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white paper

Technical overview and performance of HSPA and Mobile WiMAX

How the performance of HSPA and Mobile WiMAX compare, in theory and in practice.

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Contents

1 Introduction

In a few short years, the internet has had a dramatic impact on our private and professional lives. And it continues to grow in importance in our daily lives: To fully enjoy the benefits of the internet, users need a broadband connection. And in coming years, millions of people will turn to wireless technology to deliver this experience.

A host of technologies are competing to deliver commercial mobile broadband services. By far the most successful of these is HSPA, which has been commercially deployed by more than 100 operators in more than 50 countries, with an additional 50 operators (and counting) committed to rolling out commercial services.[1] HSPA is a state-of-the art technology that can provide mobile and wireless broadband services with unsurpassed performance and economies of scale to the vast majority of the market. By 2010 we expect there to be more than 600 million mobile broadband subscribers, rising to 900 million by 2012 and the vast majority, 70 percent, will be served by HSPA networks and 20 percent by CDMA EV-DO.

A good mobile broadband system must fulfill certain criteria, including high data rate, high capacity, low cost per bit, low latency, good quality of service (QoS), and good coverage. Several techniques can be used to meet these criteria in a wireless system, including:

- for higher data rates (and capacity)
  - higher-order modulation schemes, such as 16 quadrature amplitude modulation (16QAM) and 64QAM
  - multiple-input, multiple-output (MIMO) advanced antenna systems that rely on multiple antennas at both the transmitter and receiver, effectively multiplying the peak rate
- for improved QoS and low latency
  - dynamic scheduling, with end-user traffic streams prioritized according to service agreements
  - short transmission time intervals (TTI), allowing for round-trip times approaching wired equivalents (such as DSL)
- for higher capacity
  - shared-channel transmission to make efficient use of available time/frequency/codes and power resources
  - link adaptation to dynamically optimize transmission parameters, depending on actual radio conditions
  - channel-dependent scheduling to assign radio resources to users with the most favorable radio conditions
  - hybrid automatic repeat request (H-ARQ) to enable rapid retransmission of missing data, and soft combining to significantly improve performance and robustness
- for greater coverage
  - advanced antenna systems and advanced receivers to enhance the radio link and improve cell range.

Both HSPA and Mobile WiMAX employ most of these techniques, and their performance is broadly similar. However, they differ in areas such as the duplex scheme (FDD versus TDD), frequency bands, multiple access technology, and control channel design, giving rise to differences mainly in uplink data rates and coverage.

1 Source: Global mobile Suppliers Association (GSA), April 2007

1.1 HSPA

The 3rd Generation Partnership Project (3GPP) is a collaboration that brings together a number of telecommunications standards bodies. The 3GPP was jointly formed by telecommuncation associations from the US, Europe, Japan, South Korea and China. At present, it has more than 400 member companies and institutions. The 3GPP defines GSM and WCDMA specifications for a complete mobile system, including terminal aspects, radio access networks, core networks, and parts of the service network. Standardization bodies in each world region have a mandate to take the output from the 3GPP and publish it in their region as formal standards.

3GPP specifications are structured in releases. Ordinarily, discussions of 3GPP technologies refer to the functionality in one release or another. It is worth noting that all new releases are backward-compatible with previous releases.

The development of the 3GPP technology track (GSM/WCDMA/HSPA) has been spectacular. Within a ten-year span, for example, there has been a 1000-fold increase in supported data rates. What is more, the 3GPP technologies continue to evolve. WCDMA 3GPP Release 99 provided data rates of 384kbps for wide-area coverage. However, greater speed (data rates) and capacity were soon required (at lower production cost) as the use of packet data services increased and new services were introduced.

Among other things, WCDMA 3GPP Release 5 extended the specification with a new downlink transport channel, the high-speed downlink shared channel, which enhanced support for high-performance packet-data applications. Compared with Release 99, the enhanced downlink gave a considerable increase in capacity, which translated into reduced production cost per bit. It also significantly reduced latency and provided downlink data rates of up to 14Mbps. These enhancements, which commonly go under the denomination HSDPA (High Speed Downlink Packet Access), were a first step in the evolution of WCDMA.

Although a great deal of traffic is downlink-oriented, several applications also benefit from an improved uplink. Examples include the sending of large e-mail attachments, pictures, video clips and blogs. The key enhancement in WCDMA 3GPP Release 6 was a new transport channel in the uplink, enhanced uplink (EUL) – also sometimes referred to as HSUPA (High Speed Uplink Packet Access) – which improved throughput, reduced latency and increased capacity. EUL provides data rates of up to 5.8Mbps.

The combination of HSDPA and EUL is called as HSPA (High Speed Packet Access).

3GPP Release 7 introduced HSPA evolution (also called HSPA+), which supports MIMO, 64QAM in the downlink, and 16QAM in the uplink, to further boost the peak data rate and capacity. HSPA evolution supports data rates of up to 42Mbps in the downlink and 11.5Mbps in the uplink.

LTE (Long Term Evolution), currently being specified by 3GPP for Release 8 (scheduled for completion by the end of 2007), introduces OFDM/OFDMA in the downlink and single-carrier FDMA (SC-FDMA) in the uplink. LTE supports very high data rates, exceeding 300Mbps in the downlink and 80Mbps in the uplink. LTE will support operation in both paired and unpaired spectrum (FDD and TDD) using channel bandwidths of approximately 1.25MHz up to at least 20MHz.

Table 1: Progressive enhancements to 3GPP specifications

Version	Released	Info
Release 99	2000 Q1	Specified the first UMTS 3G networks, incorporating a WCDMA air interface
Release 4	2001 Q2	Added features, including an all-IP core network
Release 5	2002 Q1	Added IMS and HSPA
Release 6	2007 Q4	Integrated operation with Wireless LAN networks, added enhanced uplink, MBMS and enhancements to IMS such as Push to Talk over Cellular (PoC)
Release 7	2007 Q2	Added downlink MIMO, reduced latency, improved QoS and improvements to real-time applications like VoIP
Release 8	In progress	Includes E-UTRA (LTE) and the Evolved Packet Core (SAE) architecture and further enhancements of HSPA

1.2 Mobile WiMAX

The IEEE 802.16 Working Group on broadband wireless access standards, which was established by the IEEE Standards Board in 1999, prepared the formal specifications for broadband wireless metropolitan area networks (WirelessMAN, the 802.16 family of standards is the basis of Mobile WiMAX).

IEEE 802.16-2004 (also called simply 802.16d) provides support for non-line of sight (NLOS) and indoor end-user terminals for fixed wireless broadband. In 2005, the standard was amended (IEEE 802.16e-2005 or 802.16e) adding support for data mobility.

IEEE 802.16e, or Mobile WiMAX, improves on the modulation schemes used in the original (fixed) WiMAX standard by introducing SOFDMA (scalable orthogonal frequency division multiple access).

The system profile in IEEE 802.16e-2005 is not backward compatible with the fixed WiMAX system profile.

The charter of the WiMAX Forum, which has more than 400 members, is to promote and certify the compatibility and interoperability of broadband wireless access equipment that conforms to IEEE 802.16 and the ETSI HiperMAN standard.

The WiMAX Forum thus defines and conducts conformance and interoperability testing to ensure that different vendor systems work seamlessly with each other.

WiMAX certification profiles specify characteristics including spectrum band, duplexing and channelization. Several profiles exist for fixed and Mobile WiMAX.

There are currently two waves of certification planned for Mobile WiMAX equipment:

- Wave 1: Mobile WiMAX system profile with single-input single-output (SISO) terminals for the 2.3GHz and 3.5GHz bands
- Wave 2: Mobile WiMAX system profile with multiple-input, multiple-output (MIMO) terminals and beamforming support for the 2.6GHz band (sometimes referred to as the 2.5GHz band).

Because IEEE 802.16 standardization only covers basic connectivity up to the media access (MAC) level, the WiMAX Forum also addresses network architecture issues for Mobile WiMAX networks. The focus of the first network architecture specification (Release 1.0) is on delivering a wireless internet service with mobility.

Release 1.5 will add support for telecomgrade mobile services, supporting full IMS interworking, carrier-grade VoIP, broadcast applications, such as mobile TV, and over-the-air provisioning. While Mobile WiMAX offers the promise of high-speed wireless broadband services, it is still very much in its infancy and real-life performance has yet to be proved.

Table 2: Evolution of WirelessMAN (802.16 family of standards)

Version	Released	Info
IEEE 802.16d IEEE 802.16-2004	2004 Q2	Replaced all previous 802.16 specifications. Support for non-line of sight operation
IEEE 802.16e IEEE 802.16e-2005	2005 Q4	Enhanced 802.16-2004 with support for data mobility
WiMAX Forum Network Architecture Specification Release 1.0	2007 Q1	Networking specifications for fixed, nomadic, portable and mobile WiMAX systems. Release 1.0 covers internet applications and data mobility
WiMAX Forum Network Architecture Specification Release 1.5	In progress	Enhancements to the Release 1.0 specification for carrier-grade VoIP, location-based services, MBMS, full IMS interworking and over-the-air client provisioning

2 Technical comparison

The HSPA and Mobile WiMAX technologies have been designed for high-speed packet-data services. They feature similar technology enablers, including dynamic scheduling, link adaptation, H-ARQ with soft combining, multiple-level QoS, and advanced antenna systems. Notwithstanding, their performance differs due to differences in the physical layer signal format, duplex scheme, handover mechanism, and operating frequency bands. This chapter provides a high-level description of the similarities and differences between HSPA and Mobile WiMAX. Technical details of HSPA can be found in the 3GPP specifications. Likewise, details of Mobile WiMAX can be found in the IEEE 802.16e-2005 standard and the WiMAX Forum Mobile System Profile.

2.1 Similarities

2.1.1 Dynamic scheduling

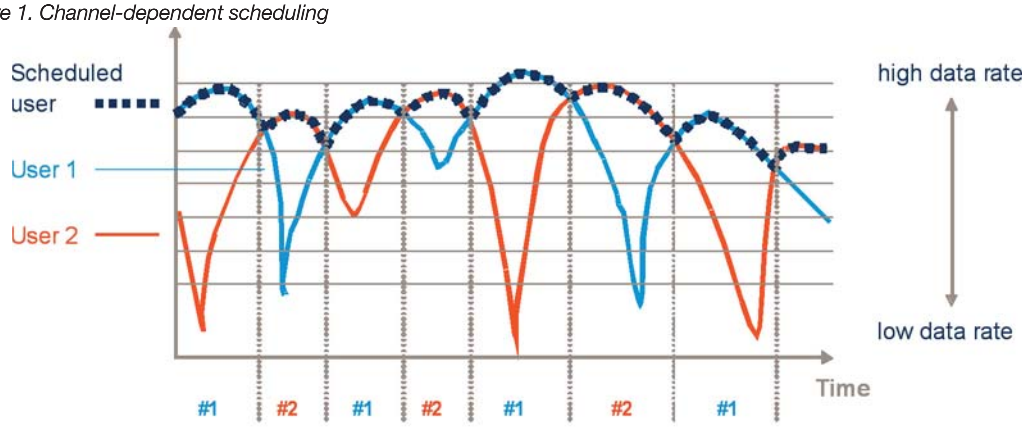
Traditional circuit-switched telephone systems set up connections as dedicated links during the entire session. This approach wastes communication resources for packet data because the dedicated link is tied up even during idle periods. For high-speed packet-data systems with bursty traffic, it makes better sense to allocate radio resources only during active periods.

Given the volatile nature of wireless channels, radio links often experience fluctuations in signal strength. It is thus more effective to schedule the base station and terminal to communicate only when radio conditions are good. HSPA and Mobile WiMAX systems use channel-dependent scheduling (Figure 1) for efficient and effective use of resources for packet data.

When a mobile device is scheduled for transmission, the quality of its radio link will vary in time. The modulation scheme and channel-coding rate used for a scheduled link can be adapted to minimize errors under a variety of radio conditions. Link adaptation (Figure 2) enables full utilization of channel capacity for each communication link in the wireless environment and so maximizes the throughput of scheduling-based systems.

HSPA and Mobile WiMAX support dynamic selection between QPSK, 16QAM and 64QAM modulation schemes, as well as of the channel-coding rate, where the lowest coding rate without repetition is 1/2 for Mobile WiMAX and 1/3 (additional coding gain) for HSPA. Overall, HSPA has finer granularity of modulation and coding formats than Mobile WiMAX.

Figure 1. Channel-dependent scheduling



Scheduling: determines which end user to transmit to, at a given moment
Channel-dependent Scheduling: transmit at fading peaks

2.1.2 Link adaptation

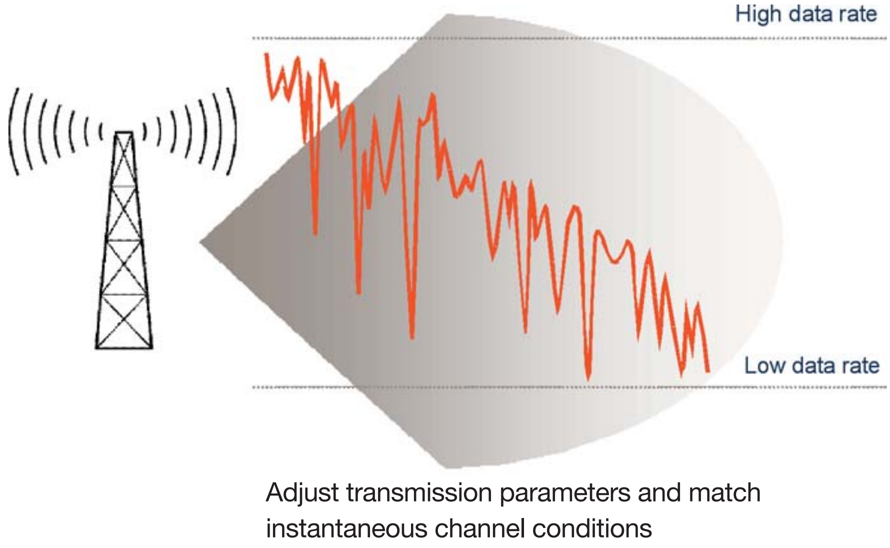


Figure 2. Link adaptation

2.1.3 H-ARQ with soft combining

Because of delays in channel quality feedback, link adaptation may suffer from errors incurred between time instances of reporting and scheduling. H-ARQ with soft combining on the downlink and uplink quickly corrects these error packets without having to rely on higher-layer ARQ.

H-ARQ with soft combining is an effective remedy to link adaptation errors and reduces retransmission delays that are vital for higher-layer throughput.

On the uplink, H-ARQ with soft combining also reduces transmission power and improves system capacity, thanks to lower interference and more stable power control. In HSPA, incremental redundancy is used for extra coding gain of the lower coding rate that goes along with the retransmission. In Mobile WiMAX, only Chase combining is available for energy gain; the coding rate is not adjusted after retransmission.

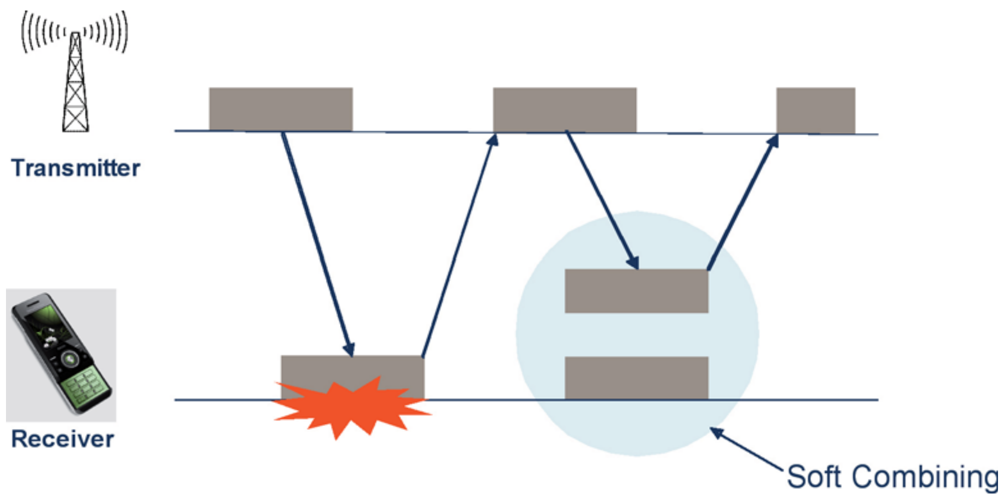


Figure 3. Hybrid acknowledgement request (H-ARQ) with soft combining

2.1.4 Multi-level quality of service

HSPA and Mobile WiMAX support multiple QoS levels. In HSPA, QoS levels are divided into four categories: conversational, streaming, interactive, and background.

In Mobile WiMAX, there are five scheduling mechanisms defined for different QoS levels in the uplink: unsolicited grant service (UGS), extended real-time polling service (ertPS), real-time polling service (rtPS), non-real-time polling service (nrtPS), and best-effort.

2.1.5 Advanced antenna technologies

Advanced multiple antenna technologies improve the performance and capability of modern mobile communication systems. In general, they rely on the use of multiple transmit and/or receiver antennas to achieve:

- diversity against fading on the radio channel
- beamforming, to improve the radio link signal-to-noise/interference ratio
- spatial multiplexing, often referred to as MIMO (multiple-input, multiple-output) antenna processing, to increase the peak data rates and utilize high radio-link signal-to-noise/interference ratios more efficiently.

WCDMA supports two multi-antenna transmission schemes: open-loop transmit diversity, and closed-loop transmit diversity. WCDMA open-loop transmit diversity uses modified Alamouti coding and can be applied to dedicated as well as common channels. Open-loop transmit diversity provides diversity against radio-channel fading. WCDMA closed-loop transmit diversity allows for adjustment of transmission phase and amplitude, based on instantaneous downlink channel conditions. Therefore, in addition to diversity, WCDMA closed-loop transmit diversity allows for beamforming gains.

WCDMA open-loop and closed-loop transmit diversity are also available for HSPA. In addition, 2x2 spatial multiplexing (in HSPA Release 7) effectively doubles downlink peak data rates.

The Mobile WiMAX system profile specifies two types of multi-antenna transmission schemes:

- transmit diversity using the Alamouti space-time code (STC), which is similar to WCDMA/HSPA open-loop transmit diversity
- spatial multiplexing (MIMO).

Mobile WiMAX also supports beamforming, which is enabled by uplink sounding. By taking advantage of TDD channel reciprocity, the spatial characteristics measured at the base station can be used to form downlink beams. In practice, however, performance is limited by the asymmetry of interference and different antenna settings at the terminal and base station.

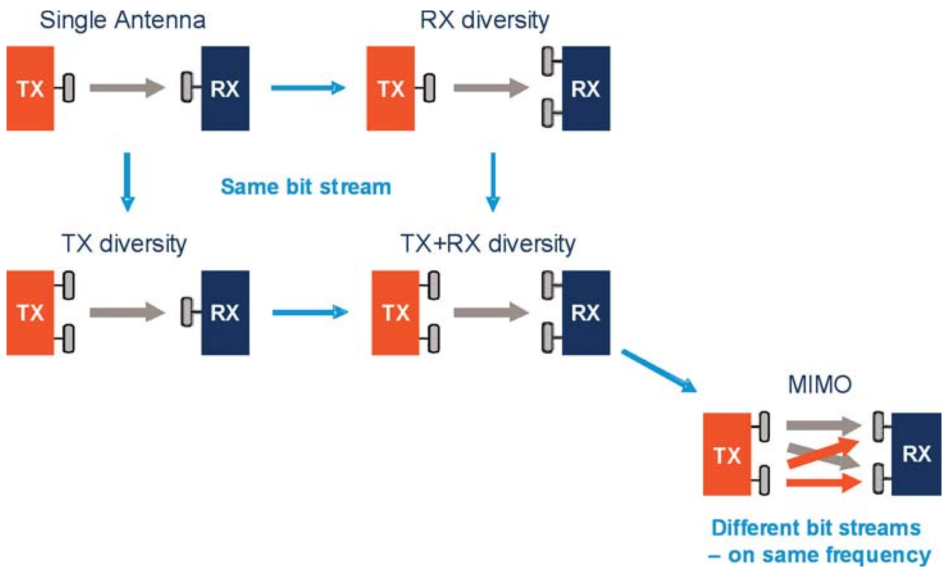


Figure 4. Overview of different antenna transmission schemes

2.2 Differences

2.2.1 Physical signal format

The main differences between Mobile WiMAX and HSPA in the physical layer lie in the signal format. Mobile WiMAX is based on orthogonal frequency domain multiplexing (OFDM), whereas HSPA is a direct-sequence spread-spectrum system. One of the most important features of OFDM is its robustness to multi-path propagation. The key enabler of this feature is the use of narrowband tones in combination with a cyclic prefix. The cyclic prefix serves two purposes: It provides a guard time against inter-symbol interference, and it ensures that the multipath channel only imposes a scalar distortion on each tone, making equalization simple and effective. When properly synchronized and protected by cyclic prefix, tones of an OFDM signal remain mutually orthogonal even after going through multipath channels. The disadvantage of using cyclic prefix is increased overhead, which effectively reduces bandwidth efficiency.

The ability of an OFDM signal to maintain orthogonality under multipath conditions gives an intra-cell interference-free system that is well suited to high-speed data transmission. However, inter-tone interference arises (degrading performance) when there are large Doppler spreads in OFDM. When OFDM signals are used for uplink multiple accesses, Mobile WiMAX base stations must fine tune the frequency errors of each terminal within tolerable ranges, and minimize the total interference level by means of power control.

OFDM signals also have a relatively large peak-to-average power ratio (PAPR), which means that for a given average power, the power amplifier must be able to handle significantly higher power peaks, while avoiding distortion of the transmitted signal.

HSPA uses CDM code (orthogonal Walsh code) aggregation to offer a high-speed downlink channel, and direct-sequence code division multiple access (CDMA) for the uplink. While this method is less sensitive to Doppler spread, the loss of orthogonality in time-dispersive channels creates intra-cell interference that limits the use of highorder modulation. Generalized RAKE receivers can alleviate interference through advanced signal processing on the receiver side at the moderate cost of additional receiver complexity.

When compared with OFDM signals, the HSPA uplink signals have lower PAPR – which implies a less complex power amplifier. Alternatively, for a given complexity, a higher average power can be used, giving greater coverage.

2.2.2 Duplex scheme

One other difference between HSPA and Mobile WiMAX is the duplex scheme. HSPA is an FDD technology, with uplink and downlink transmission taking place in separate frequency channels (usually denoted as 2x5MHz to indicate two separate 5MHz channels, one for the uplink and one for the downlink).

The Mobile WiMAX system profile, as currently defined in the WiMAX Forum, is a TDD technology with just one frequency channel (10MHz for example) that is shared in the time domain between the uplink and downlink. The ratio between the uplink and downlink defines how the frequency channel is shared. A 2:1 ratio means the channel is used two-thirds of the time for the downlink and one-third of the time for the uplink (Figure 5).

The IEEE 802.16 specification allows for FDD operation, but to date, the Mobile WiMAX system profile solely stipulates TDD. TDD has the flexibility of changing the downlink-to-uplink ratio to accommodate a variety of traffic asymmetries, although in practice the ratio needs to be fixed system-wide (unless guard bands are used to limit interference effects). In addition, TDD systems with a large downlink-to-uplink ratio, will have a link budget penalty as the uplink average power is reduced for a given peak power.

The interference scenarios are different between FDD and TDD systems (Figure 6). FDD systems use a frequency duplex gap between the uplink and the downlink to prevent interference between transmissions. TDD systems use a guard time between the uplink and downlink.

When building a TDD network, one must deal with a variety of interference scenarios:

- Interference within a network – interference between base stations and between terminals. All the base stations must be fully time-synchronized with each other (for example, using a GPS receiver at each base station).
- Between a network and an adjacent TDD network – two or more TDD networks using the same frequency band in the same geographical area. To avoid interference, synchronization must be coordinated between neighboring networks, or guard bands must be used. This scenario might occur at national or state borders, especially where only local licenses have been issued.

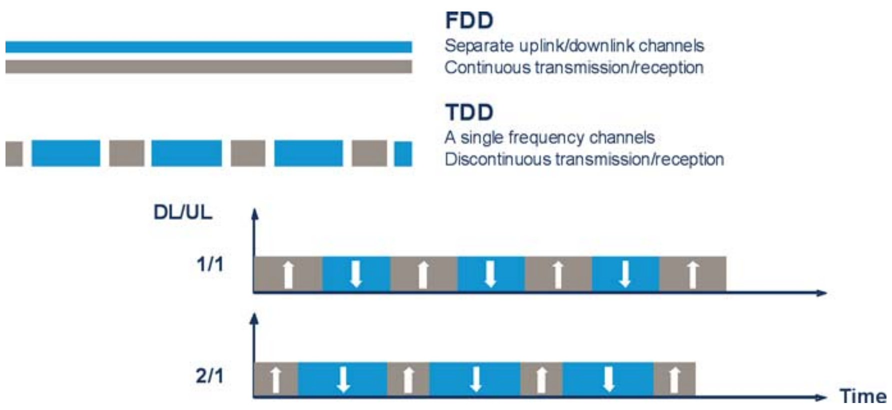


Figure 5. Overview of FDD and TDD

- Between a network and a spectrum-adjacent TDD network – one TDD network uses adjacent frequencies, giving rise to base station-to-base station interference if the base stations from the different networks are in close proximity. The uplink to one base station can suffer interference from the out-of-band leakage (ACLR) from another base station. This interference can be reduced by synchronizing the networks, or by using guard bands.
- FDD and TDD spectrum borders – an FDD network uses frequencies adjacent to the TDD network, giving rise to base station-to-base station interference if the base stations from the different networks are in close proximity. This interference can only be resolved using suitable guard bands.
- Duty cycle uplink/downlink settings in the TDD network in relation to adjacent networks – in addition to synchronization in time, when setting the uplink/downlink ratio in a TDD network, the ratio within the network and with neighboring networks must be coordinated, to avoid all the interference cases mentioned above. Alternatively, guard bands can be used.

Stringent requirements from existing satellite services in specific bands make it difficult to deploy TDD technologies in these frequencies. The tougher coexistence environment for TDD puts heavy requirements on the RF filters, which are just as complex as the duplex filter requirements for FDD.

The 3GPP specification covers FDD and TDD, but there have not been any major deployments of TDD-based cellular systems.

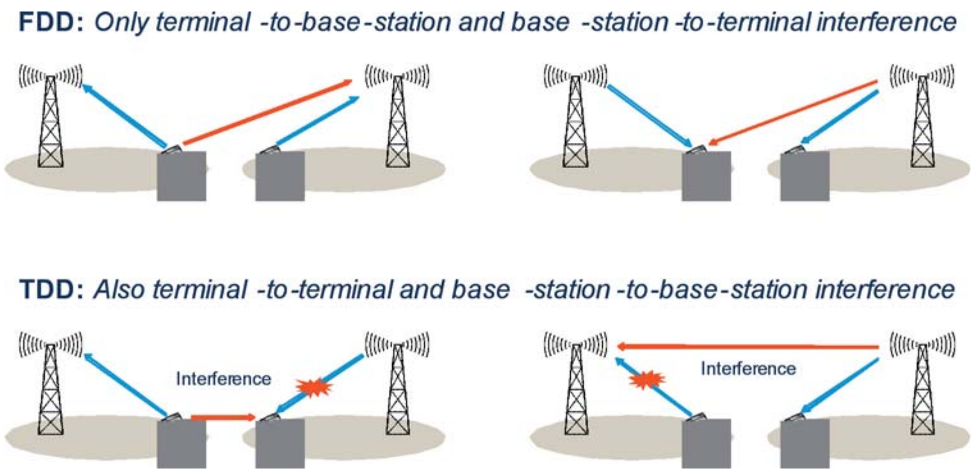


Figure 6. Overview of interference scenarios for FDD and TDD systems

2.2.3 Handover mechanism

HSPA supports soft handover in the uplink, which yields macro combining gain and improves the link budget (by 1.5dB on average). It also helps increase network capacity by reducing intra-cell interference. Hard handover is used for intrafrequency handover and inter-system handover to GSM.

The Mobile WiMAX system profile includes only hard handover.

2.2.4 Operating frequency bands

HSPA currently supports frequency bands ranging from 800MHz to 2600MHz, including most current 2G operating bands in Europe, Africa, the Americas and Asia-Pacific. The most common bands for HSPA are 2.1GHz, deployed worldwide, and the 850MHz band deployed in the Americas, Australia, New Zealand, and parts of Asia.

Several frequency bands are under discussion for Mobile WiMAX, but current Mobile WiMAX certification profiles only cover the 2.3GHz, 2.6GHz and 3.3–3.8GHz frequency bands. At present, there are only a few deployments of Mobile WiMAX, mainly in the 2.3GHz band.

Approximately 90 percent of all spectrum allocations worldwide are FDD.

2.3 Summary technical comparison

Table 3 summarizes the technical similarities and differences between HSPA and Mobile WiMAX.

Table 3. Technical comparison of HSPA and Mobile WiMAX

	HSPA	**Mobile WiMAX**
Physical signal format	DL code aggregation, UL DS-CDMA	OFDMA for both DL and UL
Hybrid ARQ with soft combining	Adaptive IR + Chase combining	Chase combining
Multi-level QoS	√	√
Link adaptation	QPSK, 16QAM, 64QAM Lowest code rate: 1/3	QPSK, 16QAM, 64QAM Lowest code rate: 1/2
Duplex scheme	FDD	TDD
Frequency bands	850MHz to 2,600MHz	2.3GHz, 2.6GHz and 3.4–3.8GHz
Handover	Hard handover, Soft handover	Hard handover
Frequency reuse one	√	√
Advance antenna technologies	• Closed- and open-loop transmit diversity • Spatial multiplexing • Beam forming	• Open-loop transmit diversity • Spatial multiplexing • Beam forming

3 Performance characteristics

Vital characteristics of system performance are data rates, delay, spectrum efficiency and coverage. For end users, these characteristics determine which services can be offered. For operators, they define number of users and base station coverage area, which directly influences the cost of operating the system.

This chapter presents the performance characteristics of HSPA and Mobile WiMAX in terms of peak data rates, spectrum efficiency and coverage. Rather than cover just one version (or release) of each system family – which might give a misleading picture – the discussion covers a set of HSPA and Mobile WiMAX releases, to enable a fair comparison. Because many features are common to both system families, including antenna (MIMO) concepts, modulation and channel coding, the performance is similar in many respects. There are some differences, however, such as the duplex scheme, frequency bands, multiple access technology and control channel design, which give rise to differences, for example, in uplink bit rates and coverage.

3.1 Peak data rates

The peak data rate indicates the bit rate a user in good radio conditions can reach when the channel is not shared with other users. Figure 7 shows the downlink and uplink peak data rates, measured above the MAC layer, for a set of system concepts. Early releases of HSPA (Release 6) and Mobile WiMAX Wave 1 achieve comparable peak rates.

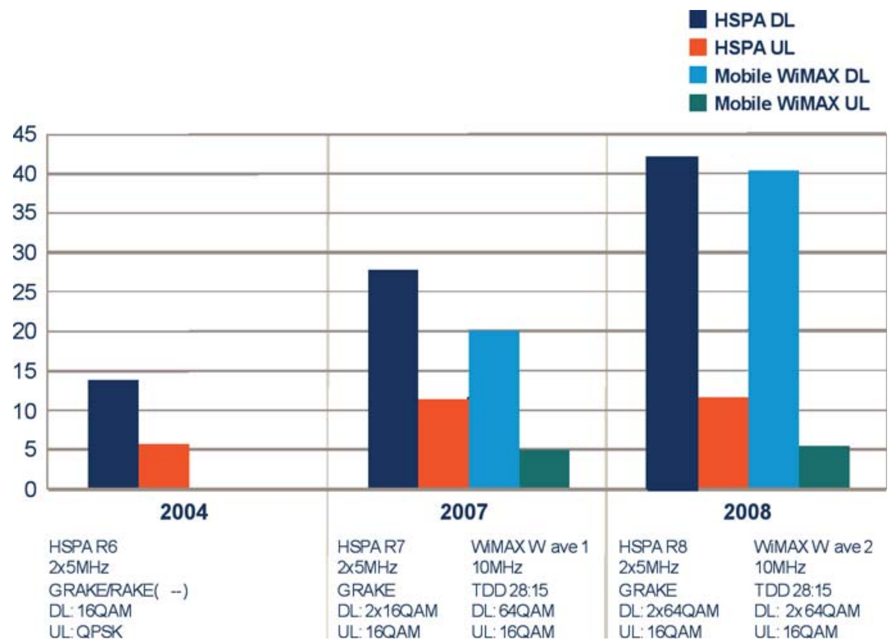


Figure 7. Peak data rates for a set of HSPA releases and WiMAX waves. For WiMAX, the TDD symmetry is expressed in terms of number of downlink and uplink slots for data (that is, 28:15). The use of multi-stream MIMO is indicated by a factor in front of the modulation scheme. The HSPA Release 8 results are based on preliminary features.

Mobile WiMAX uses higher-level modulation (64QAM in the downlink and 16QAM in uplink) than HSPA, which uses 16QAM in the downlink and QPSK in the uplink. HSPA Release 7 introduces 64QAM and two-stream MIMO in the downlink (but not for simultaneous use) and offers comparable performance to Mobile WiMAX Wave 2.

The peak data rate of HSPA Release 8 betters that of Mobile WiMAX Wave 2. In this case, the same modulation formats (64QAM and 16QAM) and comparable MIMO schemes (two streams in the downlink) are used, but HSPA has less overhead. Further enhancements for HSPA Release 8 are under evaluation.

Mobile WiMAX may use TDD asymmetries to increase downlink peak data rates at the expense of reduced uplink peak data rates.

3.2 Spectrum efficiency

Spectrum efficiency measures the maximum total amount of data that can be carried by a cell per unit of time, normalized with the occupied system bandwidth. For any given traffic load per user, spectral efficiency can be used to determine the number of users a cell can support.

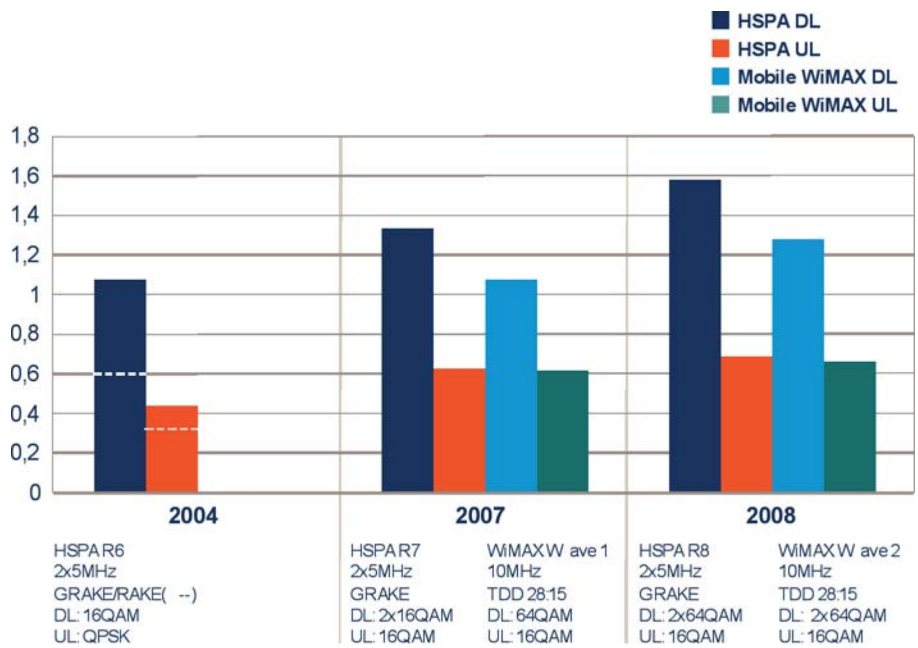


Figure 8. Spectrum efficiency comparisons (Note that absolute spectrum efficiency values vary with models and assumptions. The above values should be used for relative comparisons. The HSPA Release 8 results are based on preliminary features.)

The spectrum efficiency figures have been evaluated using models, assumptions and methodology aligned with 3GPP standards [1] (in this case, a system with 19 three-sector sites, placed on a regular grid with 500m inter-site distance). "Full buffer" type users are uniformly distributed. The selected propagation models (which model spatial correlation between antennas to enable accurate MIMO evaluations) simulate an urban environment.

System models, such as antenna solutions and output powers, have been aligned with the capabilities of the studied systems. Similar assumptions have been made for all systems, with the aim of achieving fair comparisons. The figures should be used for comparative purposes and not as absolute values.

The spectrum efficiency achieved by HSPA Release 6 is dependent on receiver type. Mobile WiMAX Wave 1 has better spectrum efficiency than HSPA Release 6 with basic RAKE receivers (indicated by the dotted line in Figure 8). However, more advanced receivers, such as GRAKE with receive diversity, give substantially higher spectrum efficiency. A comparison of HSPA Release 6 with advanced receivers (which is available earlier than Mobile WiMAX Wave 1 devices) shows that HSPA has greater spectrum efficiency.

HSPA Release 7 is modeled with two-stream MIMO in the downlink and 16QAM in the uplink. Mobile WiMAX Wave 2 performance (which has approximately the same availability as HSPA Release 7) is comparable to HSPA Release 7.

HSPA Release 8 is modeled with preliminary features and shows better spectrum efficiency than Mobile WiMAX Wave 2. These results are similar to those presented by 3G Americas. [2] The figures for Mobile WiMAX are somewhat lower than those presented by WiMAX Forum [4], probably because of differences in modeling. The WiMAX Forum does not present results for HSPA Release 7 or 8. Its HSPA Release 6 results are similar to those presented here, assuming simple receivers.

3.3 Coverage

Coverage is a crucial metric of performance, because it determines the number of sites needed to deploy a complete network, and the data rate available at a given distance in a given deployment. A common way of measuring coverage is to use link budgets, which provide an estimate of the maximum path loss the system can sustain between the base station and terminal.

Accurate absolute link budgets depend on several factors and are best simulated for a specific case. Relative comparisons of link budgets for different system concepts are easy to make and informative. HSPA and Mobile WiMAX have distinctive characteristics that affect the link budget, including output power, duplex method and frequency band – especially on the uplink, which is typically the limiting link. Figure 9 summarizes the impact of these characteristics.

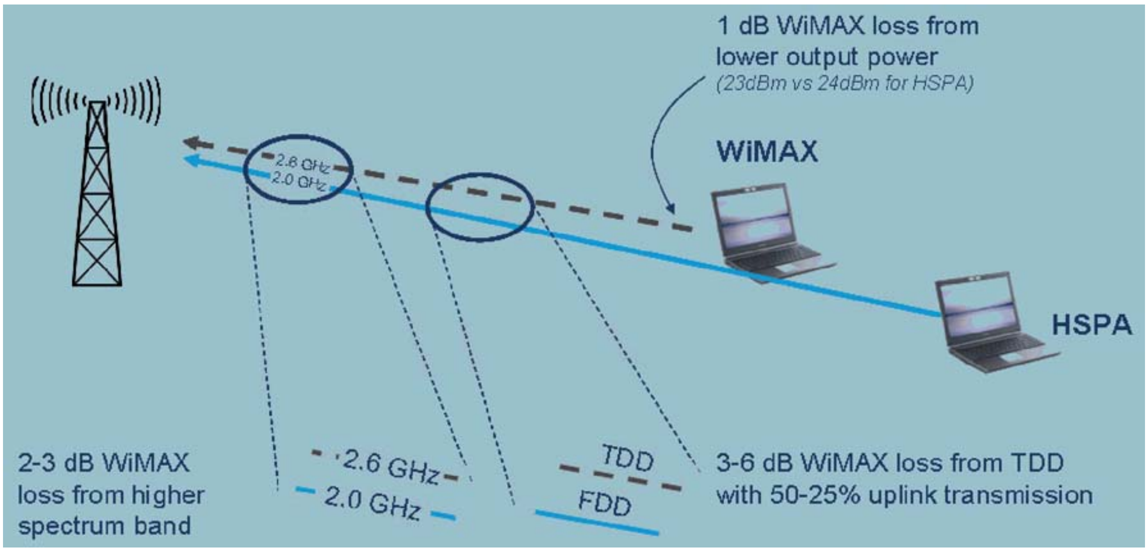


Figure 9. HSPA typically has 6-10dB greater coverage than Mobile WiMAX.

Using typical terminal power classes, the maximum output power of Mobile WiMAX terminals (23dBm) is 1dB lower for than for HSPA (24dBm), which is a difference of 1dB in the link budget. One reason for this difference is the difference in uplink modulation and multiple access methods.

With TDD, if the link is only used half the time for a given average data rate, the data rate when transmitting must be twice as high. If the link is used one-quarter of the time, the data rate when transmitting must be four times higher. Radio links to terminals at the cell border are typically power-limited, so that the bit rate achieved is proportional to the transmitted power but insensitive to channel bandwidth. To compensate for this loss, the terminal must thus have a factor 2 (3dB) or 4 (6dB) better path loss for activity factors of 50 percent and 25 percent, respectively.

Deploying Mobile WiMAX in higher frequency bands than are typically used for HSPA will lead to an additional loss in link budget. Path loss is proportional to the square of the frequency. With Mobile WiMAX operating in the 2.6GHz band and HSPA operating in the 2.1GHz band, and the uplink operating at about 2.0GHz, the path loss increases by a factor of (2.6/2.0)2 = 1.7, or 2.3dB. At 3.5GHz the corresponding figure is 4.9dB.

Apart from these differences, soft handover in HSPA improves coverage, and lower overhead improves sensitivity.

In summary, although Mobile WiMAX and HSPA are based on similar techniques, the link budget of Mobile WiMAX can be up to 6dB worse than that of HSPA. In a coverage-limited network, this would translate into the need for 2.2 times as many sites. This figure is derived on the basis of d3.5 propagation (which is typical in urban and suburban areas). In this case, a path loss increase of 6dB, or a factor of four, corresponds to a distance coverage loss of a factor of 41/3.5 = 1.5, or an area coverage loss of a factor 1.52 = 2.2. In rural areas with lower path loss exponents, the differences are larger.

For a coverage-driven deployment, Mobile WiMAX at 2.6GHz would need approximately 2.3 to 3.4 times more sites than HSPA at 2.1GHz. Even compared with HSPA at 2.6 GHz, Mobile WiMAX increases the site count by approximately 1.7 to 2.5 times.

3.4 Real-life experience

HSDPA has been commercially available since 2005, and has been rolled out for commercial operation in networks around the world. Initially, user terminals were limited to five codes and 16-QAM modulation, giving a theoretical maximum data rate of 3.6Mbps. Feedback from live networks shows that the actual rates are close to the theoretical simulations (Figure 10). User terminals are now available that support ten codes and have a theoretical maximum data rate of 7.2Mbps. Tests using these terminals on commercial systems have proved the simulated results (Figure 11).

HSPA is a mature technology that offers mobile broadband services to rival the performance of fixed broadband networks (such as ADSL and cable). Load calculations in an HSPA network show that operators can deliver a commercially viable flat rate mobile broadband service, with a 10GB monthly "bit bucket," to every subscriber in the network.

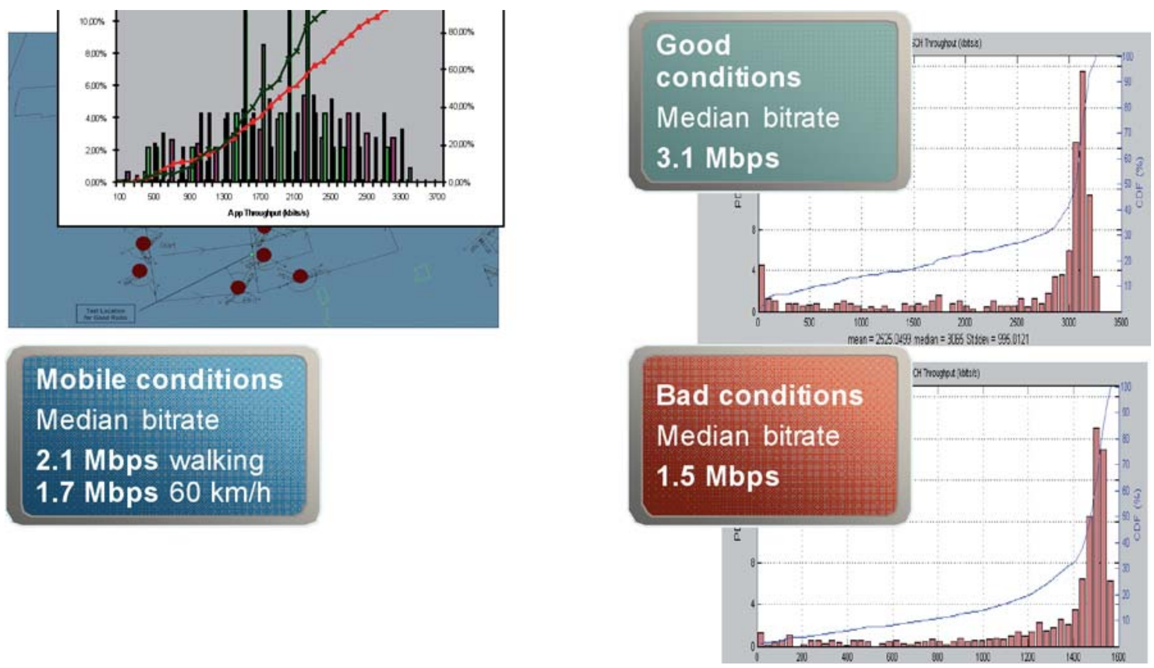


Figure 10. HSPA performance measured in a live commercial network

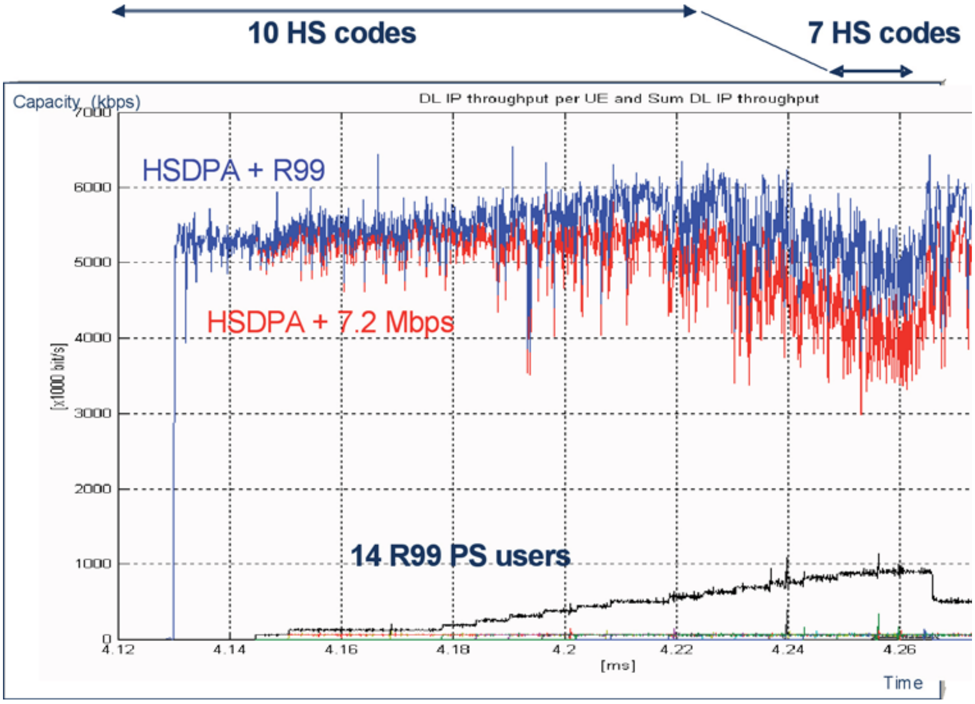


Figure 11. HSPA performance measured on a commercial system using a terminal that supports up to 7.2Mbps

4 Network architecture

The 3rd Generation Partnership Project is a collaboration agreement that brings together a number of telecommunications standards bodies. 3GPP handles GSM and WCDMA standardization for the complete mobile system, including terminal aspects, radio access networks, core networks and parts of the service network.

The radio interface is progressively being improved with every advance in the 3GPP specification, as is the network. In step with HSPA, the 3GPP Release 7 reference architecture has been enhanced with a 3G Direct Tunnel that optimizes the delivery of mobile and wireless broadband services. The Direct Tunnel architecture provides a direct data-path from the RNC to the GGSN, increasing topological flexibility and improving latency compared with 3GPP Release 6 and earlier architectures.

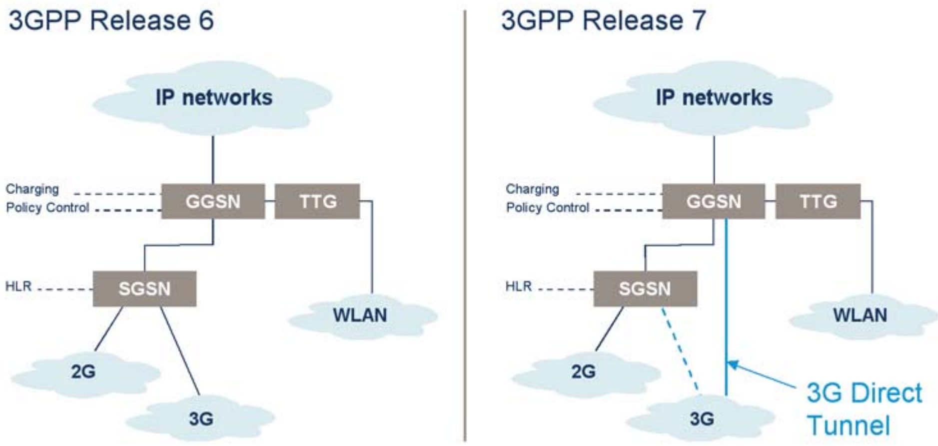


Figure 12. Overview of the 3GPP reference architecture

4.1 WiMAX Forum and IEEE

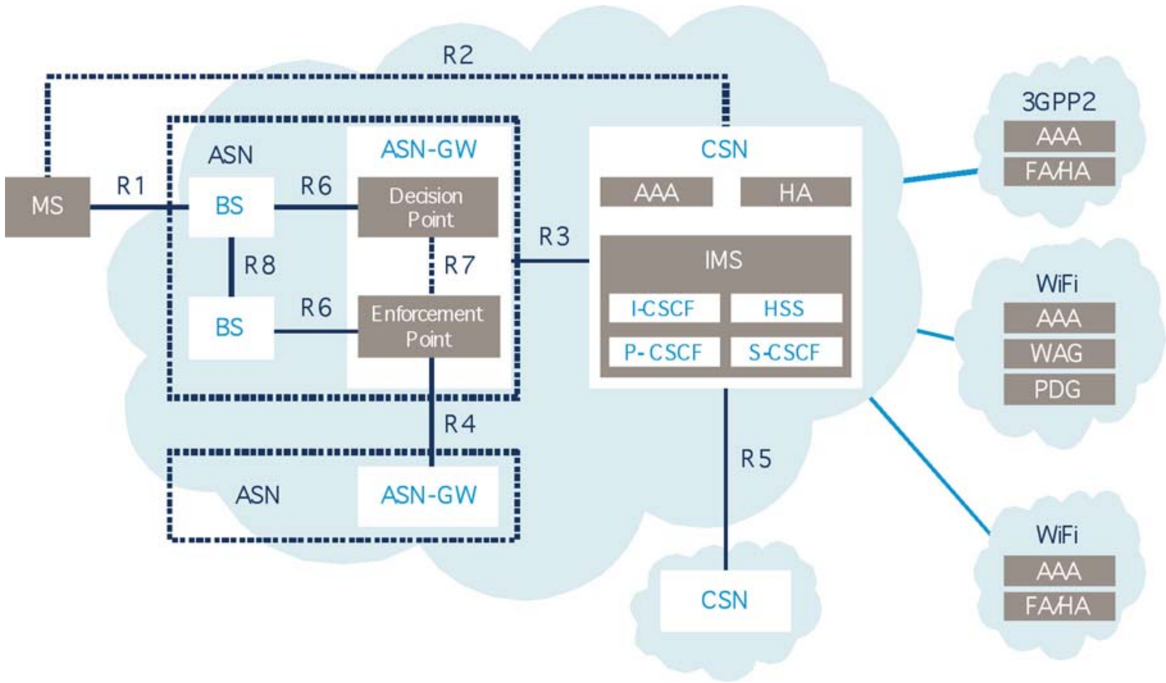


Figure 13. Mobile WiMAX network architecture

The IEEE 802.16 standard covers the air interface (IEEE 802.16e) and basic connectivity up to the media access (MAC) level. The WiMAX Forum defined the network architecture specifications for WiMAX networks. The first specification (Release 1.0) focuses on delivering internet services with mobility. At present, the network architecture defines three RAN profiles, each with a different functional allocation:

- Profile A:
  - centralized ASN model with base station and ASN gateway (ASN-GW) implemented on separate platforms, interacting through the R6 interface
  - split radio resource management, with the radio resource agent in the base station and the radio resource controller in the ASN-GW
  - open interfaces for Profile A: R1, R6, R4, and R3
- Profile B:
  - ASN solution where the base station and ASN-GW functions are implemented on a single platform
  - open interfaces Profile B: R4 and R3
- Profile C:
  - Similar to Profile A except that radio resource management is not split and is located entirely in the base station.

4.2 Architecture comparison

Figure 14 shows a comparison of the suggested Mobile WiMAX architecture and the 3GPP Release 7 architecture for mobile broadband services.

The target requirements are broadly similar with similar functional allocations and architecture. However, the selection of protocols in each standards organization has been influenced by the chosen technology. 3GPP builds on GTP and Diameter, which provides optimized interworking with legacy GSM terminals and common anchoring in the GGSN for dual-mode GSM/WCDMA/HSPA terminals. GTP also provides an efficient way of handling QoS and of creating binding to radio bearers. The WiMAX Forum, by contrast, has gone with Mobile IP and Radius; it also supports PMIP and CMIP for both IPV4 and IPV6.

A comparison of Mobile IP and GTP reveals several similarities in terms of functionality. For instance, the protocols solve the same types of problems in areas such as session management, user plane tunnel set-up for IPv4 and IPv6 payload, and multiple packet sessions.

However, using IP tunneling protocols to meet the need for wireless mobility requires a lot of functionality in areas such as bearer management, QoS, charging, radio access type information and others. From the very outset GTP has been tailor made to support this functionality. This differs from the approach of the WiMAX Forum, which has instead extended the baseline IETF protocols to include wireless-specific functionality and to deploy multiple protocols in parallel over the same interface.

At a high level, Radius and Diameter look quite similar. Both were developed by IETF, and Diameter is an evolved version of Radius. Diameter is widely used within IMS specifications and provides functionality beyond Radius, mainly in the area of carrier-grade performance. This translates into functionality, such as standardized application packages (instead of vendor-specific attributes), reliable transport layer, bidirectional communication, and heartbeat mechanisms.

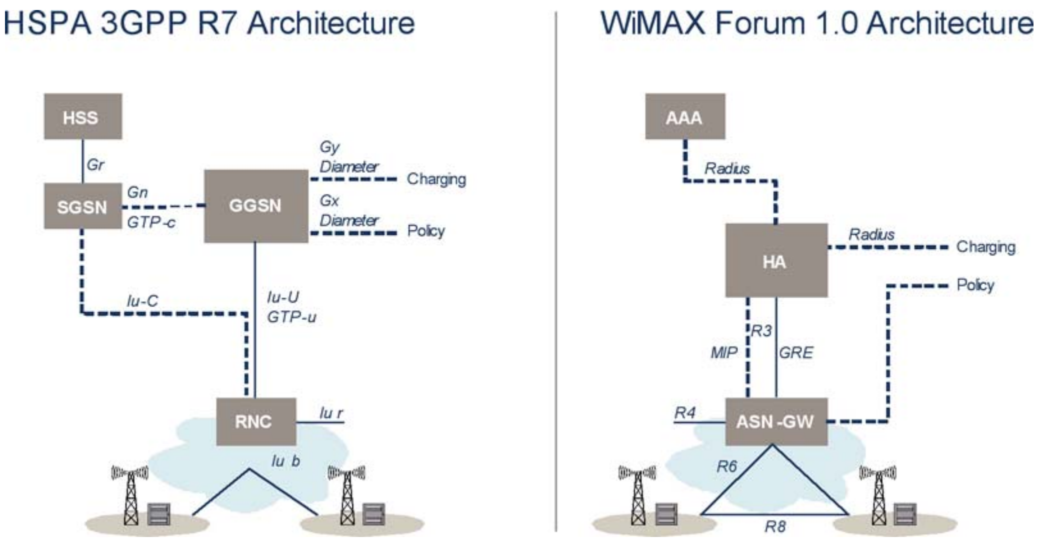


Figure 14. HSPA and Mobile WiMAX network architectures

4.3 System Architecture Evolution

The System Architecture Evolution (SAE), specified together with LTE, is the next step in the 3GPP architecture evolution. It will deliver flattened network architecture with simplified QoS, for the delivery of IP services (Figure 15).

Scheduled for completion in 2007, SAE is an evolution of 3GPP Release 7, with support for 3GPP LTE and non-3GPP access technologies, as well as current 2G and 3G access technologies.

The architecture splits packet core control and user plane functionality into separate nodes. Moreover, it further optimizes the HSPA architecture for mobile broadband services with two nodes (eNodeB and SAE gateway, SAE-GW) in the user plane for the main use cases.

The mobility management entity (MME), an evolution of the SGSN server, has been specified for 3G Direct Tunnel functionality in 3GPP Release 7. In all likelihood, many implementations, will co-locate the MME with the SGSN.

The SAE-GW node will include evolved GGSN functionalities including IP networking interfaces and end-user IP point of presence, shallow and deep packet inspection, as well as real-time charging, policy control, and mobility to non-3GPP accesses using mobile IP. What is more, operators who evolve their networks to LTE/SAE from GSM/WCDMA/HSPA will enjoy full backward compatibility with legacy networks.

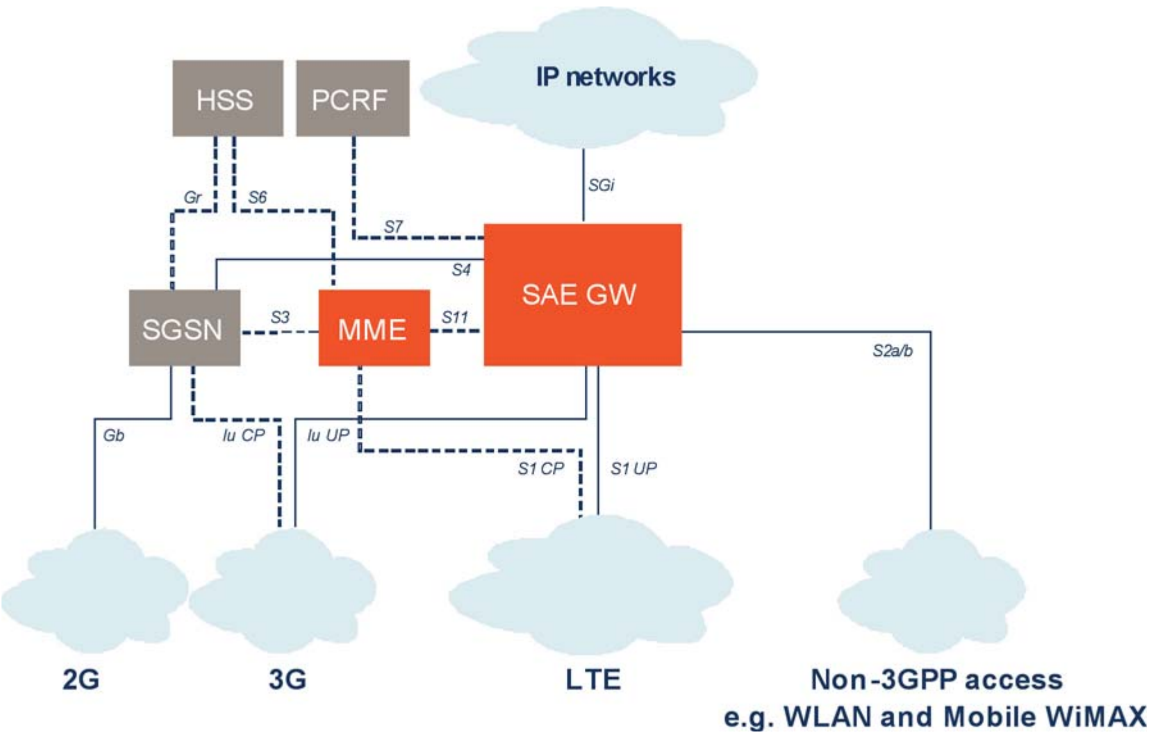


Figure 15. Overview of the SAE architecture

4.4 Mobile WiMAX

The details of the network architecture evolution for Mobile WiMAX beyond the Release 1.0, approved in March 2007, have yet to be determined. However, it is expected to include enhanced functionality, such as policy management and IMS support, prepaid support, emergency services, and roaming.

5 Conclusion

Given that HSPA and Mobile WiMAX employ many of the same techniques, their performance is comparable in many areas. However, key differences in areas such as duplex mode (FDD versus TDD), frequency bands, multiple access technology, and control channel design give rise to differences in uplink bit rates and coverage.

While the peak data rates, spectral efficiency and network architecture of HSPA Evolution and Mobile WiMAX are similar, HSPA offers better coverage. In short, Mobile WiMAX does not offer any technology advantage over HSPA.

What is more, HSPA is a proven mobile broadband technology deployed in more than 100 commercial networks. It is built on the firm foundations of the 3GPP family, offering users the broadband speeds they want and the carrier-grade voice services they expect.

HSPA can be built out using existing GSM radio network sites and is a software upgrade of installed WCDMA networks. When used together with dual-mode terminals, these factors help ensures nationwide coverage for voice (GSM/WCDMA) and data (HSPA/EDGE).

Thanks to its heritage, HSPA gives operators a single network for multiple services with a sound business case built on revenues from voice, SMS, MMS, roaming, and mobile broadband.

HSPA offers an ecosystem of unrivalled breadth and depth as well as unmatched economies of scale that benefit all players in the ecosystem, which currently serves more than two billion subscribers.

Operator choices of technology today will influence operations for many years to come. The good news in this context is that 3GSM technologies are future-proof in terms of initial investment, economies of scale, and the ability to extend and continuously enhance the solution.

Compared with other alternatives, HSPA is the clear and undisputed choice for mobile broadband services.

6 Glossary

AAA	authentication, authorization and accounting
3G (third generation)	Radio technology for mobile networks, telephones and other devices. Narrowband digital radio is the second generation of technology.
3GPP	3rd Generation Partnership Project – a collaboration agreement that brings together a number of telecommunications standards bodies
3G LTE/SAE	3G Long Term Evolution/System Architecture Evolution
DSL	digital subscriber line
EDGE	Enhanced Data rates for Global Evolution
FDD	frequency division duplexing
GSM	Global System for Mobile communications
GPRS	General Packet Radio Service
HSPA	High Speed Packet Access – an extension of WCDMA to provide high bandwidth and enhanced support for interactive, background, and streaming services
IEEE	Institute of Electrical and Electronics Engineers
IMS	IP Multimedia Subsystem
IPR	intellectual property rights
ITU	International Telecommunication Union
MAC	Media Access Control
MIMO	multiple input, multiple output
OFDM	orthogonal frequency division multiplexing – a digital encoding and modulation technology used by 802.16-based systems (including WiMAX) as the air interface
PC	personal computer
TDD	time division duplexing
WCDMA	Wideband Code Division Multiple Access – a wideband spread-spectrum 3G mobile telecommunication air interface
WiMAX	Worldwide Interoperability for Microwave Access – a standards-based technology that enables the delivery of last mile wireless broadband access as an alternative to cable and DSL
VoIP	Voice over IP technology enables users to transmit voice calls via the internet using packet-linked routes; also known as IP telephony.

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