcard that holds the subscriber identity.
    • Stores authentication algorithms.
    • Stores authentication and encryption keys.
    • Subscription information that is needed at the terminal.
UMTS Architectural Elements

• UMTS Terrestrial RAN (UTRAN)
  – Node B
    • Converts the data flow between the wired and wireless interfaces.
    • Generically termed the ‘Base Station’.
  – Radio Network Controller (RNC)
    • Controls the radio resources in its domain.
    • Similar to BSC in GSM.
High-Speed Downlink Packet Access (HSDPA)
HSDPA Introduction

- HSDPA (High Speed Downlink Packet Access) concept has been designed to increase downlink packet data throughput (5-30 Mbps) by means of
  - Fast PHY (L1) retransmission and transmission combining for packet drops.
  - Fast link adaptation controlled by the Node B (Base Transceiver Station (BTS)) – to efficiently use wireless channel.
HSDPA Features

New Node B functionality, fast scheduling based on
• Quality Feedback
• UE Capability
• Resource Availability
• Buffer Status
• Qos and Priority

Channel Quality feedback
Channel quality indicator, Power Control Commands, ACK/ NACK info
HSDPA Features

• Adaptive modulation and coding (AMC)
• Extensive multi-code operation.
  – A Single user may simultaneously utilize up to 15 multi-codes in parallel.
• A fast and efficient retransmission strategy.
• Scheduling decisions are done in the Node B.
## HSDPA vs WCDMA Features - Comparison

<table>
<thead>
<tr>
<th>Feature</th>
<th>WCDMA</th>
<th>HSDPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft Handover</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Fast Power Control</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>AMC</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Multi-Code</td>
<td>Yes</td>
<td>Yes, Extended</td>
</tr>
<tr>
<td>Fast Retransmission</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>BTS Scheduling</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>