UMTS Forum

HSPA: High Speed Wireless Broadband

From HSDPA to HSUPA and Beyond

Introduction

From the first launches of UMTS service in the Japanese Market by NTT Docomo in 2002, UMTS has shown itself to be the fastest growing cellular technology in history. As of August 2005, it is estimated that over 30 million subscribers were using UMTS services globally. Services such as video telephony, video streaming, mobile TV and mobile e-mail are now commonplace and the public awareness of the capabilities of 3G networks and terminals has helped considerably in moving the public perception of the mobile terminal from a pure voice and text communication instrument to a multimedia device. The levels of speed and interactivity offered improve utility to the end-user and significantly improve productivity and opportunities for operators, end-users and enterprises.

The challenge facing the mobile telecommunications industry today is how to continually improve the end-user experience, offer appealing services through a delivery mechanism which offers improved speed, service attractiveness and service interaction. Possibly the most important improvement is the arrival of a new series of technologies referred to as High Speed Packet Access (HSPA). These technologies will be available as a relatively straightforward upgrade to existing UMTS networks and will offer improved bandwidth to the end-user, improved network capacity to the operator, and improved interactivity for data applications.

This paper seeks to explain in everyday industry terms what HSPA is, what it can do and what the benefits to all industry stakeholders will be. It is not an exhaustive technical description but an informational paper which seeks to raise industry awareness of how HSPA will affect the mobile telecommunications industry.

HSPA Explained

High Speed Packet Access (HSPA) is a generic term adopted by the UMTS Forum to refer to improvements in the UMTS Radio Interface in the Releases 5 and 6 of the 3rd Generation Partnership Project (3GPP) standards. HSPA refers to both the improvements made in the UMTS downlink, often referred to as High Speed Downlink Packet Access (HSDPA) and the improvements made in the uplink, often referred to as High Speed Uplink Packet Access (HSUPA) but also referred to as Enhanced Dedicated Channel (E-DCH).

HSDPA enables data transmission speeds of up to 14.4Mbit/s per user. Both HSDPA and HSUPA can be implemented in the standard 5 MHz carrier of UMTS networks and can co-exist with the first generation of UMTS networks based on the 3GPP Release 99 (R99) standard. As HSPA standards refer uniquely to the access network, there is no change required of the core network outside of the capacity increases that will be required to handle the expected increase in traffic generated by HSPA.

HSPA Technology

HSDPA

HSDPA introduces a number of new technical capabilities to the radio access network, which when combined offer a significant improvement for both end users and operators. These capabilities are;

- A new common High Speed Downlink Shared Channel (HS-DSCH) which can be simultaneously shared by multiple users,
- The use of a shorter Transmission Time Interval (TTI) of 2ms, which enables higher speed transmission in the physical layer,
- The use of fast scheduling,
- The use of Adaptive Modulation and Coding (AMC),
- The use of fast retransmission based on fast Hybrid Automatic Response reQuest (HARQ) techniques.

The **HS-DSCH** is shared channel with a number of Spreading Factor 16 (SF-16) CDMA codes. Within each 2 ms TTI, a constant spreading factor of 16 is used with a maximum of 15 parallel channels in the HS-DSCH. These channels may all be assigned to one user during the TTI, or may be split amongst several HSDPA users. There is no Power Control with HSDPA and the HS-DSCH is transmitted at a constant power while the modulation, the coding and the number of codes are changed to adapt to the variations of radio conditions.

The shorter **2ms TTI** (compared to TTI of between 10ms and 80ms in UMTS R99) means that the systems is more reactive to changing user or radio conditions and can quickly allocate capacity to users.

Fast data traffic scheduling means that variations arising from changing radio conditions can be accommodated and that the BTS is able to allocate as much of the particular cell's capacity to a particular user for a short period of time. This means that a user is able to receive as much data as radio conditions will allow. This capability is often compared to the mechanisms used in Wireless LAN (WLAN) systems.

Adaptive Modulation Coding (AMC) with fast link adaptation means that the modulation and coding formats can be changed in accordance with variations in the channel conditions, leading to a higher data rate for users with favourable radio conditions. Whereas UMTS Release 99 used only Quadrature Phase Shift Keying (QPSK) modulation, HSDPA provides the ability to use 16-QAM when the link is sufficiently robust, which can lead to a significant increase in data rate.

Fast H-ARQ enables erroneous packets to be resent within a 10ms window, ensuring that the TCP throughput remains high. In addition, in HSDPA the mechanisms for ARQ are moved to the BTS (from the RNC in R99). By using these approaches, all users, whether near or far from the base station, are able to receive the optimum data rate.

HSUPA

Similarly to HSDPA in the downlink, HSUPA defines a new radio interface for the uplink communication. The overall goal is to improve the coverage and throughput as well as to reduce the delay of the uplink dedicated transport channels. From a 3GPP point of view, the first set of standards was approved in December 2004, and performance aspects were finalised during the summer of 2005. E-DCH is the name adopted in 3GPP for HSUPA which is in 3GPP Release 6.

Key technical capabilities introduced with HSUPA are;

- A new dedicated uplink channel,
- Introduction of H-ARQ,
- Fast Node B scheduling.

Unlike HSDPA, HSUPA remains based on a **dedicated channel**. A series of new channels are introduced for both signaling and traffic to improve overall uplink capabilities.

Like HSDPA, HSUPA introduces fast retransmissions based on the **Hybrid ARQ** Protocol for error recovery at the physical layer.

The **Node B scheduling** enables the Node B to control, within the limits set by the RNC, the set of Transport Format Codes from which the UE may choose. This will enable improved coverage and capacity in the uplink.

HSPA Terminals

HSDPA will require new terminals. However, HSDPA and R99 capabilities will co-exist in these terminals and will be compatible with UMTS R99 networks. A typical upgrade strategy for an operator will be to upgrade the network to HSDPA progressively so that for a significant period both standards will be in operation. Therefore, all new terminals should support both R99 and HSDPA. The first terminals will be a data card enabling 1.8 Mbit/s of peak data rate (Category 12) and 3.6 Mbit/s of peak data rate (Category 6).

HS-DSCH Category	Max number of HS-DSCH codes (SF16) received	Minimum inter TTI interval	Modulation	Max peak rate
Category 1	5	3	QPSK & 16-QAM	1.2Mbps
Category 2	5	3	QPSK & 16-QAM	1.2Mbps
Category 3	5	2	QPSK & 16-QAM	1.8Mbps
Category 4	5	2	QPSK & 16-QAM	1.8Mbps
Category 5	5	1	QPSK & 16-QAM	3.6Mbps
Category 6	5	1	QPSK & 16-QAM	3.6Mbps
Category 7	10	1	QPSK & 16-QAM	7.3Mbps
Category 8	10	1	QPSK & 16-QAM	7.3Mbps
Category 9	15	1	QPSK & 16-QAM	10.2Mbps
Category 10	15	1	QPSK & 16-QAM	14.4Mbps
Category 11	5	2	QPSK only	900kbps
Category 12	5	1	QPSK only	1.8Mbps

Figure 1: HSDPA Capability per 3GPP Category

HSUPA will also require new terminals. Similarly, they will co-exist with R99 capabilities and will be compatible with UMTS R99 networks. First HSUPA capable terminals are foreseen for 2H 2006. Like HSDPA, the capability of the terminal has been standardized per category.

E-DCH category	Maximum number of E-DCH codes transmitted	Minimum spreading factor	Support for 10 and 2 ms TTI EDCH	Maximum number of bits of an E-DCH transport block transmitted within a 10 ms E-DCH TTI	Maximum number of bits of an E-DCH transport block transmitted within a 2 ms E-DCH TTI
Category 1	1	SF4	10 ms only	7296	-
Category 2	2	SF4	10 ms and 2ms	14592	2919
Category 3	2	SF4	10 ms only	14592	-
Category 4	2	SF2	10 ms and 2ms	20000	5837
Category 5	2	SF2	10 ms only	20000	-
Category 6	4	SF2	10 ms and 2ms	20000	11520

Figure 2: HSUPA Capability per 3GPP Category

Theoretically, the maximum physical throughput is 5.5 Mbit/s for the Uplink, which leads to 4 Mbit/s at the application layer. Recent studies have concluded that the use of HARQ with Node-B scheduling and 2ms TTI can lead the following improvements when compared with R99 systems;

- 50-70% improvement in UL capacity,
- 20-55% reduction in end-user packet call delay,
- Around 50% improvement in user packet call throughput.

HSPA Benefits

The key benefits of HSPA can be categorized in 3 ways;

- Improved speed for end user applications
- Improved interactivity for end user applications,

- Improved network capacity for the operator.

UMTS networks deployed based on the 3GPP release 99 standard offer a maximum data throughput per user of 384kbit/s. With HSDPA there is the possibility to offer the end user up to 14.4Mbit/s. How often or how many users will be able to achieve this throughput will obviously depend on network and radio conditions as well as the type of terminal being used. A more reasonable scenario will see a large number of users with a category 6 HSDPA terminal allowing them to communicate at data speeds up to 3.6Mbit/s. This is already almost a factor of 10 increase from the maximum throughput available to UMTS users today. This will bring new applications such as high quality video streaming as well as faster music and entertainment downloads, and improved time savings for ubiquitous corporate email services. Note that the peak rate of 14.4 Mbps occurs with a coding rate of 4/4, 16 QAM and all 15 codes in use. Despite these capabilities, researchers and developers are working on additional enhancements. First devices will support five codes with a peak rate of 3.6 Mbps. Subsequent devices will support ten to fifteen codes with a peak rate of 10.7 Mbps. Other enhancements include two-branch diversity reception and equalizers in mobile devices. These improvements will occur one to two years after the initial deployment of HSDPA. Simulations show these features to further improve user data rates and network capacity. Further evolution of HSPDA peak data rates can be achieved with multiple-input multiple-output (MIMO) antenna techniques of 3GPP Rel.'6. No changes are required to the networks except increaded capacity within the infrastructure to support the higher bandwidth.

One of the major improvements with HSPA technology is the improvement in network latency or round trip delay for data applications. First deployments of HSDPA indicate a round trip delay of as low as 60ms, meaning that many real time interactive services can be delivered over HSDPA. This will be true for Voice and Video but also for applications such as multi-user gaming where immediate real time interaction with other users is key to stimulate high levels of game usage. This will be the key enabler for the beginning of a new era of mobile multimedia over UMTS networks and terminals.

With the introduction of new improved coding and modulation with HSPA, the spectral efficiency of the access network is much improved. Early tests and measurements indicate that the data capacity available in the standard UMTS carrier bandwidth of 5MHz is increased by a factor of 5 with the upgrade to HSDPA. This will offer the operator a much improved cost structure for offering data services with the cost per bit reducing significantly. This should help drive adoption rates of mobile data services as the cost to deliver the services to a wider audience will be significantly decreased.

The figure below illustrates that HSDPA maximizes data throughputs, maximizes capacity and minimizes delays. For users, this translates to better network performance under loaded conditions, faster application performance, a greater range of applications that function well, and increased productivity.

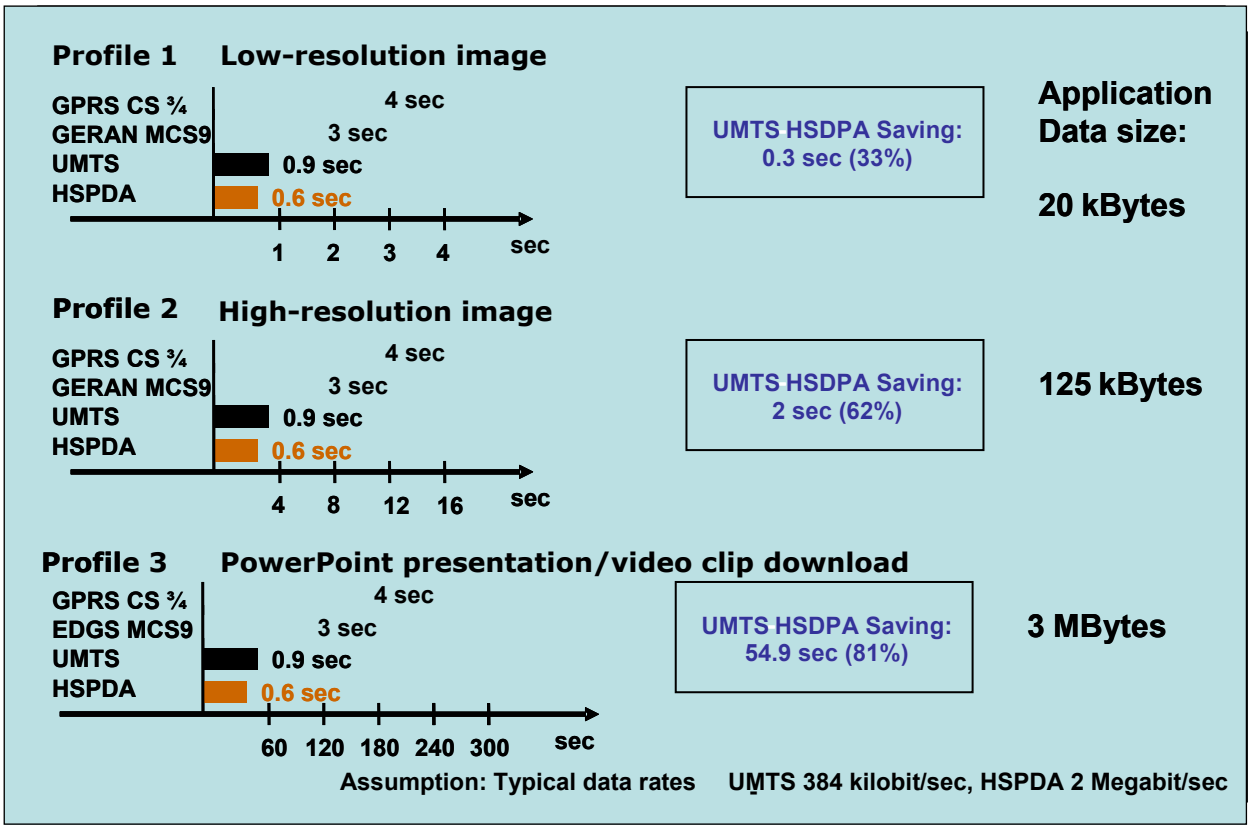

Figure 3. Up to 81% download time saving with HSDPA!

HSPA Applications

The new network and terminal capabilities introduced by HSPA will drive new applications and stimulate new usage patterns. At the UMTS Forum we believe that these new applications and behaviors will fall into 3 categories;

- Introduction of new applications,
- Improvement of existing applications,
- Stimulation of new usage patterns.

Introducing new applications

New data applications require varying bandwidth to deliver the required end user experience. Mobile data applications can require anything from a couple of kilobits for text messaging to many hundreds of kilobits for high quality video streaming or conferencing.

As the network and terminal capabilities improve and the economics of delivering mobile broadband improve, the number of applications that can be delivered is increased as well as the number of users that can access these applications. This will provide a major stimulus to the mobile data market.

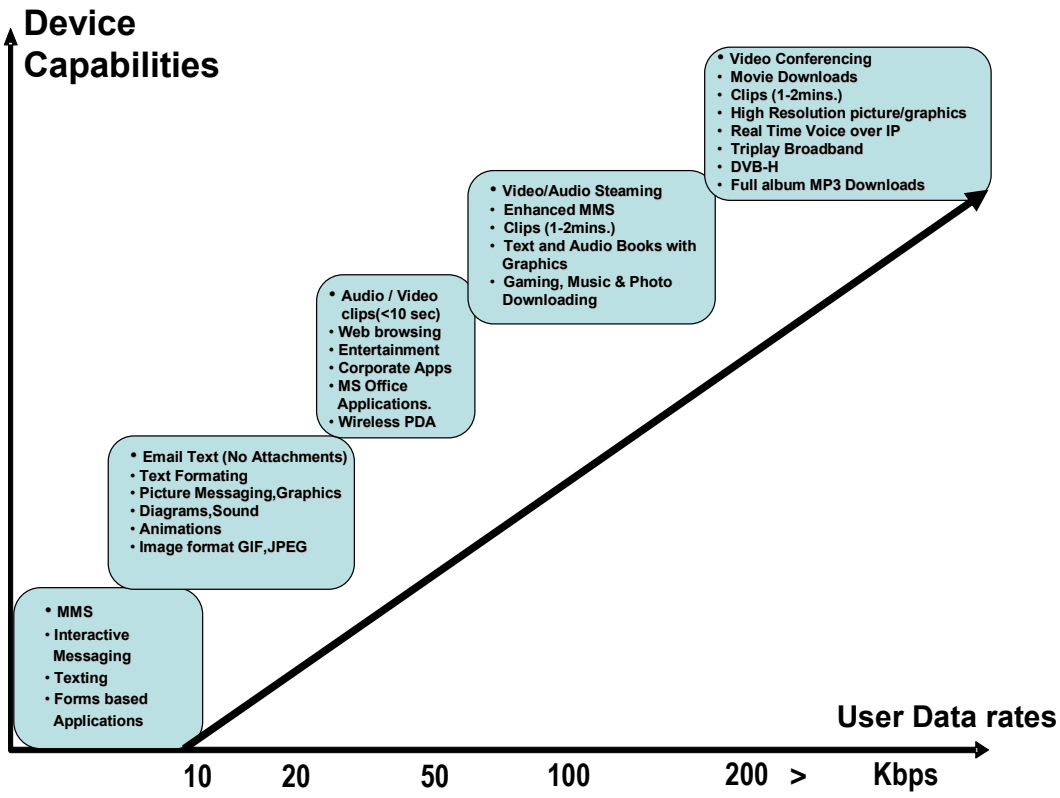

Figure 4. Mapping of Wireless Data Services to ideal bit rates

HSPA will stimulate many new applications, a large number of which have yet to be introduced or conceived. As an extrapolation of today's usage patterns, it can be expected that new applications in the following areas will present in the market.

High-Speed Internet Access

With HSPDA offering similar speeds to most DSL connections, with the added value of ubiquitous mobility, UMTS can be expected to become to preferred connection medium for a range of users, whether it be via a laptop or a handheld terminal.

Voice over IP

Voice is clearly not a new application but when delivered over IP and coupled with other interactive media such as video and text, this new service mix will become very attractive.

Multi-player Gaming

The improved interactivity of the networks supporting HSPA is expected to have a significant impact on the mobile gaming industry. Multi-user games, whether broadband or narrowband will benefit from the real time interactivity that will be possible and the end user experience will be significantly enhanced.

Improving Existing applications

HSPA will improve the end user experience for the many existing applications. The improvement in speed and interactivity will make a significant difference to many applications which previously appeared to be slow or tedious. The most often cited example of this will be the corporate email service based on Microsoft Outlook, where there is significant communication between the device and the server which in high latency networks can make the service appear slow. With the arrival of HSPA and the improvements in system latency, there will be major improvements and it is expected that the end user perception will be significantly improved.

	ADSL	GERAN	UMTS	HSDPA
Typical Throughput (5 MHz)	1 - 15 Mbps	1 Mbps	1 Mbps	10 Mbps
Average Throughput (kpbs / user)	2048	160-200	128-300	500-700
Capacity (users/cell)*	-	8	9	40
Latency (ms for a 32 bytes ping)	5-200	260**	120	60

Figure 5: HSDPA Capability per 3GPP Category

Streaming Live TV

With the increased capacity of HSPA networks, more streaming services can be offered to more and more users. These TV streaming services have already shown themselves to be extremely popular in many markets and this trend can be repeated and improved on with HSPA.

Video Telephony and Conferencing

Video conferencing or the delivery of multiple video streams to a single terminal will become more feasible now that the video services can be delivered using an IP stream.

Driving new usage patterns

With an improved experience to the end-user for mobile data services, and an improved cost of delivery for the operator, the market is expected to demonstrate some significantly new behavioral and usage patterns.

These behaviors can be placed in a number of categories;

- New mobile business behaviors,

- New Peer to Peer application behaviors,
- New Mobile commerce behaviors.

For business users, it is expected that HSPA will drive significantly different usage patterns. In particular the usage of mobile email which is now synonymous with the Blackberry device, is today restricted to the text of an email and the attachments are discarded. This can be expected to change as networks and mobile devices become truly broadband and the storage capabilities of devices continue to increase. The use of the corporate intranet while mobile is expected to increase as HSPA enables a user experience which closer approximates to that of WLAN, while adding the extra benefit of ubiquitous mobility.

Peer to Peer applications drive the mobile industry. Whether it is voice or text, the desire for people to communicate with each other is insatiable and as HSPA rolls out and offers more users a broadband IP connection, the peer to peer possibilities will increase significantly. As well as communicating via voice and text, the end-user will use the same IP stream to communicate potentially by video, by sharing photos, by sharing presence information and by opening a gaming session. Just as text messaging and mobile email have driven the last major changes in end-user behavior patterns, peer to peer IP multimedia services offer the next major user behavior revolution. HSPA will be a key enabler of this revolution.

For mobile commerce, the increased omnipresence of mobile data will stimulate the purchasing opportunities for the end-users. As i-Tunes has demonstrated, using consumer media while mobile meets our lifestyle demands and there is little reluctance to purchase this media over the internet. This offers a major opportunity to operators and content creators, as well as delivering an improved mobile experience to the end-user.

HSPA Availability

In March 2003, HSDPA was introduced in 3GPP Release 5 Specifications and the final and stable specifications were finally agreed in June 2004.

The first set of standards for E-DCH, or HSUPA, was approved in December 2004. However, corrections have still to be done and the final version of 3GPP Specifications for HSUPA is expected in December 2005.

The first demonstrations of HSDPA technology were made in the final months of 2004. The 3GSM conference in Cannes in February 2005 was where the first public demonstrations of the technology were made by infrastructure and terminal vendors together. By summer 2005 (the initial publishing date of this paper) commercial terminals in the form of data cards for PCs were available. These data cards support connection speed of up to 1.8Mbit/s and will be category 12 terminals. It is expected that the first handset form factor terminals will be available during the first half of 2006. A wider variety of handsets are expected to become available at the beginning of the second half of the year. These commercial handsets are expected to be category 6. In each case network infrastructure is expected to be in place and capable of supporting these terminals and that commercial service will be launched during 2006 in many markets.

The first HSUPA terminals are expected to become commercially available in the first half of 2007.

HSPA Evolution

With all areas of the wireless industry developing rapidly, it has become necessary for the UMTS industry and its constituent member to provide it's vision for the long term evolution of UMTS networks and services. The 3GPP has been active to provide a vision of this evolution through its activities. Indeed, important milestones were achieved in 3GPP Release 6 with IMS, HSDPA enhancements, HSUPA, WLAN integration and IP Transport.

For Release 7 of the 3GPP specifications a number of key objectives have been set in place;

- IP Centric,
- VoIP,
- High peak data rate, up to 50Mbit/s
- Reduced latency with 20 ms to 40 ms of Round Trip Delay.

The Preliminary activities started in March 2005 and the completion of the standards is expected for mid 2007.

Conclusion

HSPA defines a series of straight forward upgrades to UMTS R99 networks which will offer improvements of a factor of ten in the speed of service delivery, improvements of a factor of five in network capacity and a significant improvement in service latency. HSPA refers to improvements in both the downlink and uplink of the radio access network, known as HSDPA and HSUPA respectively. New terminals are required to support these capabilities and the first terminals for HSDPA will be available at the end of 2005 and are expected to be category 6 terminals, capable of supporting up to 3.6Mbit/s.

HSPA will thus offer cost effective wide-area broadband mobility and play a significant role in stimulating the demand for data services, whether they be consumer multimedia and gaming or corporate email and mobile access.

Acronym List

ADSL	Asynchronous Digital Subscriber Line
AMC	Adaptive Modulation and Coding
E-DCH	Enhanced Dedicated Channel
GERAN	GSM Edge Enhanced Radio Access Network
HARQ	Hybrid Automatic Response reQuest
HSPA	High Speed Packet Access
HSDPA	High Speed Downlink Packet Access
HS-DSCH	High Speed Downlink Shared Channel
HSUPA	High Speed Uplink Packet Access
MIMO	Multiple-Input Multiple-Output
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RNC	Radio Network Controller
SF-16	Spreading Factor 16
TTI	Transmission Time Interval
UMTS	Universal Mobile Telecommunication System
WCDMA	Wideband Code Division Multiple Access
WiMax	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network