Multi-Services Broadband Wireless Networks : Beyond 3G

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Abstract

The main goal of this paper is to review the most recent development of new technologies related to the topic of the high-speed packet data of wireless Internet and potential applications. This paper will provide an overview of HSDPA and will focus on the business values that such a highly-efficient access technology will bring to wireless operators, including higher capacity and newer services. The key mechanisms of HSDPA and the performances will be explained. The other future evolutions like HSUPA or MIMO and OFDM will also be presented. HSDPA increases the downlink data rate within a cell to a theoretical maximum of 14Mbps, with 2Mbps on the uplink. The changes that HSDPA enables include better quality and more reliable, more robust data services. In other words, while realistic data rates may only be a few Mbps, the actual quality and number of users achieved will improve significantly.

Keywords — HSDPA, UMT, 3GPP, HARQ, CQI.

1. Introduction

The volume of IP-based traffic has already exceeded that for circuit switched traffic in most fixed networks. The same change will happen in mobile networks as new IP-based mobile services become available and are used by more people in their daily communications.

In recent several years, wireless high speed packet data has received enormous attention in wireless industry under the context of 3G standardization (third generation) [1]. This trend is believed to be driven by the wireless internet although the "killer application" is not so obvious yet.Recent 3G standardization and related technology development reflects the need of the high-speed packet data of wireless internet. For 3G, there are two standard organizations studying the relevant concepts and defining the relevant system specifications. They are 3GPP (third generation partnership project) defining WCDMA and 3GPP2 defining CDMA2000 [1, 2]. Unfortunately, their efforts are relatively independent although a lot of concepts and principles are similar in theory HSDPA, High Speed Downlink Packet Access, offers breakthrough data speeds – up to five times (10 Mbps) higher than is possible in the most advanced 3G networks – as well as two-fold base station capacity[4]. For end-users this means shorter service response times and less delay. HSDPA is based

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on WCDMA evolution, standardized as part of 3GPP Release 5 WCDMA specifications. The new modulation method of HSDPA greatly improves the peak data rate and throughput, which enhances spectral efficiency. In addition to these benefits, users will perceive faster connections to services through shorter round trip times. As a result of these enhancements,operators using HSDPA will be able to support considerably higher numbers of high data rate users on a single radio carrier than is possible with any existing 3G technology[5]. HSDPA (High Speed Downlink Packet Access) will empower UMTS networks by providing higher data rates and lower latency to end users. The three essential pillars of UMTS are 2G/3G continuity of service, multimedia support by enabling the support of voice and data applications at the same time, and higher data rates like 384 kbps. HSDPA will go beyond with an average throughput of 800 kbps and even 1.5 Mbps in the field, thanks to high peak data rates with 3.6 Mbps for a Category 6 Mobile and up to 14.4 Mbps for a Category 10 Mobile. In addition, HSDPA provides lower latency with Round Trip Delays of 70 ms, enabling great interactive applications like multi-user gaming [5]. In addition, HSDPA will empower UMTS networks by providing much more capacity than planned with the same network design as explained in the next sections. The use of HSDPA optimizes the investment in the network as some traffic normally transported on a dedicated channel can be supported by HSDPA more efficiently, saving capacity that can be allocated to new users. At least twice as many subscribers per cell should be supported with HSDPA. The race of the high-speed packet data in CDMA started roughly in late 1999. Before then, WCDMA and CDMA2000 systems support the packet data but the design philosophy is still old in the sense that the system resources such as power, code and data rate are optimized to voice like applications. There was a change since late 1999 when system designers realize that 1) the main wireless data applications will be internet protocol (IP) related, thus 2) optimum packet data performance is the primary goal for the system designers to accomplish. With the design philosophy change, some new technologies have appeared in the last two years such as reflected in references [9]. Key concepts include adaptive and variable-rate transmission, adaptive modulation and coding, hybrid ARQ, etc. The theoretical justifications are well known in the literatures, e.g. [6, 7, and 8]. The primary concept is to adapt the IP based network for a given channel conditions and workload to maximize the system performance by using various adaptive techniques, while satisfying the QoS (Quality of Service) constraints.

2. Market Overview and Applications

Entering the 21st century, markets will require higher and higher bandwidth, as in the case of Internet in wireline modems. Wireless Internet will make wireline and wireless converge. New applications will demand higher bandwidth. In the future a data rate of up to 10-20Mbps will be needed for some applications like real-time streaming video. The mobile office concept will be one of drivers behind this bandwidth need. HSDPA promises a date rate of up to 10Mbps and higher spectrum efficiency. The economic downturn in the mobile and Internet industry sectors and in the high technology markets in general have prompted new concerns about the commercial viability of mobile data services, including 3G. The re-examination shows [12] that due to the current negative market conditions, the short term revenue generated by 3G services will be reduced 17% through 2004 –a total reduction of $10 billion. Over the long term, however, services enabled by 3G technologies still represent a substantial market opportunity of $320 billion in 2010, $233 billion of which will be generated by new 3G services [12]. Using the conservative assumptions in this analysis, cumulative revenue of over one trillion dollars is still expected over this decade.

2.1 Video telephony and videoconferencing

Multimedia applications [12, 13] are enablers for broadband services with either real-time (e.g. video telephony) and/or non real-time (e.g. Internet access, file transfer) requirements. Third generation systems take care of the resulting basic bandwidth demand in combination with global mobility and interactivity. This unique combination of capabilities enables new applications and opens new areas of business .Video telephony and videoconferencing are typical communication services, which can be economically supported by third generation networks for mobile users.

To date, video telephony and videoconferencing have not become as successful as anticipated. Lack of bandwidth, high cost, lack of equipment and services and the need for dedicated equipment rooms have been some of the major restricting factors. Videoconference services have generally been offered to corporate customers and have been unable to reach the volume expectations of manufacturers and operators. Availability of high bandwidth is now emerging in both fixed and mobile telecommunications networks. Video telephony and videoconferencing are now possible on a broad scale and have acceptable quality. UMTS/Third Generation systems support both the required bandwidth and provide mobility, which enables videoconferencing to take place independent of a fixed location.

2.2 Internet Protocols Trends

In less than five years, the Internet has grown from 16 million to over 190 million users, according to the Nua Internet Surveys. It has spurred billions of dollars of economic growth and enabled the meteoric growth of thousands of companies, from small start-ups to multinational corporations. It has started to transform businesses, governments, and other organisations around the world into e-businesses. Yet the Internet revolution is less than three per cent complete. In about five years, we expect to see over a billion people using the Internet, whether with a PC, a mobile phone, a PDA or some other type of wireless terminal. Mobility, in all its many forms, is becoming the watchword of our society. An inherent characteristic of wireless systems is their potential for accommodating device roaming and mobility. Everything moves faster and faster. IP is becoming the end-to-end protocol of the future delivery of most services since it will exist in the wire line and wireless world, in Office Extension environments and Home networks. In order to advance the Internet to a new level of efficiency for networked communications and applications development, a new Internet Protocol version 6 (IPv6) has been specified by the IETF and is being promoted by the IPv6 Forum. It fixes a number of limitations of IPv4 and, in addition to a number of specialised protocols, offers the following features for cellular networks and users in its "native" form.

Mobile IP is a specific protocol that has been specified by the IETF (e.g. RFC 2002 for IPv4) and essentially provides a mechanism for re-routing packets from one part of the IP network to another, and which allows the mobile nodeto keep its fixed-assigned IP address. Mobile IPv6 (MIPv6) is well suited for cellular networks for a number of reasons, two of which are:1) The increased addressing space does not require the mobile node to use dynamic address allocation; there is enough addressing space in the foreseeable future for every mobile terminal in the world to use at least two IP addresses, and this could significantly speed up the registration process.

One address would be used as a globally unique identifier of the terminal, and the other would be used to identify its, temporary, location in the global Internet. However, it is feasible to assign many more IPv6 addresses to terminals, depending on the specific applications; 2) MIPv6 does not use the concept of foreign agents, which means that a mobile node must use a co-located care-of address. This address can be acquired by IPv6's stateless address autoconfiguration; this method allows a mobile node to add its own link-layer (MAC) address (which is assumed to be globally unique) to the prefix of the local network to which the mobile node is attached to form the co-located care-of address. In this way, it is not necessary for the mobile node to query a DHCP server for example, which also saves time.

3. WCDMA HSDPA : Concepts and Principles

We believe that high speed wireless data up to 10 Mbps and higher spectral efficiency are needed in mobile industry. WCDMA HSDPA provides Unprecedented speed and mobility: 1)IP-based network, optimized for packet data; 2) Complementary to existing and future voice networks; 3) Enabling wireless web lifestyle; 4) Next generation performance.

HSDPA introduces a new common High Speed Downlink Shared Channel (HS-DSCH) shared by several users. Nowadays when the quest for bandwidth is accelerating competition among wireless technologies, WCDMA appears to have hit a speed bump. WCDMA technology, which provides the radio interface in the 3G UMTS mobile system defined by the 3GPP, theoretically can deliver peak data rates up to 2.4 Mb/s. In actual networks, though, the average data throughput rate reportedly doesn't go much beyond 384 kb/s. Release 5 of the 3GPP WCDMA specification adds HSDPA technology in an effort to make the system more efficient for bandwidth-intensive data applications. A WCDMA network upgraded to HSDPA will support downlink data rates well over 2 Mb/s, up to a theoretical 14 Mb/s [1, 2]. HSDPA is a major evolution of WCDMA wireless network. The service classes that should be considered for HSDPA are the following [10, 11]: (1) streaming, (2) interactive, (3) background. It is important to assess whether the three types of services given above can be potentially mapped to HSDPA. In addition, an indication of the benefit of using the HS-DSCH for supporting these services with respect to the DCH/DSCH should be provided. In general, we do not wish to inherently restrict the number of services that can be used with HSDPA. Thereby, we would like to ensure that all services positively assessed do not undergo any detrimental restriction during the specification process. The environment we believe should be considered (with priority) in the HSDPA investigations is the urban environment. The HS-DSCH should provide significant capacity enhancement for best effort packet services when operated in both macrocells and microcells.

The current 3G WCDMA technology (Release 99/Release 4 of 3GPP) allows a data rate of up to 2Mbps. There are the following limitations: 1) the system design does not take advantage of the packet data that is popular in the wireline backbone; 2) for 2Mbs the current design is not efficient; 3) the current design cannot handle higher date rate of up to 10 Mps. Release 5 will overcome these limitations. Release 5 is a major evolution of the 3G wireless network since the inception of WCDMA for 3G wireless network in 1997. In contrast, the counterpart of WCDMA/HSDPA is called cdma2000-DO (data only) for the first phase and cdma2000-DV (data and voice) for the second phase. Since cdma2000-DO will be deployed or begin deployment by the end of 2001; the market pressure of development of WCDMA/HSDPA is very demanding.

WCDMA/HSDPA is the hottest topic in the last 6 months in 3GPP. For example, in May 2001 3GPP meeting, 4 days out of 5 days are dedicated to the discussions of WCDMA/HSDPA. Around 50 contributions were discussed. We summarize the technical features as follows : 1) Similar to cdma2000 1xEV(HDR); 2) Adaptive Modulation and Coding; 3) High Data Rate Carrier in 5 MHz bandwidth: 4) 64 QAM provides ~10.8 Mbps peak; 5) 16 QAM provides ~7.2 Mbps peak; 6) Turbo codes; 7) Error correction near theoretical limit; 8) Adaptive Hybrid ARQ; 9) Automatically adapts to instantaneous channel conditions by adding redundancy only when needed; 10) Enabled by Dual or N-Channel Stop-and-Wait Hybrid ARQ; 11) AMC when combined with HARQ improves the capacity of the system;12) Techniques offered for HSDPA have peak rates of 10 Mbps; 13) Best effort packet data average sector service throughput for a HSDPA system with 30% overhead using a maximum C/I scheduler was shown to about 2.7Mbit/s; 14) HSDPA has twice the throughput of a HSDPA system using only QPSK modulation and no AMC and HARQ; 15) In an integrated voice and data system with voice user (12.2kbit/s) load of about 30 Erlangs/sector the Data 'equal power' sector throughput is still about 1Mbit/s.

The goal of HSDPA is to provide high speed downlink packet access by means of a high-speed downlink shared channel (HS-DSCH) and support integrated voice on DCH and high-speed data on HS-DSCH on the same carrier (similar to Release-99 DSCH). The main Features of HSDSCH for Release-5 are 1) Adaptive Modulation and Coding, 2) Hybrid ARQ, 3) MAC-HSDSCH at the Node B with HARQ and scheduling functionality, and 4) Applicable for both FDD and TDD mode.

3.1 Adaptive Modulation and Coding (AMC)

The principle of AMC is to change the modulation and coding format (transport format) in accordance with instantaneous variations in the channel conditions, subject to system restrictions. AMC extends the systems ability to adapt to good channel conditions. Channel conditions should be estimated based on feedback from the receiver. For a system with AMC, users close to the cell site are typically assigned higher order modulation with higher code rates (e.g. 64 QAM with R=3/4 Turbo Codes). On the other hand, users close to the cell boundary, are assigned lower order modulation with lower code rates (e.g. QPSK with R=1/2 Turbo Codes).

In choosing of HS-DSCH Transport Format (modulation/coding scheme) UE estimates/predicts the downlink channel quality and calculates a suitable transport format that is reported to the Node-B. First, UE estimates/predicts the downlink channel quality and report this to the Node-B. Second, Node-B determines the transport format without feedback from the UE e.g. based on power control gain of the associated dedicated physical channel. Any combination of the above two approaches can be adopted. To detect MCS at the UE, MCS mode and assignment of OVSF codes can be explicitly transmitted to UE (TFCI-like signaling). Performance of higher order modulation schemes with multicodes degrades with multipath. Channel-quality reporting and MCS selection should support use of more advanced receiver structures such as the LRP concept proposed by Wiscom Technologies.

3.2 Adaptive Hybrid ARQ

Simple form of hybrid ARQ shows significant gains over link adaptation alone through e.g. Chase combining. Hybrid ARQ self-optimizes and adjusts automatically to channel conditions without requiring frequent or highly accurate C/I measurements: 1) adds redundancy only when needed; 2) receiver saves failed transmission attempts to help future decoding; 3) every transmission helps to increase the packet success probability. N Channel Stop-and-Wait Protocol parallelizes the stop-and-wait protocol and in effect runs a separate instantiation of the Hybrid ARQ protocol when the channel is idle. The advantages include the following: 1) no system capacity goes wasted since one instance of the algorithm communicates a data block on the forward link at the same time that the other communicates an acknowledgment on the reverse link; 2) UE memory requirements can be made low by choosing low value of N (e.g. 2, 4 or 6). Three different methods for N-channel HARQ: 1) Signal the subchannel number explicitly (fully asynchronous); 2) Tie the subchannel number to e.g. frame timing (partially asynchronous); 3) UE does not have flexibility to re-schedule re-transmissions i.e. retransmissions occur immediately in the next allowed slot (synchronous). Choice of HARQ methods will depend on: 1) Ease of implementation; 2) TTI size; 3) Buffering complexity at the UE; 4) Processing time at Node-B and UE.

3.3 Physical Layer Structure of HSDPA

There are two alternatives to HS-DSCH mapping to physical channels (codes). First, physical channels to which HS-DSCH is mapped are shared between “users” in the time domain ("time multiplex") as well as in the code domain ("code multiplex"). Physical channels to which HSDSCH is used may have different spreading factors (as in Release-99). The physical channel to which HS-DSCH is mapped has a fixed spreading factor. Second, physical channels to which HS-DSCH is mapped can still be shared between “users” in the time domain as well as in the code domain.

3.4 HSDPA TTI shorter than one radio frame (10ms)

Another concept is shorter TTI. Shorter TT should be selected from the set {Tslot, 3´Tslot, 5´Tslot}. Depending on the typical payload size, signaling load with shorter TTI, e.g. TTI=1slot, may be too high. No power margin necessary when scheduling data users in an integrated voice and data system with TTI of 1 slot. There are three approaches for TTI in HSDPA: fixed and semi-static TTI (inline with Release-99) as well as dynamic TTI.

3.5 Basic Principles for Signaling for HSDPA

For Downlink Signaling, We can use a two StageApproach. This approach conserves code resource and interference and Quality of Service can be maintained independently of the HS-DSCH. It is also robust to undetected errors. The basic concept is as follows. First, UE is notified of the assignment status of the HS-DSCH and the shared associated control channel attributes through an indicator on the associated DPCH. Second, the associated shared control channel conveys for e.g. MCS, Hybrid ARQ states, HS-DSCH gain in case of 16/64QAM and code allocations to the UE for proper demodulation of the data. Finally, the timing structure of the indicator on the associated DPCH and the shared control channel should match the TTI of the HS-DSCH. Uplink signaling is used to convey measurement report and signaling related to HARQ. In the system design, timing structure should match the TTI of the HS-DSCH. Also channel should be designed to reduce the miss probability and to increase the detection probability.

This fast retransmission scheme is of paramount importance for the TCP performances as generally, TCP has not performed well in a wireless environment due to a significant level of non-congestion loss.TCP was initially designed for wireline networks, and packet loss is dealt with as congestion — which leads to an unnecessary reduction of the sending rate and therefore reduces throughput. Loss leads also to an initiation of the slow restart mechanism. This is slowest to reach a steady state when the Round Trip Delay is large. Variable delay leads to inaccurate Time Outs and so extra TCP retransmissions are generated (Spurious TCP Retransmissions). With UMTS Rel’99, in case of loss during transmission, the RLC located in the RNC uses an ARQ error recovery mechanism to retrieve the lost RLC frame. The process for recovery of erroneous frames is initiated by the receiver by requesting retransmission of the missing or damaged frames. A larger delay at the RLC is due to the fact that the RLC detects a bad RLC frame when it detects a “hole" (i.e., a missing number or a sequence of numbers). This could take several frames if, for instance, the mobile is in a deep fade for a long time. Only after detecting a hole can an RLC NACK be sent by the receiver.

4. Going Further Than 1xEV/DO Capability

Both HSDPA and 1xEV/DO — the HSDPA solution for CDMA2000 — enhance downlink packet data performances. HSDPA and 1xEV-DO are based on the same set of technologies to improve spectral efficiency for data services like shared downlink packet data channel, high peak data rates, using high-order modulation and adaptive modulation and coding [6], HARQ retransmission schemes, fast scheduling and shorter frame sizes. Both technologies have the same spectral efficiency as they are very similar, but HSDPA has higher peak data rates and can fully use the remaining voice bandwidth. In addition, multi-session support is possible with HSDPA, which means the capability to support voice and data at the same time. The 1xEV-DV system [3,4,5,9] is optimized for real time, high-speed packet data services which can operate on the same RF carrier as current cdma2000 1x services. The 1xEV-DV specification shall be compatible with the ANSI-41 core network standard. The 1xEV-DV specification will incorporate all aspects of and be an extension of the existing cdma2000 1x features, functions, applications, and services specified in the cdma2000 Release A and Release B standards. More specifically, the 1xEV-DV specification will maintain all of the voice and packet data capabilities of the cdma2000 1x and 1xEV-DO specifications.

5. Beyond HSDPA

With wireless mobile radio communication, there is an endless quest for increased capacity and improved quality. As HSDPA is about to launch, new technologies are promising even more bandwidth and new services like HSUPA (Enhanced DCH in 3GPP Release 6), MIMO (Multiple-Input Multiple-Output) and OFDM (Orthogonal Frequency Division Multiplexing) in GPP Release Going further to 3GPP Release 7 and to ensure competitiveness in an even longer time frame, i.e., for the next 10 years and beyond, a long-term evolution of the 3GPP radioaccess technology is now under investigation in 3GPP RAN Working Group.

5.1 HSUPA

The 3GPP objectives with HSUPA or Enhanced-DCHA are to improve the performance of uplink dedicated transport channels by scheduling the Uplink UE data rates depending on the interferences and on the Node B processing resources, while increasing the radio interface robustness with the HARQ protocol. The 3GPP Study has concluded that the use of these mechanisms associated with a shorter TTI of 2 ms can lead to the following enhancements: - 50-70% improvement in UL capacity MIMO increases the capacity due to the multi-stream transmissions and code reuse with multiple antennas on both the transmitter and receiver sides. MIMO has been studied for a long time, but due to the very high processing power needed to recover the transmitted signals, it was not possible to implement such a technology in former processors. MIMO is now part of the 3GPP Release 7 for multi-stream transmission with code reuse and Transmit Diversity with more than two antennas. It is not restrictive to HSDPA. - 20-55% reduction in end-user packet call delay - Around 50% in user packet call throughput HSUPA is a very important step that can be achieved in the next two years. By reaching high spectrum efficiency and low latency for both the uplink and downlink with HSDPA/HSUPA, wireless operators will be able to provide seamless access services like VoIP, which can be challenging in UMTS Release 99 Network.

Without HSDPA/HSUPA, different options for VoIP like the use of a secondary scrambling code have been studied in 3GPP to cope with the following issues:- Robust Header Compression (ROHC) in the PDCP Layer of the RNC - Uncompressed ROHC packets as synchronization loss may occur - RTP and RTCP associated flow which are very bandwidth demanding .

5.2 MIMO

MIMO (Multiple-Input Multiple-Output) is also a very romising technology that will empower UMTS HSDPA networks by providing three times more throughput than MIMO increases the capacity due to the multi-stream transmissions and code reuse with multiple antennas on both the transmitter and receiver sides. MIMO has been studied for a long time, but due to the very high processing power needed to recover the transmitted signals, it was not possible to implement such a technology in former processors. MIMO is now part of the 3GPP Release 7 for multi-stream transmission with code reuse and Transmit Diversity with more than two antennas. Multiple-input multiple-output, or MIMO, is an abstract mathematical model for multi-antenna communication systems. During the last few years, MIMO technology has attracted a lot of attention in the area of wireless communications, since significant increases in throughput and range are possible at the same bandwidth and same overall transmit power expenditure. In general, MIMO technology increases the spectral efficiency of a wireless communication system. Wireless MIMO communication exploits phenomena such as multipath propagation to increase data throughput and range, or reduce bit error rates, rather than attempting to eliminate effects of multipath propagation as traditional SISO (Single-Input Single-Output) communication systems seek to do.MIMO can also be used in conjunction with OFDM, and is part of the IEEE 802.16 standard and will also be part of the IEEE 802.11n High-Throughput standard. Standardization of MIMO to be used in 3G standards such as HSDPA is currently under way.

5.3 OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a spread spectrum technology that distributes the data over a large number of carriers that are spaced apart at precise frequencies. OFDM has already been used in the global ADSL (asymmetric digital subscriber line) standard. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. This results in no interference between the carriers, allowing them to be spaced as close as theoretically possible. Each carrier in an OFDM signal has a very narrow bandwidth (i.e., 1 kHz), thus the resulting symbol rate is low. This results in the signal having a high tolerance to multipath delay spread, as the delay spread must be very long to cause significant intersymbol interference (e.g., > 100 micro sec). For example, without OFDM and for a data rate of 1 Mbps, any delay spread longer than one microsecond would cause delayed reflections from multi-path to overlap the direct signal for the next bit, thus causing intersymbol interferences. If instead, we transmit 1000 bits in parallel at a time on 1000 separate OFDM sub-channels, we can transmit them 1000 times slower; that is, one millisecond to send them. A multi-path delay spread of one microsecond would only overlap 1/1000th of the transmission interval for any given bit, thus causing hardly any interference at all.

6. Conclusion and Future Work

HSDPA technology is incorporated in WCDMA Release 5 to increase data throughput and improve the efficiency of the system for downlink data traffic. WCDMA HSDPA, a relatively new wireless network, promises to provide services of up to 10Mbps and higher spectral efficiency for packet data.

It represents a major evolution of the air interface since 1997. The basic concept and principles of WCDMA HASDPA are discussed in the paper intended for an overview of the 3.5G wireless network. The applications and trends are just illustrated to justify the market drives for the technical development.The main changes introduced by HSDPA are new high-speed data channels, the combination of time-division multiplexing with code-division multiplexing, the use of AMC and HARQ techniques, and the relocation of MAC layer scheduling to the Node-B. With a thorough understanding of these changes, design and test engineers can begin to successfully implement HSDPA into network and UE. Looking forward to Release 6, the content of which is being finalized at this time, the most significant feature targeted for the radio interface is the EUDCH. This feature will introduce techniques similar to HSDPA to improve coverage, increase throughput, and reduce delay on the uplink this time. Release 7 will likely include MIMO antennas, which support higher data rates and are considered an enhancement to HSDPA. HSDPA provides lower latency with a Round Trip Delay of 70 ms, enabling great interactive applications like multi-user gaming.

HSDPA is an important ingredient needed to ignite global commerce and to enhance human experience as it will provide a ubiquitous access to Wi-Fi applications without any constraint of hot spots and provide seamless access to every type of broadband service that is already used with ADSL. In addition, to meet the growing demand for data services, innovations in MIMO and OFDM radio technology will allow the ability to cost-effectively add capacity to support the emerging broadband wireless era. With wireless mobile radio communication, there is an endless quest for increased capacity and improved quality. As HSDPA is about to launch, new technologies are promising even more bandwidth and new services like HSUPA (Enhanced DCH in 3GPP Release 6), MIMO (Multiple-Input Multiple-Output) and OFDM (Orthogonal Frequency Division Multiplexing) in 3GPP Release 7.

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