UMTS – W-CDMA

- The 3G global cellular standard set to supersede GSM
- Universal Mobile Telecommunication System (UMTS)
- Slow on the uptake – by mid-2008 UMTS only had 250 million subscribers worldwide, compared to 2.5 billion on GSM
- Standards developed and maintained by the Third Generation Partnership Project (3GPP)
UMTS – W-CDMA

- It has been a long development time-line to roll-out 2003/2005

3GPP

- Established in 1998
- ARIB (Japan), ATIS (USA), CCSA (China), ETSI (Europe), TTA (Korea), and TTC (Japan)
- Technical Study groups focus on each aspect of the network
UMTS Network

- Developed as an evolution of GSM network
- High-level network topology
- Essentially a combination of GSM C-S network with GPRS P-S network

GPRS developed the Core Network to be packet switched
UMTS Network

- UMTS Terrestrial Radio Access Network (UTRAN)
  - Enhanced air data rates – 2Mbps in R99 and potentially 10Mbps in R6
- Universal Integrated Circuit Card (UICC)
  - Generalisation of the SIM card to a greater diversity of User Equipment
- IP Multimedia Sub-system (IMS)
  - For the provision of IP-based multimedia services

UICC

- Contains the:
  - SIM (for GSM)
  - Universal SIM (for UMTS)
  - IP multimedia Services Identity Module (ISIM)
UMTS Network

- Co-existence of the GSM core network with the UMTS network

UMTS Protocol Suite

- Inherits the GPRS TCP/IP packet based protocol stack
UMTS Protocol Suite

• Some modifications to the GSM-based circuit-switched core

Protocol and Channels for UTRAN

• Formalised the idea of the Transport Channel as a logical channel grouping
Channel Structure

- Logical Channels are mapped to Transport Channels which are in turn mapped to Physical Channels

Logical Channels

Main Types of Logical Channels are:
- BCCH (Broadcast Control Channel) – Downlink only. Broadcasts system and cell specific information.
- PCCH (Paging Control Channel) – Downlink only. For paging and short messages.
- DCCH (Dedicated Control Channel) – Bi-directional. For point to point control information transfer.
- CCCH (Common Control Channel) – Bi-directional. For point to multipoint control information transfer.
- DTCH (Dedicated Traffic Channel) – Bi-directional. To transmit user data.
- CTCH (Common Traffic Channel) – Downlink point to multipoint channel. For the transfer of data to multiple users.
Transport Channels

Main types of transport channels:
- RACH (Random Access Channel) – Uplink, contention-based channel, using the Slotted ALOHA protocol. Used for initial access or non-real-time dedicated control or user data. Has a limited size data field.
- CPCH (Common Packet Channel) – Uplink, contention-based channel, for the transmission of bursty data traffic.
- FACH (Forward Access Channel) – Downlink common channel, and may carry small amounts of user data.
- DSCH (Downlink Shared Channel) – Used for dedicated control or traffic data. Associated to a DCH (doesn’t exist alone).
- BCH (Broadcast Channel) – Downlink, for the broadcast of system and cell specific data.
- PCH (Paging Channel) – Downlink.
- DCH (Dedicated Channel) – Either uplink or downlink, and associated with a single UE.

Physical Channels

Finally, types of physical channels:
- CPICH (Common Pilot Channel) – this is at a fixed data rate of 30 kbps. There are two types: Primary CPICH, used as a phase reference for the SCH, primary CCPCH, AICH, and PICH, and other downlink physical channels; and the Secondary CPICH, used as a reference for the secondary CCPCH and the downlink DCH.
- CCPCH (Primary – Common Control Physical Channel) – carries the BCH at 30 kbps.
- CCPCH (Secondary – Common Control Physical Channel) – carries the FACH and PCH, and is variable rate.
- SCH (Synchronisation Channel) – used for cell searches.
- PDSCH (Physical Downlink Shared Channel) – carries the DSCH, and always associated to a DPDCH.
Physical Channels

- AICH (Acquisition Indicator Channel) – carries signatures for the random access procedure.
- PICH (Page Indication Channel) – carries indicators to indicate the presence of paging messages on the PCH.
- AP-AICH (Access Preamble Acquisition Indicator Channel) – carries AP acquisition indicators of the associated CPCH.
- CSICH (CPCH Status Indicator Channel) – carries CPCH status information.
- CD/CA-ICH (Collision Detection/Channel Assignment Indicator Channel).
- DPDCH (Dedicated Physical Data Channel) – carries a DCH, containing data from above layer 2.
- DPCCH (Dedicated Physical Control Channel) – carries uplink control information.
- PRACH (Physical Random Access Channel) – carries the RACH.
- PCPCH (Physical Common Packet Channel) – carries the CPCH.

UTRAN - Physical Layer

- The transport channels are mapped onto physical channels
- Transport Format Combination Indicator (TFCI) designates which channel type it is
Spreading

- Two spreading codes are used:
  - Channelization codes and scrambling codes

- Their usage differs for the up-link and down-link
- Scrambling Codes: typically Gold codes

Scrambling Codes

- For the Uplink: Used to distinguish MS. For security and spectral performance
- For the Downlink: Used to distinguish different cells
Channelisation Codes

- Orthogonal Variable Length Spreading (OVSF)

![Channelisation Code Tree](image)

Modulation

- Modulation is Quadrature Phase Shift keying with complex spreading
- Quadrature multiplexing of Traffic and Control
- Root-raised cosine pulse shaping with roll-off of 0.22

![Modulation Diagram](image)
Channel Coding

• The standard allows for the use of convolutional encoders or turbo coders
• Their particular applications depend on the QoS service required (the type of data to be protected)
• Both rate 1/2 and rate 1/3 convolutional encoders are specified

Channel Coding

• Turbo coders can be used for higher data rate traffic
Speech Codec

- Adaptive Multi-Rate codec
- Bit rates are based on frames of 160 bits that are 20ms in duration
- Bit rates of 12.2, 10.2, 7.95, 7.40, 6.70, 5.90, 5.15 and 4.75 kbps are produced
- Uses Algebraic Code Excited Linear Predictive Coding
- Features discontinuous transmission (DTX), Voice activity detection (VAD), and Comfort Noise Generation (CNG)

Downlink Processing

- A summary of the downlink data processing

**Figure 7.4** Downlink procedure.
Uplink Processing

- A summary of the data processing for the uplink

![Diagram of Uplink Processing]

Summary of W-CDMA Features

- Employs both Open loop and closed loop power control
- Macro-diversity in both uplink and downlink
- Typical 5MHz channel, with chip rate 3.84Mcps (other values are also possible)
- Asynchronous network (unlike cdma2000)
- Standard 10ms frame, containing 16 timeslots
- Uses both frequency division duplexing (FDD) and Time Division Duplexing (TDD)
Variable QoS

- Different data types are provided different degrees of radio resources
- QoS classes

Summary of W-CDMA Features

- There is support for Smart Antennae and Beam-forming at the base stations (Node B)
- Employs soft-handovers (and macro-diversity)
- Open loop and Closed loop power control (at 1500Hz)
- Pilot tone is embedded by TDM. This allows carrier synchronisation for coherent detection, channel estimation and equalisation to be performed
- RAKE Receiver is employed
RAKE Receiver

- W-CDMA employs a three finger RAKE receiver with MRC
- Resolution is 0.26µs, equivalent to 78m (chip rate is 3.84Mcps)
- Number of RAKE fingers can be increased during a soft handoff

![RAKE Receiver Diagram](image)

Interoperability with GSM

- Ability to handover to a GSM network to extend coverage

![Interoperability with GSM Diagram](image)
High Speed Packet Access (HSPA)

• Enhancement to W-CDMA to increase the available data rate
• HSDPA was deployed in 2006, followed by HSUPA in 2007
• Capable of achieving data rates of up to 9Mbps in ideal conditions
• Included in UMTS Release 5 and Release 6

HSPA Features

- 16 QAM modulation.
- A highly-efficient rate 1/3 turbo coder.
- Rapid feedback on channel conditions.
- Time-division multiplexing of user transmission using maximum channel resources.
- Dynamic maximisation and adjustment of transmit power.
- Use of multiple code channels.
- Use of code division multiplexing (CDM) for multi-user transmission during a TDM interval.
- Incremental redundancy in the form of Hybrid ARQ (H-ARQ).
HSDPA Operation

The operation of the HSDPA downlink is as follows:

1. Every 2 ms each mobile unit that has an active packet data connection measures and reports its channel quality in the form of a Channel Quality Indicator (CQI) value.

2. A scheduler at Node B considers a variety of factors (CQIs of servicing mobiles, length of data queues, subscriber profiles, and fairness measures), and determines which users will be serviced in the next frame.

3. Based on the reported CQIs, and the data buffer lengths, the base station determines the data rate and the modulation type for each selected user.

4. Upon receipt of the transmitted information, and after verification with the CRC code, the each user responds with an ACK or NACK.