Introduction to WCDMA
(Chapter 3)

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Outline

- What is spread spectrum and where does it come from
- Spreading
- Correlator and RAKE receiver
  - Matched Filter
- Uplink and downlink diversity
- WCDMA power control
  - Closed loop
  - Outer loop
- WCDMA handovers
  - Soft handover
  - Softer handover
- Concluding remarks
What is Spread Spectrum?

- Transmission bandwidth is much larger than the information bandwidth
- Bandwidth is not dependant of the information signal
- Processing gain = Transmitted bandwidth / Information bandwidth
- Classification
  - Direct Sequence (spreading with pseudo noise (PN) sequence)
  - Frequency hopping (rapidly changing frequency)
  - Time Hopping (large frequency, short transmission bursts)
Where Does Spread Spectrum Come from...

- First publications, late 40s
- First applications: Military from the 50s
- Rake receiver patent 1956
- Cellular applications proposed late 70s
- Investigations for cellular use 80s
- IS-95 standard 1993

...and where is it heading to

- 2001/2002 Commercial launch of WCDMA technology
GSM System is TDMA Based

Users divide the common frequency by time slots

MS = Mobile Station

Typical GSM Frequency Usage Pattern

BTS

200 kHz
UMTS System is CDMA Based

FDD = Frequency-division duplex
- Uplink and Downlink operate in separated frequency bands

TDD = Time-division duplex
- Uplink (UL) and downlink (DL) use the same frequency band, which is time-shared by the UL and DL

All users share the same frequency/time domain
Processing Gain & Spreading

- A narrowband signal is spread to a wideband signal

- High bit rate means less processing gain and higher transmit power or smaller coverage
Spreading

Data

Code (pseudo noise)

Data x Code

Despreading

Symbol

Symbol

Chip

Chip

Spectrum

Data

Code
Detecting Own Signal. Correlator

Own signal

Code

Data after multiplication

Data after integration

Other signal

Code

Data after multiplication

Data after integration
WCDMA Codes

- Channelisation codes used for channel separation from a single source
  - same codes in all cells ==> need for scrambling
- Scrambling codes separate
  - Uplink: different mobiles
  - Downlink: different cells/sectors
  - Have good interference averaging (correlation) properties

[Diagram showing short code, long code, and combined code with waveforms]
Fading of a Multipath Component
Maximal Ratio ("RAKE") Combining of Symbols

- Channel can rotate signal to any phase and to any amplitude
- QPSK symbols carry information in phase
- Energy splitted to many fingers -> combining
- Maximal ratio combining corrects channel phase rotation and weights components with channel amplitude estimate
Matched Filter

• To make a successful despreading, code and data timing must be known. Can be detected e.g. by a matched filter.

When samples of incoming serial data are equal to bits of predefined data, there is a maximum at filter output.
Delay Profile Estimation with MF

- Multipath propagation causes several peaks in matched filter (MF) output
- Allocate RAKE fingers to these peaks
- Later: track and monitor the peaks
UL Receiver Diversity (Space Diversity)

Antenna RAKE combining (MRC)

Amplitude

- = Antenna 1
- = Antenna 2

Fading

Time
DL Receiver Diversity (Space Diversity)

- Antenna 1
- Antenna 2

Amplitude
- = Antenna 1
- = Antenna 2

Time

Fading

Antenna RAKE combining (MRC)

RNC
The purpose of power control is to ensure that each user receives and transmits just enough energy to properly convey information while interfering with other users no more that necessary.
Fast Closed Loop Power Control

- Effective power control is essential in WCDMA due to frequency re-use
- Open loop power control for *initial* power setting of the MS
- Across the air-interface: closed loop power control 1.5 kHz
  - Eliminates near-far problem
  - Typically up or down 1 dB, approx 70 dB range (21 dBm to -50 dBm)

![Diagram of power control](image)

- If SIR > (SIR) set then "down"
- Else "up"

MS adjusts power according to TPC commands
Uplink Outer Loop TPC

- Outer loop TPC maintains link quality
- *during soft handover*: comes after soft handover frame selection

required (SIR) set for 1% FER

![Diagram showing the flow of information between MS, RNC, and CN with conditions for adjusting (SIR) settings based on FER increase or decrease.]

if FER increase then (SIR) set "up" else (SIR) set "down"
WCDMA Handovers

Soft handover
- MS handover between different base stations

Softer handover
- MS handover within one cell between different sectors

Hard handover
- MS handover between different frequencies or between WCDMA and GSM (or TDD)
Softer Handover

- BTS internally
- No extra transmissions in the network side
- Same Rake processing basically
- Provides additional diversity gain
Soft Handover

- Needs extra transmissions in the network
  - UL / DL diversity processing different
    - MS: MRC RAKE combining
    - RNC: frame selection

except for the TPC symbol exactly the same information (symbols) is sent via air. Differential delay in order of fraction of symbol duration
Concluding Remarks

- WCDMA benefits from and also requires:
  - Fast power control
    - Due near far problem
  - Soft/Softer handover
    - Due frequency reuse of 1

- WCDMA RAKE receiver
  - Allows various diversity methods
  - Is well known technology from research and 2nd generation systems
WCDMA Physical Layer
(Chapter 6)
Main 3G Requirements on Physical Layer

- High bit rates up to 2 Mbps
- Bandwidth-On-Demand = Flexible variable bit rate
- Multi-service = Multiplexing of different services on a single physical connection
- Efficient packet data operation = support for all-IP
- High spectral efficiency, especially in downlink

How can we fulfill these requirements with WCDMA physical layer?
Variable bit rate
Variable Bit Rate (Dedicated Channels)

- **DPCCH** (Dedicated physical control channel) is **constant** bit rate and carries all information needed to keep physical connection running
  - Reference symbols for channel estimation in coherent detection and for SIR estimation in fast power control
  - Power control signalling bits (TPC)
  - Transport format combination information (TFCI) = bit rate, interleaving

- **DPDCH** (Dedicated physical data channel) is **variable** bit rate
  - User data
  - Higher layer signalling, e.g. mobile measurements, active set updates, packet allocations

- DPDCH bit rate is indicated with TFCI bits on DPCCH
Uplink Dedicated Physical Channel

- I-Q/code multiplexed DPCCH and DPDCH
- Frame 10 ms, slot 0.667 ms (≈2/3 ms)

---

(1) Channel estimate + SIR estimate for PC

(2) Detect PC command and adjust DL tx power

(3) 10 ms frame: Detect TFCI

(4) Interleaving: Detect data

Super frame 720 ms

Frame 1
Frame 2
Frame 72

Slot 1
Slot 2
Slot 15

DPCCH
DPCCH

DPDCH
DPDCH

Data
Data

Pilot
Pilot TFCI
TPC

Slot 0.667 ms = 2/3 ms
Uplink Variable Rate

- DPDCH bit rate can change frame-by-frame (10 ms)
- Higher bit rate requires more transmission power
- Continuous transmission regardless of the bit rate
  - Reduced audible interference to other equipment (nothing to do with normal interference, does not affect the spectral efficiency)
  - GSM audible interference frequency ~217 Hz (=1/4.615 ms)
- Admission control in RNC allocates those bit rates that the connection can use on physical layer
I-Q/code Multiplexing in Uplink

- Code multiplexing of DPCCH and DPDCH → multicode transmission → envelope variations
- ETSI/WCDMA solution: I-Q/code multiplexing with complex scrambling (Dual channel BPSK)

Channelization code $c_D$

DPDCH (data)

I

DPCH (control)

Q

* $j$

Channelization code $c_c$

$\sqrt{G}$ = gain factor

Complex scrambling code

I+$jQ$
I-Q/code Multiplexing in Uplink

- Signal constellation **before** complex scrambling
- Depending on $G$, constellation can be close to BPSK or QPSK
- $G =$ power ratio between DPCCH and DPDCH

![Diagram showing constellations for different $G$ values](image)

Requires linearity → Would be difficult for mobile power amplifier
**I-Q/code Multiplexing in Uplink**

- Signal constellation *after* complex scrambling (at power amplifier)
- Signal envelope variations are similar to single code QPSK with all values of $G$
- $G =$ power difference between DPCCH and DPDCH

![Diagram showing signal constellations for different values of $G$]

Less linearity requirements for mobile power amplifier
Downlink Dedicated Physical Channel

- Time multiplexed DPCCH and DPDCH
- Support for blind rate detection
- Discontinuous transmission

Super frame 720 ms

10 ms

Slot 0.667 ms = 2/3 ms
Downlink Variable Rate

- DPDCH bit rate can change frame-by-frame (10 ms)
- Rate matching done to the maximum bit rate of that connection
- Lower bit rates obtained with discontinuous transmission (audible interference not a problem in downlink)
- Admission control allocates those bit rates that can be used on physical layer
Spreading and Scrambling

- Channelization code (=short code) provides spreading = increase of the transmission bandwidth
- Scrambling code (=long code) provides separation of users/cells, and does not affect the transmission bandwidth

![Diagram showing the process of spreading and scrambling with channelization code and scrambling code applied to data with Bit rate, Chip Rate, and Chip Rate indicated.](attachment:image.png)
## Long and Short Codes

<table>
<thead>
<tr>
<th>Usage</th>
<th>Short code = Channelisation code</th>
<th>Long code = Scrambling code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uplink: Separation of physical data (DPDCH) and control channels (DPCCH) from same terminal</td>
<td>Uplink: Separation of mobile Downlink: Separation of sectors (cells)</td>
<td></td>
</tr>
<tr>
<td>Downlink: Separation of downlink connections to different users within one cell</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>4–256 chips (1.0–66.7 μs) Downlink also 512 chips Different bit rates by changing the length of the code</td>
<td>Uplink: (1) 10 ms = 38400 chips or (2) 66.7 μs = 256 chips Option (2) can be used with advanced base station receivers Downlink: 10 ms = 38400 chips</td>
</tr>
<tr>
<td>Number of codes</td>
<td>Number of codes under one scrambling code = spreading factor</td>
<td>Uplink: 16.8 million Downlink: 512</td>
</tr>
<tr>
<td>Code family</td>
<td>Orthogonal Variable Spreading Factor</td>
<td>Long 10 ms code: Gold code Short code: Extended S(2) code family</td>
</tr>
<tr>
<td>Spreading</td>
<td>Yes, increases transmission bandwidth</td>
<td>No, does not affect transmission bandwidth</td>
</tr>
</tbody>
</table>

Downlink codes must be managed

Downlink codes are orthogonal

Simple code planning in downlink
Tree of Orthogonal Short Codes in Downlink

- Hierarchical selection of short codes from a code tree to maintain orthogonality
- Several long scrambling codes can be used within one sector to avoid shortage of short codes

Example of code allocation

Spreading factor:
- SF = 1
- SF = 2
- SF = 4
- SF = 8
Physical Channel Bit Rates
## Physical Layer Bit Rates (Downlink)

<table>
<thead>
<tr>
<th>Spreading factor</th>
<th>Channel symbol rate (kbps)</th>
<th>Channel bit rate (kbps)</th>
<th>DPDCH channel bit rate range (kbps)</th>
<th>Maximum user data rate with ½-rate coding (approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>512</td>
<td>7.5</td>
<td>15</td>
<td>3–6</td>
<td>1–3 kbps</td>
</tr>
<tr>
<td>256</td>
<td>15</td>
<td>30</td>
<td>12–24</td>
<td>6–12 kbps</td>
</tr>
<tr>
<td>128</td>
<td>30</td>
<td>60</td>
<td>42–51</td>
<td>20–24 kbps</td>
</tr>
<tr>
<td>64</td>
<td>60</td>
<td>120</td>
<td>90</td>
<td>45 kbps</td>
</tr>
<tr>
<td>32</td>
<td>120</td>
<td>240</td>
<td>210</td>
<td>105 kbps</td>
</tr>
<tr>
<td>16</td>
<td>240</td>
<td>480</td>
<td>432</td>
<td>215 kbps</td>
</tr>
<tr>
<td>8</td>
<td>480</td>
<td>960</td>
<td>912</td>
<td>456 kbps</td>
</tr>
<tr>
<td>4</td>
<td>960</td>
<td>1920</td>
<td>1872</td>
<td>936 kbps</td>
</tr>
<tr>
<td>4, with 3 parallel codes</td>
<td>2880</td>
<td>5760</td>
<td>5616</td>
<td>2.3 Mbps</td>
</tr>
</tbody>
</table>

- The number of orthogonal channelization codes = Spreading factor
- The maximum throughput with 1 scrambling code ~2.5 Mbps or ~100 full rate speech users

Half rate speech
- 144 kbps
- 384 kbps
- 2 Mbps

Full rate speech
- 144 kbps
- 384 kbps
- 2 Mbps
Number of Orthogonal Codes in Downlink

- Part of the orthogonal codes must be reserved for
  - common channels
  - soft handover overhead

- The maximum capacity with one set of orthogonal codes = code limited capacity per sector per 5 MHz
  - Full rate speech (SF=128) : 98 channels
  - Half rate speech ≤ 7.95 kbps (SF=256) : 196 channels
  - Data : 2.5 Mbps

- Typically, air interface interference limits the capacity before the code limitation (see the capacity discussion later)

- Code limitation can be avoided with 2nd set of codes (which are not orthogonal) by using 2 scrambling codes per sector

- 2nd set of codes is probably needed with smart antennas which improve the air interface capacity.
Downlink Shared Channel (DSCH)

- The number of orthogonal codes in downlink is limited and the code is reserved according to the maximum bit rate in transport format set.
  - Variable bit rate connections consume a lot of code resources.
  - Downlink shared channel concept saves code space.

- DSCH is shared between a group of downlink users.

- Existence of data on DSCH for a particular user is indicated with TFCI (frame-by-frame) or with higher layer signalling (slower).

- DSCH is not frame synchronized with the corresponding dedicated channel.

Frame structure for the DSCH when associated to a DCH.
**DSCH (2)**

- Conceptually DSCH can be seen as reserving a code resource and then sharing it in time and code domain.
- Example: frame N 1 user with SF 8, frame N+1 two users with SF 16.
Random Access Channel (RACH)

- With Random Access Channel (RACH) power ramping is needed with preambles since the initial power level setting in the mobile is very coarse with open loop power control.
- Preamble: mobile sends 1 ms signature sequence with increasing power.
- L1 acknowledgement: base station acknowledges the sequences received with high enough power level (AICH = Acquisition Indication CH).
- Mobile RACH message follows the acknowledgement.

Diagram:

- **Downlink / BS**
  - Not detected
- **Uplink / MS**
  - P1
  - P2
  - Preamble
  - RACH
  - Message part
Uplink Common Packet Channel (CPCH)

- The CPCH is basically RACH with:
  - Longer message duration (up to 640 ms vs. 10 or 20 ms on RACH)
  - Power controlled (power control commands provided in the DPCCH in the downlink)
  - Status indication provided in the downlink to avoid collisions

- In Release - 99 optional for all terminals, Release 2000 developments remain to be seen
Downlink Common Channels

- Primary common control physical channel (primary CCPCH)
  - carries BCH
  - constant symbol rate of 27 kbps

- Secondary CCPCH
  - carries FACH and PCH
  - variable bit rate
Service Multiplexing
Service Multiplexing

• MAC layer multiplexing
  • No further requirements on the physical layer
  • The same quality provided for all multiplexed services

• Physical layer multiplexing
  • Can provide different quality for different services
    • e.g. speech FER=1%, packet data FER=10%, video FER<0.1%
  • Different quality is obtained by rate matching
    • Higher quality required ➞ more repetition coding applied
Physical Layer Multiplexing

Channel coding + MAC multiplexing

Inter-frame interleaving

Rate matching:
- $E_b/N_0$ balancing
- matching to channel bit rate

Intra-frame interleaving

Service 1

Coding

1st interleaving

Rate matching

Multiplexing of services

2nd interleaving

Service 2

Coding

1st interleaving

Rate matching

Multiplexing of services

2nd interleaving
Channel Coding

- Dedicated channel (DCH) and the following common channels (CPCH, DSCH and FACH)
  - Convolutional code 1/3-rate or 1/2-rate, $K=9$
    - Mainly for speech service and other low bit rate services
  - Turbo codes 1/3-rate, $K=3$
    - Gives gain over convolutional code especially for high bit rates ($\geq 32$kbps) and low BER requirements
  - Transmission without channel coding is also possible

- Other common channels
  - Convolutional code 1/2-rate, $K=9$
WCDMA ↔ GSM Inter-system Handovers
WCDMA Compressed Mode

<table>
<thead>
<tr>
<th></th>
<th>WCDMA</th>
<th>IS-95A</th>
<th>GSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why inter-frequency</td>
<td>For inter-frequency &amp; inter-system</td>
<td>No IF-measurements</td>
<td>For all handovers</td>
</tr>
<tr>
<td>measurements?</td>
<td>handovers</td>
<td>=&gt; utilization of multiple</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>frequencies difficult</td>
<td></td>
</tr>
<tr>
<td>How to make IF-</td>
<td>Compressed mode</td>
<td></td>
<td>Simple since discontinuous tx &amp; rx</td>
</tr>
<tr>
<td>measurements?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- More power is needed during compressed mode
  - => affects WCDMA coverage

- Power control cannot work during compressed frame => higher Eb/N0
  - => affects WCDMA capacity
Handover from WCDMA to GSM

1. Handover triggering thresholds are set from NMS to RNC
2. HO trigger fulfilled in RNC (=load/service/coverage reason)
3. RNC commands selected mobile(s) to make IS-measurements
4. RNC selects target cell based on mobile measurements, service priorities, and load

Initiate inter-system measurements
Command inter-system handover
Multivendor Inter-system Handovers

- Handovers between GSM and WCDMA can be done also between different vendors' networks.
- Handovers from GSM to WCDMA are triggered in GSM BSS.
- Handovers from WCDMA to GSM are triggered in WCDMA RAN.

Handover triggers:
- GSM → WCDMA
- WCDMA → GSM

Core network:
- A
- Iu
WCDMA ↔ GSM Inter-system Idle Mode Cell Re-selection
Without Hierarchical Cell Priorities

- Mobile stays within one frequency if received pilot Ec/I0 is good enough = above \( S_{\text{Intersearch}} \) and \( S_{\text{searchRATn}} \)
- \( S_{\text{Intersearch}} \) threshold for starting inter-frequency measurements
- \( S_{\text{searchRATn}} \) threshold for starting inter-frequency measurements
- Inter-frequency and inter-system measurements consume more battery in terminal \( \rightarrow \) thresholds must be low enough
With Hierarchical Cell Priorities

- Parameter HCS_PRIO
  - HCS priority value 0..7
  - For keeping idle mobiles in micro layers, example below
  - For keeping idle mode mobiles in one system (GSM or WCDMA)
Further Notes

- High mobile speeds can be directed to macro cells in idle mode based on the frequency of the cell re-selections
  - Parameters $N_{CR} / T_{CR_{max}}$
  - If the number of cell reselections during time period $T_{CR_{max}}$ exceeds $N_{CR}$, high-mobility has been detected

- Mapping rule can be optionally used between WCDMA and GSM
  - WCDMA RSCP and GSM RSSI can also be directly compared by using just offset parameters = default case
Why to Force Dual-modes to Camp to GSM or to WCDMA?

Any intermediate cases can also be used between these two extremes

<table>
<thead>
<tr>
<th>Camping to GSM</th>
<th>Camping to WCDMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Less location updates</td>
<td>• 3G services available for all dual-mode mobiles even without 2G→3G handover</td>
</tr>
<tr>
<td>• 3G → 2G handover is not necessary</td>
<td>or network controlled cell reselection</td>
</tr>
<tr>
<td>• Lower MS power consumption in idle mode</td>
<td>• 3G network is utilized as fully as possible</td>
</tr>
</tbody>
</table>

Useful if 3G→2G handover is not supported, and 3G coverage is not continuous

Initial phase solution to fully utilize 3G network and to provide 3G services

• Equal idle mode priority could also be used for GSM and for WCDMA, especially when dual-mode penetration and traffic in WCDMA increases
Downlink Transmit Diversity

- **Background**
  - More capacity expected to be needed in downlink than in uplink
  - Uplink capacity tends to be higher than downlink because better receiver techniques can be applied in the base station than in the mobile (antenna diversity and multiuser detection)
  - Antenna diversity not practical for low-priced mobiles

- **Three transmit diversity modes specified**
  - Open loop transmit diversity mode with space-time coding
  - Closed loop transmit diversity mode with feedback from the mobile
    - mode 1: with frequency of 1500 Hz, adjust only relative phases of the two antennas
    - mode 2: with frequency of 1500/4 Hz, adjust both relative phase and amplitudes from the two antennas (Command Bit rate 1500 Hz, 4 bits combined together for phase and amplitude adjustment)
Downlink Transmit Diversity

- **Open loop transmit diversity**

  - 2 symbols
  - Antenna 1
    - $S_1$ $S_2$
  - Antenna 2
    - $S_1$ $S_2$
    - $-S_2^*$ $S_1^*$

- **Closed loop transmit diversity**

  - Feedback from mobile to control transmission phases
  - Two downlink signals combine coherently
  - Different fading channels
  - Transmission from two antennas
  - Feedback from mobile to control transmission phases
Downlink Transmit Diversity

- Transmission from two base station antennas
- Both modes give gain against fading
- Closed loop mode targets for coherent combining of the received signals in the mobile

Space diversity
antenna separation
~3 m

Polarization diversity
±45°
## Receive Diversity vs. Transmit Diversity

<table>
<thead>
<tr>
<th></th>
<th>Uplink receive diversity</th>
<th>Downlink transmit diversity with feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(1) Coherent combining gain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain from ideal coherent combining is 3.0 dB with two antennas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How to obtain coherent combining</td>
<td>Rake receiver with channel estimation from pilot symbols</td>
<td>Feedback loop from mobile to base station to control the transmission phases to make received signals to combine coherently in mobile</td>
</tr>
<tr>
<td>Non-idealities in coherent combining</td>
<td>Inaccurate channel estimation in Rake receiver</td>
<td>Inaccurate channel estimation in mobile</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discrete steps in feedback loop</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Delay in feedback loop</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multipath propagation</td>
</tr>
<tr>
<td>Practical gain of coherent combining</td>
<td>2.5–3.0 dB gain</td>
<td>Gain is lower than with receive diversity</td>
</tr>
<tr>
<td><strong>(2) Diversity gain against fading</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diversity gain with fast power control</td>
<td>Diversity gain = reduction of power rise. Example values:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ITU Pedestrian A: 2.8 dB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ITU Vehicular A: 0.8 dB</td>
<td></td>
</tr>
<tr>
<td><strong>Total gain in reduction of transmission powers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total gain from antenna diversity</td>
<td>3.0–6.0 dB</td>
<td>0.0–5.0 dB</td>
</tr>
</tbody>
</table>
Cell Search / Synchronization Channel (SCH)

256-chip sequence
the same in every cell

Primary SCH

0

1

... 14

Secondary SCH

256 chips

2560 chips

256-chip sequence
modulated, identifies the code group of the cell

10 ms
Cell Search

1. The terminal searches the 256-chip **Primary SCH**, being identical for all cells.
   - Chip, symbol and slot synchronization can be obtained

2. The terminal seeks the largest peak from the **Secondary SCH** code word. There are 64 possibilities for the secondary synchronization code word. The terminal needs to check all 15 positions, as the frame synchronization is not known from Primary SCH.
   - Frame synchronization and code group of the cell can be obtained

3. The terminal then seeks the primary **scrambling codes** that belong to that particular code group. Each group consists of eight primary scrambling codes. These need to be tested for a single position only, as the starting point is known already.
   - Scrambling code of the cell can be obtained
Differences Between 3G/WCDMA and 2G/GSM and 2G/IS-95
## Differences Between WCDMA and GSM

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<thead>
<tr>
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<th>WCDMA</th>
<th>GSM</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>Power control frequency</td>
<td>1500 Hz</td>
<td>2 Hz or lower</td>
</tr>
<tr>
<td>Quality control</td>
<td>Radio resource management algorithms</td>
<td>Network planning (frequency planning)</td>
</tr>
<tr>
<td>Frequency diversity</td>
<td>5 MHz bandwidth gives multipath diversity with Rake receiver</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 for improving downlink capacity</td>
<td>Not supported by the standard, but can be applied</td>
</tr>
</tbody>
</table>

### Key Points

- **High bit rates**
- **Spectral efficiency**
- **Different quality requirements**
- **Efficient packet data**
- **Downlink capacity**
## Differences Between WCDMA and IS-95

<table>
<thead>
<tr>
<th>Feature</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>Chip rate</td>
<td>3.84 Mcps</td>
<td>1.2288 Mcps</td>
</tr>
<tr>
<td>Power control frequency</td>
<td>1500 Hz, both uplink and downlink</td>
<td>Uplink: 800 Hz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Downlink: slow power control</td>
</tr>
<tr>
<td>Base station synchronisation</td>
<td>Not needed</td>
<td>Yes, typically obtained via GPS</td>
</tr>
<tr>
<td>Inter-frequency handovers</td>
<td>Yes, measurements with slotted mode</td>
<td>Possible, but measurement method not specified</td>
</tr>
<tr>
<td>Efficient radio resource management algorithms</td>
<td>Yes, provides required quality of service</td>
<td>Not needed for speech only networks</td>
</tr>
<tr>
<td>Packet data</td>
<td>Load-based packet scheduling</td>
<td>Packet data transmitted as short circuit switched calls</td>
</tr>
<tr>
<td>Downlink transmit diversity</td>
<td>Supported for improving downlink capacity</td>
<td>Not supported by the standard</td>
</tr>
</tbody>
</table>
Differences Between WCDMA and IS-95

- Wider bandwidth: WCDMA: 3.84 Mcps / IS-95: 1.2288 Mcps
  - Multipath diversity improves coverage performance. In small cells ~1MHz bandwidth does not provide multipath diversity.
  - 3.84 Mcps ⇔ 1 chip corresponds to 78 m (=3e8/3.84e6)
  - 1.2288 Mcps ⇔ 1 chip corresponds to 244 m (=3e8/1.2288e6)
  - Higher multiplexing gain especially for high bit rates

- Fast closed loop power control in downlink
  - Improves downlink performance
  - Requires new functionalities in the mobile: SIR estimation, outer loop PC

- Inter-frequency handovers
  - Support for several carriers per base station
Differences Between WCDMA and IS-95

- Soft handover algorithm with relative thresholds in WCDMA
  - Easier parameterization + optimization

- Asynchronous base stations
  - No need for synchronization from GPS

- Support for advanced radio resource management algorithms
  - Provides efficient packet data
  - Guarantees the quality of service
  - Prevents effectively cell breathing which exceeds planned limits

- Most differences between WCDMA and IS-95 reflect the 3G requirements of WCDMA