UMTS: High Speed Packet Access (HSPA) Technology

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Outline

• Introduction
• Basics of CDMA
• UMTS: WDMA Release 99
• UMTS: HSDPA Release 5
• UMTS: HSUPA Release 6
Introduction
IMT-2000 (3G)

• The International Telecommunications Union (ITU) defined the key requirements for International Mobile Telecommunications 2000 (IMT-2000) services.
• These requirements were that the system should support data rates of:
  • 2 Mbps in fixed or in-building environments
  • 384 kbps in pedestrian or urban environments
  • 144 kbps in wide area mobile environments
• IMT-2000 is more commonly known as… 3G.
Migration Path

2000  2001  2002  2003

Japan

PDC  →  W-CDMA

GSM  →  GPRS  →  EDGE

HSCSD

Europe

AMPS/D-AMPS  →  D-AMPS

IS-95A  →  IS-95B  →  CDMA2000

America

2G System

- Easy upgrade
- Upgrade requiring new modulation
- Upgrade requiring entire new radio system

3G System
Timeline: For UMTS and CDMA2000
Number of 3G subscribers: 550 Million

Source: www.3gtoday.com (Retired), Above slide: July 31, 2007
What is UMTS/WCDMA?

• Universal Mobile Telecommunication System/Wide-band CDMA is a 3G, Direct Sequence CDMA-based Radio Access Network (RAN), with chip rate of 3.84 Mcps.

• Designed to be deployed under GSM/GPRS network.

• “WCDMA” refers to the FDD Physical Layer and the protocols that support it.

• “UTRAN” refers to the WCDMA Radio Access network.

• “UMTS” refers to the entire network.

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
UMTS Releases

- Release 99: WCDMA
- Release 4: TD-SCDMA
- Release 5: HSDPA
- Release 6: HSUPA
- Combined HSDPA and HSUPA is called HSPA.
The UMTS Network

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
The carrier frequency is designated by the UTRA Absolute Radio Frequency Channel Number (UARFCN), where

\[ F_{\text{center}} = \text{UARFCN} \times 200 \text{ KHz} \]
# UMTS Terminology

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE</td>
<td>User Equipment</td>
</tr>
<tr>
<td>USIM</td>
<td>Universal Subscriber Identity Module</td>
</tr>
<tr>
<td>Node B</td>
<td>Base Station</td>
</tr>
<tr>
<td>RNC</td>
<td>Radio Network Controller</td>
</tr>
<tr>
<td>MSC</td>
<td>Mobile Switching Center</td>
</tr>
<tr>
<td>HLR</td>
<td>Home Location Register</td>
</tr>
<tr>
<td>AuC</td>
<td>Authentication Center</td>
</tr>
<tr>
<td>GMSC</td>
<td>Gateway MSC</td>
</tr>
<tr>
<td>VLR</td>
<td>Visitor Location Register</td>
</tr>
<tr>
<td>SGSN</td>
<td>Serving GPRS Support Node</td>
</tr>
<tr>
<td>GGSN</td>
<td>Gateway GPRS Support Node</td>
</tr>
<tr>
<td>PSTN</td>
<td>Public Switched Telephone Network</td>
</tr>
<tr>
<td>ISDN</td>
<td>Integrated Services Digital Network</td>
</tr>
</tbody>
</table>
UMTS Network Topology

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Basics of CDMA
Universal Frequency Reuse

Frequency Reuse Factor = 7 for AMPS

Frequency Reuse Factor = 4 for TDMA systems
Universal Frequency Reuse
Codes in UMTS/WCDMA

- OVSF Codes: Orthogonal Codes
- Gold Codes: Spreading Codes
  - DL PSC: 512, SSC: 7680
  - UL Scrambling Codes: 16.8 million
Orthogonal Codes

Orthogonal functions have **zero correlation**.

Two binary sequences are orthogonal if the process of “XORing” them results in an equal number of 1s and -1s:

**Example:**

\[
\begin{array}{cccc}
-1 & -1 & 1 & 1 \\
-1 & 1 & -1 & 1 \\
-1 & 1 & -1 & 1 \\
1 & -1 & -1 & 1 \\
\end{array}
\]

Orthogonal codes in WCDMA are termed orthogonal variable spreading factor (OVSF) codes.
User Separation using Orthogonal Codes

Spread Waveform Representation of User A's signal

+1
-1

Spread Waveform Representation of User B's signal

+1
-1

Spread Waveform Representation of User C's signal

+1
-1

Analog Signal Formed by the Summation of the Three Spread Signals

+1
-1
-3

A = 1 -1
Spreading Code for A = -1 1 1-1

B = -1 -1
Spreading Code for B = -1 1 -1 1

C = 1 1
Spreading Code for C = -1 -1 -1 -1

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Recovering the user data

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
OVSF Codes

Orthogonal Variable Spreading Factor (OVSF)

- Preserves the orthogonality between Downlink channels of different rates and spreading factors.
- Used on the Uplink to channelize multiple channels from a single UE.
- Used on the Downlink to channelize multiple UEs.
- 256 UL channel codes, 512 DL channel codes

\[
\begin{bmatrix}
    C_{ch,2,0} \\
    C_{ch,2,1}
\end{bmatrix}
= \begin{bmatrix}
    C_{ch,1,0} & C_{ch,1,0} \\
    -C_{ch,1,0} & -C_{ch,1,0}
\end{bmatrix}
= \begin{bmatrix}
    1 & 1 \\
    1 & -1
\end{bmatrix}
\]

\[
\begin{bmatrix}
    C_{ch,4,0} \\
    C_{ch,4,1} \\
    C_{ch,4,2} \\
    C_{ch,4,3}
\end{bmatrix}
= \begin{bmatrix}
    C_{ch,2,0} & C_{ch,2,0} \\
    -C_{ch,2,0} & -C_{ch,2,0} \\
    C_{ch,2,1} & C_{ch,2,1} \\
    -C_{ch,2,1} & -C_{ch,2,1}
\end{bmatrix}
= \begin{bmatrix}
    1 & 1 & 1 & 1 \\
    1 & 1 & -1 & -1 \\
    1 & -1 & 1 & -1 \\
    1 & -1 & -1 & 1
\end{bmatrix}
\]

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
OVSF Code Usage

For spreading, each DL channel assigned an OVSF code

- SF 1
- SF 2
- SF 4
- SF 8
- SF 16
- SF 32

Static allocations on the PSC
- CPICH $C_{ch, 256, 0}$
- PCCPCH $C_{ch, 256, 1}$

Typical DL Spreading Factors:
- SF 8 for UE 384 kbps data
- SF 128 for UE 12.2 kbps voice

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
OVSF Tree

Using a branch...

\[ C_{ch,1,0} = (1) \]

\[ C_{ch,2,0} = (1,1) \]

\[ C_{ch,4,0} = (1,1,1,1) \]

\[ C_{ch,4,1} = (1,1,-1,-1) \]

\[ C_{ch,4,2} = (1,-1,1,-1) \]

\[ C_{ch,4,3} = (1,-1,-1,1) \]

\( SF = 1 \quad SF = 2 \quad SF = 4 \)

Higher Data Rates \( \leftarrow \) \( \rightarrow \) Lower Data Rates

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Gold Codes

- Gold codes (produced using M-sequences)
- M-sequences (maximum length pseudorandom binary sequences) or PN codes

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Asynchronous Cell Operations

CDMA2000

GPS

PN_{t0} → PN_{t1} → PN_{t2}

PN_{t3} → PN_{t4} → PN_{t5}

PN_{t6} → PN_{t7}

UTRA-FDD

S_0 → S_1 → S_2

S_3 → S_4 → S_5

S_6 → S_7

PN_{t0-n} - Time offset scrambling code

- Cell sites transmission and reception are synchronized through GPS timing
- Adjacent cell sites use different time offsets of same scrambling code for spreading

S_{1-n} - Scrambling codes

- Cell sites are not synchronized
- Each cell site uses a different scrambling code for spreading

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Generation of Gold Codes \((2^5\text{-}1)\)

- Using two preferred M-sequence generators of degree \(r\), with a fixed non-zero seed in the first generator.
- The Downlink Gold code sequences are of length \(2^{18}\text{-}1\). They begin at phase 0, go up to phase 38399, and are repeated.
- The Uplink Gold code sequences are of length \(2^{25}\text{-}1\).

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Cross-Correlation of Gold Codes

\[ t(n) = \begin{cases} \frac{n-1}{2} & \text{for } n \text{ odd} \\ 1 + \frac{n+2}{2} & \text{for } n \text{ even} \end{cases} \]

Example: \( N=18, t(n)=1+2^{10}=1025 \)
\( \text{ACF}=218=2^{10} \cdot 144 \), Normalized=1.
Normalized Cross corr. = 0.0039
UMTS: WCDMA Release 5
Generic Physical Layer Procedures

- Coding
- Interleaving
- Mapping data onto physical channels
- Spreading using OVSF Channel codes
- PN Scrambling
- QPSK Modulation

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Spreading and Scrambling (DL)

- Spread with Channelization codes
- Scramble with PN codes

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Spreading and Scrambling (UL)

- Spread with Channelization codes
- Scramble with PN codes

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Scrambling Codes

Downlink PSCs

Uplink Scrambling Codes

Reference: WCDMA (UMTS) Overview, QUALCOMM UMTS University.
UMTS Channels

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
Soft Handover

Messages used in Soft Handover:
- Measurement Control
- Measurement Report
- Active Set Update
- Active Set Update Complete

Combining vs. Selecting:
- UE combines symbols received from each Node B
- RNC selects the best radio frame from each Node B

Reference: WCDMA(UMTS) Overview, QUALCOMM UMTS University.
High Speed Packet Access (HSDPA): Release 5
Evolution of 3G

- MM streaming
- MM sharing
- Wireless Broadband Access
- Interactive Gaming
- VoIP with AMR-WB

Data Services Evolution

- Rich Voice
  - Video Telephony
- Push-to-Talk
- Customized Infotainment
- Multimedia Messaging
- Text Messaging
- Speech

Spectral Efficiency

Peak Data Rate

- WCDMA (R99)
  - Voice & High Speed Data
- EDGE
  - Medium Speed Data
- GPRS
- Voice & Limited Data
- GSM

Evolved 3G

HSDPA/HSUPA
(Rel5 / Rel6)
Evolution of 3G: Data Rates

<table>
<thead>
<tr>
<th></th>
<th>Uplink Peak Data Rate (Typical Deployment)</th>
<th>Downlink Peak Data Rate (Typical Deployment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM</td>
<td>9.6 kbps</td>
<td>9.6 kbps</td>
</tr>
<tr>
<td>GPRS</td>
<td>20 kbps</td>
<td>40 kbps</td>
</tr>
<tr>
<td>EDGE</td>
<td>60 kbps</td>
<td>120 kbps</td>
</tr>
<tr>
<td>WCDMA Release 99</td>
<td>64 kbps</td>
<td>384 kbps</td>
</tr>
<tr>
<td>HSDPA - Release 5</td>
<td>384 kbps</td>
<td>10 Mbps*</td>
</tr>
<tr>
<td>HSUPA - Release 6</td>
<td>1.4 Mbps (early deployment)</td>
<td>10 Mbps</td>
</tr>
</tbody>
</table>
## Packet Data in Release 99

### How do we do Packet Data in Release 99

<table>
<thead>
<tr>
<th>Mode</th>
<th>DCH</th>
<th>FACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Type</td>
<td>Dedicated</td>
<td>Common</td>
</tr>
<tr>
<td>Power Control</td>
<td>Closed Inner Loop at 1500 Hz - Slower Outer Loop</td>
<td>None or slow (based on measurement report)</td>
</tr>
<tr>
<td>Soft Handover</td>
<td>Supported</td>
<td>Not Supported</td>
</tr>
<tr>
<td>Setup Time</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Suitability for Bursty Data</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Data Rate</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Radio Performance</td>
<td>Good</td>
<td>Poor</td>
</tr>
</tbody>
</table>
Release 99 Downlink Limitations

• **Limited Peak Data Rate**
  – Maximum implemented Downlink of 384 kbps

• **Capacity and Throughput**
  – Modulation and coding
    ◆ QPSK
    ◆ Convolution coding (R=1/2, 1/3) or turbo coding (R=1/3)
  – Link adaptation due to channel conditions
    ◆ Fast closed inner loop power control, but
    ◆ Slower outer loop

• **Minimum TTI of 10 ms**

• **Slow Rate and Type Switching**
HSDPA Basic Concepts

How does HSDPA address the limitations of Release 99?

• **Adaptive modulation and coding**
  – Fast feedback of channel condition
  – QPSK and 16-QAM
  – Coding from R=1/3 to R=1

• **Multi-Code operation**
  – Multiple codes allocated per user
  – Fixed spreading factor

• **Node B scheduling**
  – Physical Layer HARQ

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
The New Data Channel

Common Channel for data transfer using the HS-PDSCH

Node B

High Speed Physical Downlink Shared Channel (HS-PDSCH)

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
HS-PDSCH

- Fixed Spreading Factor SF=16
  - (Typical Spreading Factor for 128 kbps in Release 99)
- 1-15 codes can be reserved for HS-PDSCH
- Can be TDM or CDM between users

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
Adaptive Modulation and Coding

- Coding from R=1/3 to R=1
- HSPDA supports 16-QAM modulation
  - 4 bits per symbol versus 2 bits per symbol with QPSK

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
Link Adaptation Versus Power Control

- **Release 99**
  - Use fast power control with fixed data rate (DCH)

- **HSDPA**
  - Adapt the modulation and coding to the link quality

**Fast Link adaptation:**
- Rate #3: e.g. 16-QAM, R=3/4
- Rate #2: e.g. QPSK, R=3/4
- Rate #1: e.g. QPSK, R=1/2

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
Hybrid ARQ (HARQ)

• Scheme combining ARQ and Forward Error Correction
• FEC decoding based on all unsuccessful transmissions
• Stop-and-Wait (SAW) protocol
• Two basic schemes:
  – Chase Combining
    - Same data block is sent at each retransmission
  – Incremental Redundancy (IR)
    - Additional Redundant Information sent at each retransmission

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
HARQ Example

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
## Comparison Summary

<table>
<thead>
<tr>
<th>Mode</th>
<th>DCH</th>
<th>FACH</th>
<th>HSDPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Type</td>
<td>Dedicated</td>
<td>Common</td>
<td>Common</td>
</tr>
<tr>
<td>Power Control</td>
<td>Closed Inner Loop at 1500 Hz - Slow Outer Loop</td>
<td>None</td>
<td>Fixed Power with link adaptation</td>
</tr>
<tr>
<td>Soft Handover</td>
<td>Supported</td>
<td>Not Supported</td>
<td>Not Supported</td>
</tr>
<tr>
<td>Suitability for Bursty Data</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Data Rate / Traffic Volume</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>
Network Architecture with HSDPA
HSDPA Channels

Transport Channel

• High Speed Downlink Shared Channel (HS-DSCH)
  – Downlink Transport Channel

Physical Channels

• High Speed Shared Control Channel (HS-SCCH)
  – Downlink Control Channel
• High Speed Physical Downlink Shared Channel (HS-PDSCH)
  – Downlink Data Channel
• High Speed Dedicated Physical Control Channel (HS-DPCCH)
  – Uplink Control Channel

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
HSDPA Channels

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
HS-PDSCH and HS-SCCH
Spreading and Modulation

- **HS-PDSCH** is spread with SF 16, scrambled with Primary or Secondary Scrambling Code.
- **HS-SCCH** is spread with SF 128, scrambled with same code as HS-PDSCH.

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
HSDPA Operation

1. Each UE reports channel quality on HS-DPCCH.
2. The Node B determines which and when each UE is to be served.
3. The Node B informs the UE to be served via HS-SCCH.
4. Then deliver the data to the UE via HS-DSCH.
5. The UE sends feedback (ACK/NAK) back to Node B on HS-DPCCH.

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
HSDPA Operation: Timeline

1. HS-DPCCH
2. HS-SCCH
3. HS-PDSCH 1
4. HS-PDSCH N

ACK/NAK  CQI
High Speed Physical Downlink Shared Channel (HS-PDSCH)

- Carries UE data
- Up to 15 HS-PDSCH may be assigned simultaneously
  - UE capability indicates maximum number of codes it supports
- Uses Spreading Factor = 16
High Speed Dedicated Physical Control Channel (HS-PDCCH)

- 1\textsuperscript{st} slot carries ACK or NAK for received HS-DSCH blocks
- 2\textsuperscript{nd} and 3\textsuperscript{rd} slots carry Channel Quality Indicator (CQI)
  - UE measures Downlink CPICH channel quality
  - CQI indicates the highest data rate for error rate < 10\%
  - Frequency of CQI reports configured by UTRAN
- DTX during ACK/NAK and CQI slots if nothing to send
- Uses Spreading Factor = 256
**HS-SCCH**

**Downlink Channel**

- **Part 1**
- **Part 2**

2 ms
3 slots

**High Speed Shared Control Channel (HS-SCCH)**

- 1st part carries modulation information
  - OVSF code assignment
  - Modulation scheme
- 2nd part carries transport block size, Hybrid ARQ parameters
- UE Identity encoded over each part
  - UE decodes each part independently
- UE assigned up to 4 HS-SCCHs to monitor
- Uses Spreading Factor = 128

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
Question:

Assuming a transport block size of 320 bits, what HSDPA data rate can be achieved by a single UE using the channel allocation timing shown above?
HSDPA Data Rate

Answer:

320 bits are transmitted every 10 ms, so the maximum data rate is 32 kbps.
Theoretical HSDPA Data Rate

How do we get from 32 kbps to 14.4 Mbps?

• Multi-code transmission
• Consecutive assignments using multiple Hybrid Automatic Repeat Request (HARQ) processes
• Lower coding gain
• 16-QAM
Use of Multiple Codes

Data Rate with 15-code Multi-code

32 kbps X 15 = 480 kbps

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
Consecutive Assignment

Data Rate with Consecutive Assignments

480 kbps X 5 = 2.4 Mbps

HS-DPCCH

HS-SCCH

HS-PDSCH 1

HS-PDSCH 15

ACK
ACK
ACK
ACK

2 ms
Code Puncturing and use of QAM

Data Rate with Rate 1 Turbo Coding and QPSK Modulation

2.4 Mbps X 3 = 7.2 Mbps

Going from QPSK to 16-QAM: 7.2Mbps X 2 = 14.4 Mbps
Review

Review: How do we get to 14.4 Mbps?

- Multi-code transmission
  - Node B must allocate all 15 OVSF codes of length 16 to one UE

- Consecutive assignments
  - Node B must allocate all time slots to one UE
  - UE must decode all transmissions correctly on the first transmission

- Lower Coding Gain
  - Effective code rate = 1
  - Requires very good channel conditions to decode

- 16-QAM
  - Requires very good channel conditions
OVSF Allocation

Reference: WCDMA (UMTS) HSDPA Protocols and Physical Layer, QUALCOMM UMTS University.
High Speed Uplink Packet Access (HSUPA): Release 7
Release 99 Uplink Packet Data

How is Uplink Packet Data handled in Release 99?

• DCH (Dedicated Channel)
  – Variable spreading factor
  – Closed loop power control
  – Macro diversity (soft handover)

• RACH (Common Channel)
  – Common spreading code
  – Fixed (negotiated) spreading factor
  – No closed loop power control
  – No soft handover

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Release 99 Uplink Limitations

• **Large Scheduling Delays**
  – Slow scheduling from RNC

• **Large Latency**
  – Transmission Time Interval (TTI) durations of 10/20/40/80 ms
  – RNC based retransmissions in case of errors

• **Limited Uplink Data Rate**
  – Deployed peak data rate is 384 kbps

• **Limited Uplink Cell Capacity**
  – Typically about 800 kbps
High Speed Uplink Packet Access (HSPA)

- Set of high speed channels is received at the Node B.
- Interference is shared by multiple users.
- Several users may be allowed to transmit at given data rate and power on a fast scheduling.

Enhanced Dedicated Physical Data Channel (E-DPDCH)
## HSUPA vs. HSDPA

<table>
<thead>
<tr>
<th>HSDPA</th>
<th>HSUPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>New high-speed Channel</td>
<td>Dedicated Channel with Enhanced Capabilities</td>
</tr>
<tr>
<td>Shared</td>
<td></td>
</tr>
</tbody>
</table>

**HARQ with Fast Retransmission at Layer 1**

<table>
<thead>
<tr>
<th>Rate/Modulation Adaptation</th>
<th>Fast Power Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Serving Cell</td>
<td>Soft Handover</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fast Node-B Scheduler</th>
<th>Fast Node-B Scheduler</th>
</tr>
</thead>
<tbody>
<tr>
<td>“One-to-Many”</td>
<td>“Many-to-One”</td>
</tr>
<tr>
<td>Shared Node-B Power and Code</td>
<td>Rise-over-Thermal (RoT)</td>
</tr>
</tbody>
</table>

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Rise-Over-Thermal Noise

In order to decode received data correctly, a minimum SINR shall be guaranteed at the Node B receiver.

**Rise-over-Thermal is a measure of the Uplink load.**

1. By increasing the number of transmitting UEs and their transmit power, the level of interference in the Uplink band increases.
2. This interference is perceived by the Node B receiver as noise, affecting the SINR.
3. The Node B controls the interference level by adjusting the UE grant assignments.
4. When the UE receives a new grant, it uses it in combination with available UE transmit power and the amount of data in the buffer...
5. ...to determine the data rate and the corresponding transmit power.

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Node B Scheduler for HSUPA

The HSUPA scheduler addresses the trade-off between:

- Several users that want to transmit at high data rate all the time
- Satisfying all requested grants while preventing overloading and maximizing resource utilization

Several UEs transmit simultaneously in HSUPA

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Rise-Over-Thermal Loading

With the introduction of HSUPA, a lower Uplink margin for preventing overload situations can be used, thanks to the fast resource allocation and control mechanisms in the Node B.

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
HSUPA Channel Operation

1. The UE sends a **Transmission Request** to the Node B for getting resources.

2. The Node B responds to the UE with a **Grant Assignment**, allocating Uplink band to the UE.

3. The UE uses the grant to select the appropriate transport format for the **Data Transmission** to the Node B.

4. The Node B attempts to decode the received data and send **ACK/NAK** to the UE. In case of NAK, data may be retransmitted.

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
1. Transmission Request

The UE requests data transmission by means of the **Scheduling Information (SI)**, which is determined according the UE Power and Buffer Data availability.

The scheduling information is sent in-band to the Node B.
2. Grant Assignment

The Node B determines the **UE Grant** by monitoring Uplink interference (RoT at the receiver), and by considering the UE transmission requests and level of satisfaction.

The grant is signaled to the UE by new grant channels.

GRANT: E-AGCH (Absolute Grant CH)
3. Data Transmission

The UE uses the received grant and, based on its power and data availability, selects the E-DCH **Transport Format** and the corresponding **Transmit Power**.

Data are transmitted by the UE on together with the related control information.

Data: E-DPDCH, Control: DPCCH
4. Data Acknowledgment

The Node B attempts to decode the received data and indicates to the UE with **ACK/NAK** if successful.

If no ACK is received by the UE, the data may be **retransmitted**.

**ACK/NAK: E-HICH (Enhanced Hybrid ARQ Indicator Channel)**
HSUPA Uplink Channels

New HSUPA Uplink Channels:

• Enhanced Uplink Dedicated Channel (E-DCH)
  – Uplink Transport Channel

• E-DCH Dedicated Physical Data Channel (E-DPDCH)
  – Uplink Physical Channel

• E-DCH Dedicated Physical Control Channel (E-DPCCH)
  – Uplink Control Channel
New HSUPA Downlink Channels:

- E-DCH Hybrid ARQ Indicator Channel (E-HICH)
  - Downlink Physical Channel

- E-DCH Absolute Grant Channel (E-AGCH)
  - Downlink Physical Channel

- E-DCH Relative Grant Channel (E-RGCH)
  - Downlink Physical Channel
Uplink Channels

E-DPDCH

• Carries the payload.
• May include a scheduling request from UE to Node B.

E-DPCCH

• Carries control information required to decode the payload carried by E-DPDCH.
• Carries an indication from UE to indicate to the Node B whether the assigned resources are adequate.

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Downlink Channels

**E-AGCH**
- The absolute grant carries maximum allowed E-DPDCH/DPCCH ratio.
- Carries information that controls HARQ process.

**E-RGCH**
- The relative grant carries a simple command to increase (UP), Decrease (DOWN), or keep (HOLD) the current grant.

**E-HICH**
- Gives feedback to the UE about previous data transmission, carrying Acknowledge (ACK) or Not Acknowledge (NAK).

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
HSUPA Channel Timing

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
HSUPA Channel Mapping

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
UMTS Network Architecture with HSUPA

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Theoretical HSUPA Maximum Data Rate

How do we get 5.76 Mbps?

- **Lower Coding Gain**
  - Effective code rate = 1
  - Requires very good channel conditions to decode

- **Lower Spreading factor**
  - UE can use SF2

- **Multi-code transmission**
  - UE can use up to 4 codes, 2 with SF4 plus 2 with SF2
  - Require some power back-off at UE side

- **Shorter TTI**
  - Requires higher processing capabilities at terminal and Node B
E-DPDCH with SF4 and Puncturing

Maximum payload for spreading factor of 4, TTI of 2 ms and coding rate of 1 is 1920 bits (for 960 kpbs).

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Lower Spreading Factor SF2

Maximum payload for spreading factor of 2, TTI of 2 ms and coding rate of 1 is 3840 bits (for 1920 kpbs).

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Multi-code Transmission

Use of multi-code transmission $2 \times SF2 + 2 \times SF4$

$(2 \times 1920 \text{ kbps}) + (2 \times 960 \text{ kbps}) = 5760 \text{ kbps}$

Reference: WCDMA (UMTS) HSUPA Protocols and Physical Layer, QUALCOMM UMTS University.
Timeline: For UMTS and CDMA2000
Other Standards

• Worldwide Interoperability Microwave Access (WiMax)
  – Operate in the 2.5, 3.5, or 5.8 GHz bands.
  – Data Rates now close to 73 Mbps (in 20 MHz of spectrum)
  – Versions: IEEE 802.16d and e with amendments like: 802.16f, g, h, i, j and k
  – Uses OFDM

• IEEE 802.20: Mobile Broadband Wireless Access (MBWA) (Fast Low-latency Access with Seamless Handoff) FLASH-OFDM. (suspended but being developed under the name of EVDO Rev C: UMB)
Amendments to the IEEE 802.16 standard

An amendment to the standard, IEEE 802.16e addressing mobility, was concluded in 2005. This is sometimes called “Mobile WiMAX”, after the WiMAX forum for interoperability.

Active amendments:

• 802.16f – Management Information Base

Amendments in development:

• 802.16g - Management Plane Procedures and Services

Amendments at pre-draft stage:

• 802.16h - Improved Coexistence Mechanisms for License-Exempt Operation
• 802.16i - Mobile Management Information Base
• 802.16j - Mobile Multihop Relay
• 802.16k - Bridging

Ref: http://www.reference.com/browse/wiki/IEEE_802.16
Cellular Technology Roadmap

Current | Development | Being Deployed | Future
--- | --- | --- | ---

GSM | GPRS | EDGE | HSDPA
TDMA | | | Wireless LANs
IS95a/b | 1xRTT | | 4G
| | 1xEV-DO | | 
| | | 3xRTT | 
| | | | 1xEV-DV
Issues

- **Why are new services/mobile content required?**
  - Tough competition
  - Low ARPU
  - No differentiation in Service Offerings

- **Problem:**
  - What services will differentiate one operator from the other?
  - How would these services be delivered?
Technologies

- 2G: Mainly Voice & SMS
- 2.5G: Limited Data Capability
- 3G and Beyond: High Speed Data coupled with data centric applications and services
Services Continue to Evolve With Enriched User Experiences

Voice  Wallpaper  2D Gaming  Location Based Services  Mobile Commerce  3D Gaming  Mobile TV

Text Messaging  Ringtones  MMS  Music & Video on Demand  Blogging  Social Networking  RSS Feeds & Tagging

Paul, how did the meeting go?

Send Options
References

1) WCDMA(UMTS) Overview, QUALCOMM UMTS University.


4) HSDPA: Protocol and Physical Layer, Qualcomm UMTS University.

5) HSUPA: Protocol and Physical Layer, Qualcomm UMTS University.

THANK YOU

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