A Comparative Study Between Next Generation UMTS and WiMAX Systems

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Outline

- Motivation
- Comparaison of the Physical Layer
- Comparaison of the Overall Architecture
- Comparaison of the QoS Management
- Conclusion
Motivation

What is WiMAX?

- **Worldwide Interoperability for Microwave Access.**
- Operates in the **10 to 66 GHz** and the **2 to 11 GHz** frequency ranges.
- Promises data transfer rates: **up to 108 Mbit/s.**

What is UMTS?

- **Universal Mobile Telecommunication System.**
- Operates in the following frequency ranges:
  - **HSDPA**: High Speed Downlink Packet Access.
    - 1920 MHz – 1980 MHz (Uplink)
    - 2110 MHz – 2170 MHz (Downlink)
  - **HSUPA**: High Speed Uplink Packet Access.
    - Promises data transfer rates:
      - up to **14.4 Mbit/s** with HSDPA
      - up to **5.8 Mbit/s** with HSUPA
Evolution

WiMAX (IEEE 802.16)

- IEEE 802.16 (Dec 2001)
- IEEE 802.16 d (Oct 2004) Fixed WiMAX
- IEEE 802.16 e (Dec 2005) Mobile WiMAX

UMTS

- R99 (March 2000)
- R00 (renaming)
- Rel-4 (March 2001)
- Rel-5 (March - June 2002)
- Rel-6 (Dec 2004 - March 2005)

Source: www.wimax-forum.com

Source: www.umts-store.net
PART ONE
Comparaison of the Physical Layer

- Some selected aspects -

- WiMAX Physical Layer
- UMTS Physical Layer
The WiMAX Physical Layer Transmission Technique: OFDM

- Divide the existing bandwidth $W$ into $N = W/\Delta f$ orthogonal frequencies (channels), the so-called OFDM-subcarriers or subcarriers.

- Simultaneous transmission of these $N$ narrow-band orthogonal frequencies instead of a single carrier transmission.

Source: "WiMAX", Nuaymi (modified)
The WiMAX Physical Layer Realisation of OFDM

- Matrix computation: Application of an IFFT operator (Inverse Fast Fourier Transform Operator) on N modulation symbols possibly different modulated: BPSK, QPSK, QAM-16, QAM-64

- Result: OFDM-signal, where each (modulation) symbol is transmitted on one of the orthogonal subcarriers (frequencies).

Source: "WiMAX", Nuaymi (modified)
The WiMAX Physical Layer
OFDMA (OFDM Multiple Access)

**Idea:**
- OFDM-design intended for a single user (signal) transmission.
- Association of a multiple access technique like TDMA or FDMA to OFDM to get multiuser transmissions.

**Principle:**
- Division of OFDM subcarriers into sets of subcarriers, the so called subchannels.
- Subcarriers composing a subchannel must not be adjacent.

→ New dimension.
The WiMAX Physical Layer
OFDMA (OFDM Multiple Access)

Source: "WiMAX", Nuaymi (modified and simplified)
Illustration of the OFDMA Multiple Access

A time and a subchannel allocation for each communication process of a downlink and an uplink user, respectively.

Source: "WiMAX", Nuaymi (modified)
The WiMAX Physical Layer Link Adaption

- Radio link OK → Use a high-level modulation (exp: 64-QAM)
- Radio link bad → Use a low-level but robust modulation (exp: QPSK)

Source:
The UMTS Physical Layer
Transmission Technique: CDMA

- All users send at the same time and with the same frequency.
- Separation of users via codes
- Application of spread spectrum technique.
- Transmit bit sequence is multiplied by a connection-specific code signal and thus spread in the frequency range.

Source: script „fundamentals of radio communications“ Prof. Dr.-Ing. T Kürner
Illustration of the CDMA Transmission Process

Data signal \( d(t) \)

Code signal \( c(t) \)

Spread signal \( c(t) \cdot d(t) \)

Source: Lüders, "Mobilfunksysteme" (modified)
CDMA uses orthogonal codes of variable length

Exp: Walsh-Hadamard codes

<table>
<thead>
<tr>
<th>Spread Factor (SF)</th>
<th>Code Patterns</th>
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<tr>
<td>2</td>
<td>SF = 2</td>
</tr>
<tr>
<td>4</td>
<td>SF = 4</td>
</tr>
<tr>
<td>8</td>
<td>SF = 8</td>
</tr>
<tr>
<td>16</td>
<td>SF = 16</td>
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</tbody>
</table>

Bit time: $T_{\text{bit}}$
Chip time: $T_{\text{chip}}$
Spread factor: $SF = \frac{T_{\text{bit}}}{T_{\text{chip}}}$

Source: script „fundamentals of radio communications“ Prof. Dr.-Ing. T Kürner
WCDMA (Wideband CDMA)

The sent signal is strongly spread. → Higher bandwidth.

→ Robustness against narrow band interference impulses.

Source: „mobile communications“ Jochen Schiller

Source: script „mobile communications“ Prof.Dr.-Ing.L Wolf
HSDPA / HSUPA

- UMTS rel-5 introduced a **high speed downlink packet access** (HSDPA) with speeds (data rates) in the order of **8 - 10 Mbit/s**
- Current HSDPA deployments support down-link speeds of 1.8, 3.6, 7.2 and 14.4 Mbit/s
  → useful for asymmetrical services that require the largest part of their capacity in the Downlink.

- HSDPA uses Adaptive modulation (QPSK, 16-QAM)

Source: script „fundamentals of radio communications“ Prof. Dr.-Ing. T Kürner
HSDPA / HSUPA

- UMTS rel-6 introduced a **high speed uplink packet access** (HSUPA) with speeds up to **5.8 Mbit/s**
  → useful for asymmetrical services that require the largest part of their capacity in the Uplink.

- Symmetrical services that require high data rates on both downlink- and uplink-connections can use both HSDPA and HSUPA.

Source of the figures: script „fundamentals of radio communications“ Prof. Dr.-Ing. T Kürner
## Summary of PART ONE

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PART TWO
Comparaison of the Overall Architecture

- The WiMAX Overall Architecture
- The UMTS Overall Architecture

- Some selected aspects -
WiMAX Architecture Is Standardized… Why?

WiMAX- outdoor antenna

BSC : Base Station Controller

Fixed users

Enterprise/campus
Nomadic users

Mobile users

Backhaul

Source: www.csie.ndhu.edu.tw/~robert/Wimax/WiMax-Architecture.pdf (modified)
The WiMAX Overall Architecture: The Network Reference Model

NAP
ASN
ASN
NSP
ASN
CSN
ASP Network or Internet

Mobile station

ASN: Access Service Network
NAP: Network Access Provider
CSN: Connectivity Service Network
ASP: Application Service Provider

For more info see: WiMAX-Forum paper [1]
The WiMAX Overall Architecture: The Network Access Provider (NAP)

**ASN 1: Profile A**
- BS
- ASN GW

**ASN 2: Profile B**
- Black-box (1 or more black boxes)
- No intra ASN interoperability possible

**ASN 2: Profile C**

**R1**
- Reference points

**R6**
- Reference points

**R3**
- Reference points

**R4**
- Reference points

**ASN**: Access Service Network
**ASN GW**: ASN gateway
**BS**: WiMAX base station

A Comparative Study Between Next Generation UMTS and WiMAX Systems
The UMTS Overall Architecture Is Classified In Domains.
The UMTS Overall Architecture: The Access Network Domain

BSC: Base Station Controller

RNC: Radio Network Controller

UTRAN: UMTS terrestrial radio access network

GSM Radio Access Network

UTRAN: UMTS terrestrial radio access network

RAN: Radio Access Network
The UMTS Overall Architecture Is Classified In Domains.
The UMTS Overall Architecture: The Core Network Domain (rel-5)

UMTS specifies a radically different core network. The GSM/GPRS-based network (UMTS rel-4) will be replaced by an almost all-IP core network. The key components of the new architecture include:

- **MSC (Mobile Switching Center)**: Responsible for call control and switching.
- **VLR (Visitor Location Register)**: Stores temporary information about a user's location.
- **SGSN (Serving GPRS Support Node)**: Supports GPRS services for a user.
- **GGSN (Gateway GPRS Support Node)**: Connects to the Internet.
- **HSS (Home Subscriber Server)**: Stores permanent user information.
- **EIR (Equipment Identity Register)**: Stores information about incompatible equipment.
- **PSDN (Public Switched Data Network)** and **PDN (Public Data Network)**: Support data services.
- **IMS (IP Multimedia Subsystem)**: Supports multimedia services over an IP network.

The diagram illustrates the connections between these components, showing how they interact within the UMTS network.
## Summary of PART TWO

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<th>UMTS Overall Architecture</th>
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<td>• UMTS rel-5: almost all-IP-core</td>
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PART THREE
Comparaison Of The QoS Management

- The QoS Classes of WiMAX and UMTS
- A WiMAX QoS Management Scenario

- Some selected aspects -
# The QoS Classes of WiMAX and UMTS

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<th>Corresponding QoS Class of WiMAX</th>
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<tr>
<td>Interactive</td>
<td>Non-real-time Polling Service (nrtPS)</td>
<td>interactive services (online video games… )</td>
</tr>
<tr>
<td>Streaming</td>
<td>Real-time Polling Service (rtPS)</td>
<td>video transmission video-on-demand, internet-radio</td>
</tr>
<tr>
<td>Conversational</td>
<td>Extended Real-time Polling Service (ertPS)</td>
<td>direct communication like telephony and video telephony.</td>
</tr>
<tr>
<td></td>
<td>Unsolicited Grant Service (UGS)</td>
<td>VoIP with activity detection</td>
</tr>
</tbody>
</table>
A WiMAX QoS Management Scenario

What happens in the base station and the mobile station?

VoIP without silence suppression

Video transmission

TFTP

HTTP

Email

MAC - CS

MAC - CPS

A Comparative Study Between Next Generation UMTS and WiMAX Systems
Summary of PART THREE

- Both WiMAX and UMTS define **QoS classes** to differentiate services.

- **Services** are mapped into QoS Classes.
## Summary

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<th>WiMAX</th>
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<td>OFDM</td>
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<td><strong>Overall Architecture</strong></td>
<td>Defined through the Network Reference Model</td>
<td>Divided into Domains</td>
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<td>Three ASN profiles</td>
<td>Two Radio Access Networks</td>
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<tr>
<td><strong>QoS Management</strong></td>
<td>Through mapping of services into QoS Classes.</td>
<td>Almost all-IP-core with release 5</td>
</tr>
</tbody>
</table>
Conclusion

The figure (left) shows a test Mobile-WiMAX base station co-locating at existing 3G base site.

Both technologies WiMAX and UMTS are being developed and are evolving at the same time (remember Motivation).

• So, which technology is going to convince and gain more users?
• Which technology is going to establish itself as standard in the few next years?

Source: www.softbank.co.jp
References

Books:
1. “WiMAX”, Nuaymi Loutfi
3. “Mobilfunksysteme”, Lüders

IEEE papers:
1. “A Survey on Mobile WiMAX”
2. “Network Architecture for 4G: Cost Considerations”
3. “Extending 3G/WiMAX Networks and Services through Residential Access Capacity”

3GPP papers:
1. “Service Requirements for the All-IP Network (AIPN)” stage1 (rel8)
2. “Architecture enhancements for non-3GPP accesses” (rel8)
References

**WiMAX-Forum papers :**

**Websites:**
1. www.wimaxforum.org/technology/downloads/
2. www.tech-invite.com/Ti-ims-releases.html#fig5
4. www3.ietf.org/proceedings/05nov/slides/16ng-4.pdf
6. www.hsdpa.com
7. www.itwissen.info
8. www.dcinside.com

**Scripts:**
1. “Fundamentals of radio communications“, Prof. Dr.-Ing. T Kürner
2. “Mobile communications“, Prof. Dr.-Ing. L Wolf
Thank you for your attention!
1. The WiMAX physical layer / Transmission technique: OFDM
2. Scalable OFDMA
3. Sublayers of the WiMAX-MAC layer
4. The WiMAX Mobile Station
5. The WiMAX Network Reference Model
6. WiMAX uses Sliding Window ARQ Mechanism
7. WiMAX-MAC uses Hybrid-ARQ
8. WCDMA (Wideband CDMA)
10. The UMTS Overall Architecture Is Classified In Domains.
11. The UMTS overall-architecture: The Core Network Domain (rel-5)
12. The QoS classes of WiMAX
13. QoS Management Scenario (WiMAX)
14. The QoS classes of UMTS
The WiMAX physical layer
Transmission technique: OFDM

OFDM-subcarriers orthogonal to each other

→ Elimination of interference between the channels.

• Possibility of different digital modulation for each subcarrier (BPSK, QPSK, QAM-16, QAM-64)

• Reduced frequency bandwidth ↔ Longer time periods

• Data symbol duration N times longer as in the single carrier transmission.

→ Better multipath resistance with regard to a single carrier.

→ Higher system robustness.
Scalable OFDMA (SOFDMA)

- OFDMA is scalable.

- Scalability:
  - Change of the magnitude \( N \) of the IFFT
  - Change of the number of subcarriers (also \( N \))

  - Adaptive occupied bandwidth and equivalently adaptive data rate.

  - Resource allocation flexibility.

- Supported FFT sizes in WiMAX: 2048, 1024, 512, 128.
Sublayers of the WiMAX-MAC layer

Map external data from the upper layers into appropriate MAC-SDUs for the MAC-CPS

System access, allocation of bandwidth, connection establishment and maintenance, QoS handling

Authentication, secure key exchange, encryption

Source: A paper of the IEEE communications magazine dec 2007 with the title: „A survey on mobile WiMAX“ (modified)
The mobile station is a mobile equipment, which ensures the connectivity between a subscriber equipment and a WiMAX base station.

Exp of WiMAX-MS: The Samsung SPH-M8100 (According to Samsung The first “Mobile WiMAX PDA phone”.)

Source: www.messe-lakten.de
The WiMAX Network Reference Model

The WiMAX Overall Architecture: The Network Reference Model

For more info see: WiMAX-Forum paper [1]

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WiMAX uses Sliding Window ARQ Mechanism
WiMAX-MAC uses Hybrid-ARQ

Source: Lüders, "Mobilfunksysteme" (modified)
WCDMA (Wideband CDMA)

The sent signal is strongly spread.

→ Higher bandwidth.

→ Robustness against narrow-band interference impulses.

Some technical features of UMTS-WCDMA:

- Radio channels are 5 MHz wide.
- Chip rate of 3.84 Mcps.
- Supports 2 basic modes of duplex: frequency division and time division.
WiMAX Architecture Is Standardized.

• Creation of the network specification.

• Definition of the network requirements and priorities.

Source: www.wimax.com
The UMTS Overall Architecture Is Classified In Domains.
The UMTS Overall Architecture is Classified In Domains.
The UMTS overall-architecture: The Core Network Domain (rel-5)

Source: http://www.tech-invite.com/Ti-ims-releases.html#fig5
The UMTS overall-architecture:
The Core Network Domain (rel-5)

Source: http://www.tech-invite.com/Ti-ims-releases.html#fig5
The QoS classes of WiMAX

1. **Unsolicited Grant Service (UGS)**:
   - real-time data stream fixed-size data packets issued periodically.
   - Exp: Voice over IP without silence suppression.

2. **Real-time Polling Service (rtPS)**:
   - real-time data streams with variable size that are issued periodically.
   - Exp: MPEG (Moving Pictures Experts Group) video transmission.

3. **Non-real-time Polling Service (nrtPS)**:
   - delay-tolerant data streams that are composed of variable-size data packets for which a minimum data rate is compulsory.
   - Exp: FTP transmission.

4. **Best Effort (BE)**:
   - data without minimum service guarantees. Exp: Email

5. **Extended Real-time Polling Service (ertPS)**:
   - combination of UGS and rtPS-class variable rate real-time applications having rate and delay requirements. Exp: VoIP with activity detection.
QoS Management Scenario (WiMAX)

The figure shows the sublayers of the WiMAX-MAC layer.

Where does the QoS management happen?

MAC: Medium Access Control
SAP: Service Access Point

source: A paper of the IEEE communications magazine dec 2007 with the title: „A survey on mobile WiMAX“ (modified)
The QoS classes of UMTS

1. **Background**: QoS-Class for data transfer (Email)
   - requires the lowest error rate possible.
   - non-critical restrictions (demands) on bandwidth, delay and jitter.

2. **Interactive**: QoS-Class for the use of interactive services (web-browsing, online video games…)
   - requires the lowest error rate possible.
   - higher demands concerning delays.

3. **Streaming**: QoS-Class for sharing services (video-on-demand, internet-radio…)
   - a minimum bandwidth is required.
   - jitter is allowed within certain limits.
   - Bit errors are not critical.

4. **Conversational**: QoS-Class for direct communication like telephony and video telephony.
   - similar requirements to the requirements of the streaming-class.
   - but jitter and delay must also be small.