Technology Evolution of 3GPP HSPA Family.

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ABSTRACT

The growing demands for wireless data are driving the need for even higher data rates and higher spectral efficiency. The Third Generation Partnership Project (3GPP) offers High Speed Packet Access (HSPA) for making broadband for all a reality everywhere. 3GPP HSPA accounts for the majority of worldwide broadband networks today, and will continue its leadership for the next decade. The industry is evolving HSPA through 3GPP releases. HSPA Evolution (HSPA+) is the natural evolution of HSPA and provides next-generation performance through an incremental and a cost-effective upgrade while leveraging existing investments. HSPA+ enables operators to offer mobile broadband and voice services at an even lower cost. HSPA+ further enhances the end-user experience through lower latency, extended talk time through Voice over Internet Protocol (VoIP), and an improved "always-on" experience. This paper provides an overview of 3GPP HSPA family including its history, features and technology evolution in various 3GPP Releases. Also, the aim of this paper is to present the future potential of HSPA+ which will make it an undisputed choice for the future mobile broadband.

(Keywords: 3GPP, UMTS, HSDPA, HSUPA, HSPA, HSPA+, mobile broadband, communications)

INTRODUCTION

Over the last 15 years, mobile communications have revolutionized how we stay in touch with each other – and broadband has connected the world in an unprecedented way. The market is set to continue its expansion thanks to broadband for individuals, enterprises, and for society as a whole. Mobile broadband will be a larger part of this future broadband growth – helping to deliver the "broadband everywhere" vision [4].

According to Informa Telecoms & Media, "Mobile broadband has become one of the key growth engines for the mobile industry, with 186 million mobile broadband subscribers worldwide at the end of 2008, up 84% from 101 million at end-2007 and by 2013 mobile broadband subscribers will represent almost one-third of total mobile subscribers worldwide" [6].

Networks with greater capacity but lower costs per bit need to be deployed to handle the future demand for mobile broadband. The roadmap developed by 3GPP enables operators to do just that – irrespective of their legacy network infrastructure. 3GPP HSPA is the first step, followed by flat network architecture options such as 3GPP HSPA Evolution (HSPA+) and 3GPP Long Term Evolution (LTE) that promise even higher throughput [2].

The latest mobile broadband statistics are enough to take the breath away. As of April 2009, according to the Global mobile Suppliers' Association, there were almost 260 commercial HSPA networks in operation in more than 110 countries, with over 1,400 different HSPA-enabled devices already available on the market. More than 320 million people now have access to 3GPP HSPA-enabled mobile broadband services [8].

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. It is clear that 3GPP HSPA will have a significant impact on the evolution of mobile broadband in both the near-term and for the foreseeable future (see figure 1). Because of its many benefits, many 3GPP HSPA operators will choose to deploy HSPA+. An affordable, simple and incremental upgrade to existing HSPA networks, HSPA+ provides mobile operators with significant increases in technology network performance as well as reduced latency on their way to LTE [7].

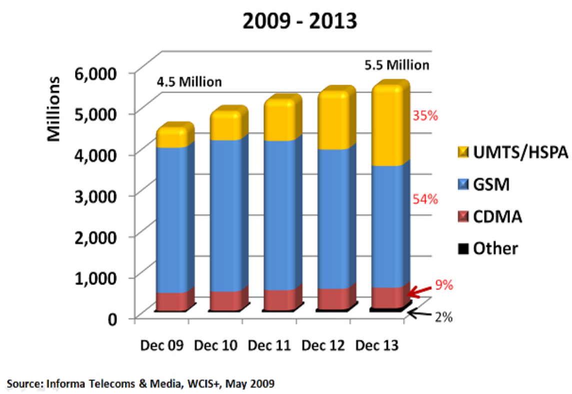

Figure 1: Global Wireless Technology Forecast [3].

HISTORY OF 3GPP HSPA FAMILY

Universal Mobile Telecommunications System (UMTS), which is based on Wideband Code Division Multiple Access (WCDMA), has been studied in Release-1999 (Rel-99) of 3GPP and published in 2000. UMTS was the next step after GSM, GPRS, and EDGE to offer improved voice and data services with a 5MHz bandwidth. Rapid growth of UMTS has led to the next step in evolutionary phase termed, Release-2005 (Rel-5) [9].

3GPP Rel-5 extended the specification of Rel-99, which provided data rates of 384kbps for wide-area coverage, 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 14.4 Mbps.

These enhancements, which commonly go under the denomination HSDPA (High Speed Downlink Packet Access), were a first step in the evolution of WCDMA. The key enhancement in 3GPP Release 6 (Rel-6), introduced in March 2005, 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 5.7Mbps. The combination of HSDPA and HSUPA is called HSPA (High Speed Packet Access) [5].

3GPP Release 7 (Rel-7) introduced HSPA evolution (also called HSPA+), which focuses on MIMO technology and flat-IP based base stations. GPRS Tunneling Protocol (GTP) has started to be used in order to connect packet switched network to radio access network. Rel-7 has also improved receiver architecture and brought interference aware receivers (referred as type 2i and type 3i).

Rel-7 also introduced the use of higher order modulations such as 64QAM with MIMO support since in Rel-6, HSPA systems used 16QAM in the downlink and QPSK in the uplink. To reduce latency when exiting the idle mode, Continuous Packet Connectivity (CPC) has been introduced for data users. In the network side, architecture has been improved as well. HSPA+ has integrated the RNC (Radio Network Controller) to NodeB (base station) to reduce latency and to make the architecture flatter and simpler [9].

As seen in Figure 2, HSPA+ further enhances the mobile broadband experience by providing up to 28 Mbps peak data rates in the downlink (DL) in R7, and up to 42 Mbps in just completed the Rel-8 specification [1]. Release 8 boosts the peak data rate in the downlink by either a combination of MIMO and 64QAM or dual carrier operation with 64QAM. Dual carrier techniques will also double the experienced user throughput throughout the network. In addition, Release 8 reduces battery consumption by introducing DRX in CELL_FACH. It also substantially improves the uplink capacity by introducing EUL mechanisms in all common states [10].

HSPA+ has a strong evolution path and will continue to evolve beyond HSPA+ R8 to further enhance the HSPA+ performance and provide a clear evolution path for current HSPA networks. The definition of HSPA+ R9 was already initiated in early 2009. HSPA+ R9 and beyond is considering enhancements such as expanding HSPA+ multi carrier beyond 10 MHz deployments combined with MIMO (Multiple Input Multiple Output) to provide peak rates of 84 Mbps and dual carriers in the uplink, giving 23Mbps [1].

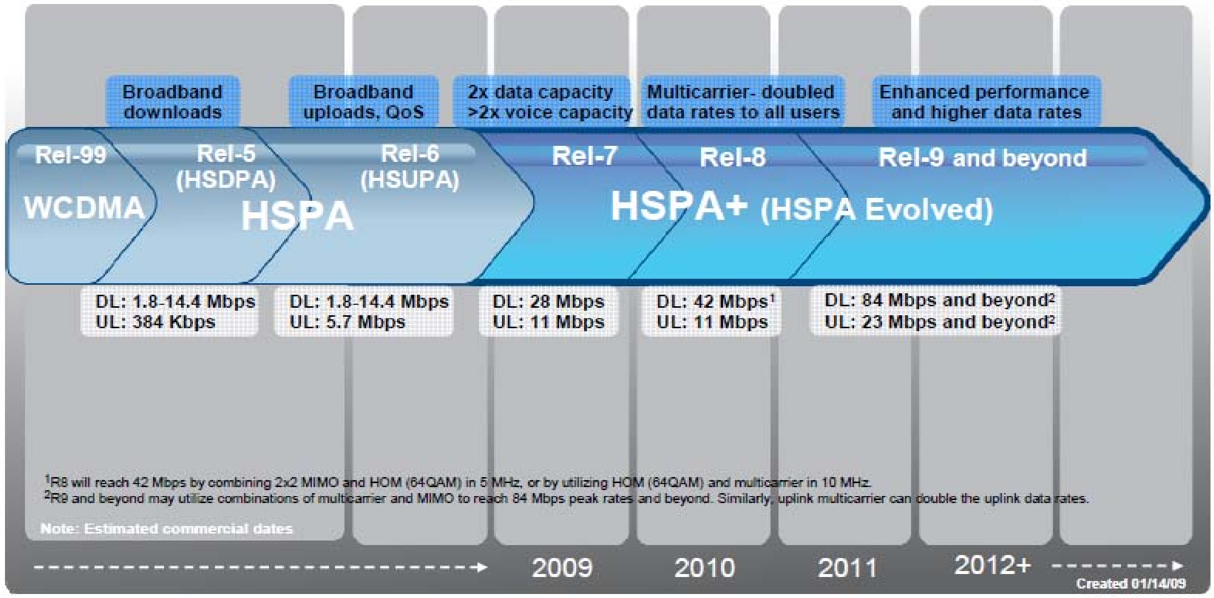

Figure 2: The HSPA+ Evolution [1].

HSPA KEY FEATURES

The key characteristics of HSPA are [11]:

- High data rates, up to 42 Mbps peak rate in the downlink as well as 11 Mbps in the uplink in just completed 3GPP Rel-8, allows users to access services and applications quickly and easily
- High Quality of Service and Low Latency for responsive and robust, services and applications
- High Capacity allow operators to provide broadband services to many users simultaneously
- Good Coverage translates in to wide area access of mobile broadband services for end users
- Flexible spectrum usage to provide HSPA services using several different frequencies

3GPP HSPA TECHNOLOGY EVOLUTION

The industry is evolving HSPA through 3GPP Releases. It started with 3GPP Release 5 with the definition of enhanced downlink (HSDPA) and still continues with Rel-8 just completed in March, 2009. The definition of HSPA+ Rel-9 has already been initiated in early 2009 to take it beyond Rel-8 for migrating mobile broadband access toward next generation.

HSDPA (3GPP Release-5)

HSDPA, specified in 3GPP Release 5, is a high-performance packet-data service that delivers peak theoretical rates of 14 Mbps. Peak user-achievable throughput rates in initial deployments are well over 1 Mbps, and as high as 4 Mbps in some networks. HSDPA is fully backward-compatible with UMTS Release 99, and any application developed for Release 99 will work with HSDPA. The same radio carrier can simultaneously service UMTS voice and data users as well as HSDPA data users. HSDPA also has significantly lower latency [12].

HSDPA elevates the performance level of WCDMA technology to provide broadband services, and it has the highest theoretical peak throughput of any cellular technology currently available. The higher spectral efficiency and higher data rates not only enable new classes of applications, but also support a greater number of users accessing the network [12]. HSDPA achieves its performance gains from the following radio features [12].

- High-speed channels shared in both code and time domains
- Short Transmission Time Interval (TTI)
- Fast Scheduling and User Diversity
- Higher order modulation
- Fast link adaptation
- Fast Hybrid Automatic Repeat Request

High-Speed Shared Channels and Short Transmission Time Interval: First, HSDPA uses high-speed data channels called High Speed Physical Downlink Shared Channels (HS-PDSCH). Up to 15 of these channels can operate in the 5 MHz WCDMA radio channel. Each uses a fixed spreading factor of 16. User transmissions are assigned to one or more of these channels for a short TTI of 2 msec, significantly less than the interval of 10 to 20 msec used in Release 99 WCDMA. The network can then readjust how users are assigned to different HS-PDSCH every 2 msec. The result is that resources are assigned in both time (the TTI interval) and code domains (the HS-PDSCH channels). Figure 3 illustrates different users obtaining different radio resources [12].

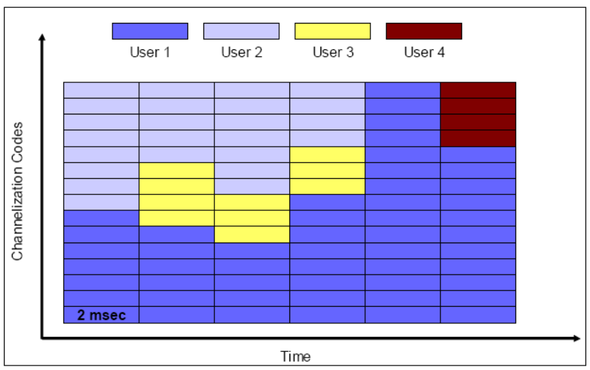

Figure 3: High Speed – Downlink Shared Channels (Example).

Fast Scheduling and User Diversity: Fast scheduling exploits the short TTI by assigning users channels that have the best instantaneous channel conditions, rather than in a round-robin fashion. Because channel conditions vary somewhat randomly across users, most users can be serviced with optimum radio conditions and thereby obtain optimum data throughput [12].

Figure 4 shows how a scheduler might choose between two users based on their varying radio conditions to emphasize the user with better instantaneous signal quality. With about 30 users active in a sector, the network achieves significant user diversity and significantly higher spectral efficiency. The system also makes sure that each user receives a minimum level of throughput. This approach is sometimes called proportional fair scheduling [12].

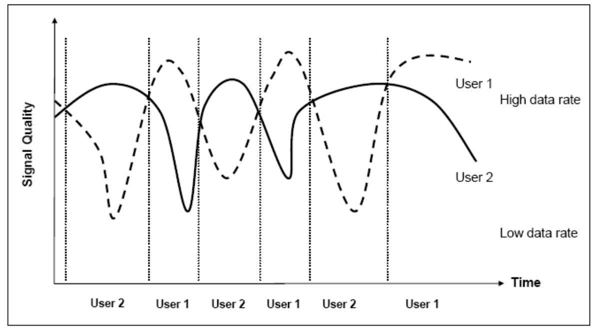

Figure 4: User Diversity.

Higher Order Modulation: HSDPA uses both the modulation used in WCDMA—namely QPSK—and, under good radio conditions, an advanced modulation scheme—16 QAM. The benefit of 16 QAM is that 4 bits of data are transmitted in each radio symbol as opposed to 2 bits with QPSK. Data throughput is increased with 16 QAM, while QPSK is available under adverse conditions. HSPA Evolution will add 64 QAM modulation to further increase throughput rates. Note that 64QAM was available in Release 7 and the combination of MIMO and 64QAM will be in Release 8 [12].

Fast Link Adaptation: Depending on the condition of the radio channel, different levels of forward-error correction (channel coding) can also be employed. For example, a three-quarter coding rate means that three quarters of the bits transmitted are user bits and one quarter are error-correcting bits. The process of selecting and quickly updating the optimum modulation and coding rate is referred to as fast link adaptation. This is done in close coordination with fast scheduling [12].

Fast Hybrid Automatic Repeat Request: Another HSDPA technique is Fast Hybrid Automatic Repeat Request (Fast Hybrid ARQ). "Fast" refers to the medium-access control mechanisms implemented in Node B (along with scheduling and link adaptation), as opposed to the BSC in GPRS/EDGE, and "hybrid" refers to a process of combining repeated data transmissions with prior transmissions to increase the likelihood of successful decoding.

Managing and responding to real-time radio variations at the base station, as opposed to an internal network node, reduces delays and further improves overall data throughput [12].

Using the approaches just described, HSDPA maximizes data throughputs and 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 [12].

HSUPA (3GPP Release-6)

HSUPA, standardized in Release 6, constitutes a set of improvements that optimizes uplink performance using the Enhanced Dedicated Channel (E-DCH). Networks and devices supporting HSUPA became available in 2007. These improvements include higher throughputs, reduced latency, and increased spectral efficiency. It results in an approximately 85 percent increase in overall cell throughput on the uplink and more than 50 percent gain in user throughput. HSUPA also reduces packet delays, a significant benefit resulting in significantly improved application performance on HSPA networks [12].

The primary uplink traffic channel defined for HSUPA is a dedicated channel that could be used for services delivered through either the circuit-switched or the packet switched domains in contrast to the primary downlink traffic channel supporting HSDPA which serves is a shared channel designed for the support of services delivered through the packet-switched domain. Such an improved uplink benefits users in a number of ways. For instance, some user applications transmit large amounts of data from the mobile station such as sending video clips or large presentation files. For future applications like VoIP, improvements will balance the capacity of the uplink with the capacity of the downlink [12].

HSUPA achieves its performance gains through the following approaches:

- An enhanced dedicated physical channel
- A short TTI, as low as 2 msec, which allows faster responses to changing radio conditions and error conditions
- Fast Node B-based scheduling, which allows the base station to efficiently allocate radio resources
- Fast Hybrid ARQ, which improves the efficiency of error processing

The combination of TTI, fast scheduling, and Fast Hybrid ARQ also serves to reduce latency, which can benefit many applications as much as improved throughput. HSUPA can operate with or without HSDPA in the downlink, though it is likely that most networks will use the two approaches together. The improved uplink mechanisms also translate to better coverage and, for rural deployments, larger cell sizes [12].

Evolution of HSPA or HSPA+ (3GPP Re-7)

HSPA+, standardized in Release 7, comprises a set of enhancements to the HSPA radio interface which increases the throughput of HSPA, taking it to the next logical level of evolution.

The goal in evolving HSPA is to exploit available radio technologies—largely enabled by increases in digital signal processing power—to maximize CDMA-based radio performance. This not only makes HSPA competitive, it significantly extends the life of sizeable operator infrastructure investments. Various RAN related enhancements in Rel-7 are:

- Multiple Input Multiple Output (MIMO)
- Higher Order Modulation (HOM)
- Continuous Packet Connectivity (CPC)
- Advanced Receivers
- Higher Data Capacity through Voice over HSPA

Multiple Input Multiple Output (MIMO): MIMO is a technique that employs multiple transmit antennas and multiple receive antennas, often in combination with multiple radios and multiple parallel data streams. HSPA+ Rel-7 supports 2x2 downlink MIMO that uses two transmit antennas at the Node B to transmit orthogonal (parallel) data streams to the two receive antennas at the device (see figure 5). Using two antennas and additional signal processing at the receiver and the transmitter, MIMO can increase the system capacity and double user data rates without using additional Node B power or bandwidth. Additionally, MIMO beam forming provides gains for cell edge users where parallel MIMO streams may not be possible [1].

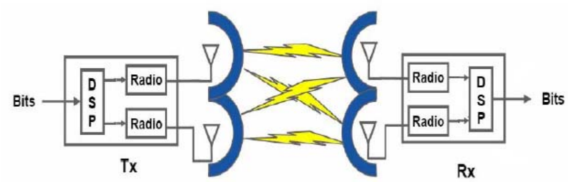

Figure 5: 2x2 MIMO System [13].

To be most effective, parallel MIMO streams need a high signal-to-noise ratio (SNR) at the device and a rich scattering environment. High SNR ensures that the device will be able to decode the signal successfully and a rich scattering environment ensures that the two data streams remain orthogonal [1].

Higher Order Modulation (HOM): HSPA supports 16QAM modulation on the downlink and QPSK on the uplink. As Figure 6 shows, the data capacity (bits/symbol) increases as we move from QPSK to 16QAM and 64QAM. HSPA+ Rel-7 introduces 64QAM on the downlink, which increases the data rates by 50% for devices in good signal conditions (high SNR). On the uplink, 16QAM doubles data rates for devices that are not power headroom limited [1].

Wireless signals transmitted with a higher modulation are more sensitive to interference and require a higher SNR at the receiver for successful demodulation. HOM significantly increases the data rates for users with high SNR. Hence, the traffic for these users can be serviced faster, leaving Node B with more time and resources to service users in weaker signal areas, such as the cell edge. Overall, this provides high data rates and improved user experience for all users in the cell [1].

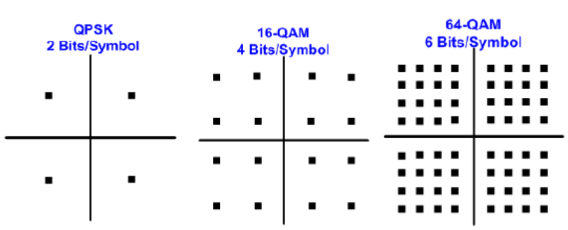

Figure 6: Higher Order Modulation [1].

Continuous Packet Connectivity (CPC): In Release 7, CPC feature Discontinuous Transmission (DTX) allows the device to gate off the control channels when there is no user data to send. In the same way, Discontinuous Reception (DRX) allows the device to turn off the receiver at certain agreed intervals in which NodeB does not transmit any downlink information to the device. Synchronized DTX and DRX operation allows the device to shut off its transmitter and receiver blocks completely, which significantly improves the device battery life for voice over HSPA services. DTX also increases the uplink capacity by reducing the uplink interference, which is especially beneficial for low-rate data applications like voice over HSPA or VoIP (See Figure 7) [1].

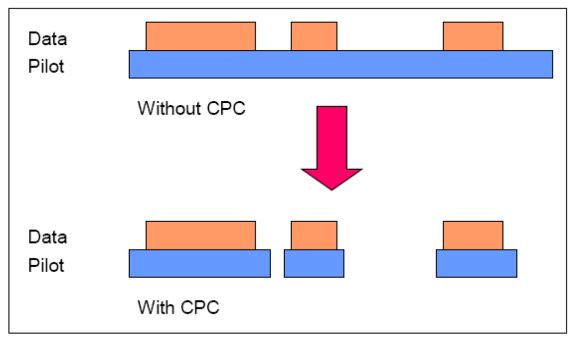

Figure 7: Continuous Packet Connectivity [12].

Advanced Receivers: In 3GPP Rel-7, Interference aware receivers, referred to as type 2i and type 3i, were defined as extensions of the existing type 2 and type 3 receivers, respectively. The basic receiver structure is that of an LMMSE sub-chip level equalizer which takes into account not only the channel response matrix of the serving cell, but also the channel response matrices of the most significant interfering cells. HSDPA throughput estimates were developed using link level simulations, which include the other-cell interference model plus Orthogonal Carrier Noise Simulator (OCNS) models for the serving and interfering cells based on the two network scenarios considered [14].

This type of receiver attempts to cancel the interference that arises from users operating outside the serving cell, which is also referred to as other-cell interference. Interference models/profiles were developed for this other-cell interference in terms of the number of interfering Node Bs to consider, and their powers relative to the total other cell interference power [14].

RAN Architecture Improvement: In addition to PHY/MAC related enhancements, 3GPP also studies possibilities to evolve the HSPA architecture. The basis for the evolved architecture is the one tunnels solution (OTS) in which the network establishes a direct transfer path for user data between RNC and GGSN while the SGSN still performs all control functions. This brings several benefits such as eliminating hardware in the SGSN and simplified engineering of the network. The integrated RNC/NodeB architecture option for HSPA+ is compared to the traditional HSPA architecture and the architecture with OTS in Figure 8 [14].

The integrated RNC/NodeB option for HSPA+ has been agreed in standards development as a viable architecture alternative for PS based services, but it will only represent an optional, complementary architecture for HSPA, (i.e. for support of CS services), HSPA+ can, and must, be deployed in the traditional hierarchical architecture as well [14].

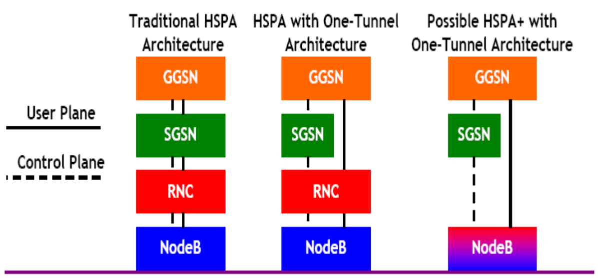

Figure 8: HSPA Architecture Options for the PS Domain [14].

One benefit of this new architecture option is that there are fewer nodes, which reduces latency, making it flatter and simpler. Further, the distribution of RNC functions out to the NodeBs could provide scaling benefits for potential femtocell HSPA deployments by not having a centralized RNC acting as the Controlling RNC for thousands of femtocells. Finally, the integrated RNC/NodeB architecture is similar to the SAE/EPC architecture to be shown later in this paper. From an architecture point of view, especially on the PS core side, the integrated RNC/NodeB option provides synergies with the introduction of LTE/EUTRAN [14].

Circuit switched (CS) Voice over HSPA: HSPA channels employ many optimizations to obtain a high degree of data throughput, which is why it makes sense to use them to carry voice communications. Doing so with VoIP, however, requires not only supporting packetized voice in the radio channel, but also within the infrastructure network. There is an elegant alternative: To packetize the circuit-switched voice traffic which is already in digital form, use the HSPA channels to carry the CS voice, but then to connect the CS voice traffic back into the existing CS infrastructure (MSCs, etc.) immediately beyond the radio access network. This requires relatively straightforward changes in just the radio network and in devices. Figure 9 shows the infrastructure changes required at the Node B and within the RNC [12].

With this approach, legacy mobile phones can continue using WCDMA-dedicated traffic channels for voice communications while new devices use HSPA channels. HSPA CS voice can be deployed with Release 7 or later networks [12].

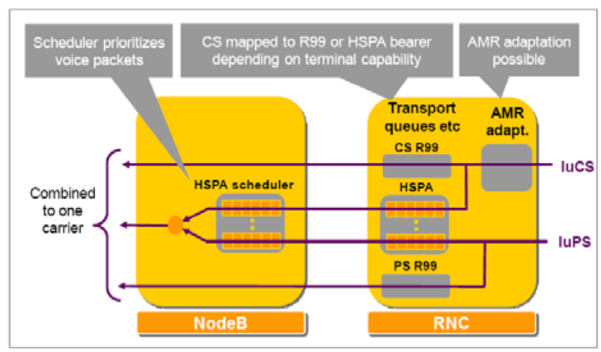

Figure 9: Implementation of HSPA CS Voice.

HSPA+ (3GPP Release-8)

The 3GPP Rel-8 specifications, which completed March 2009, contains improvements to the downlink to support data rates up to 42Mbps, using either a combination of MIMO and 64QAM or dual-carrier HSDPA for operation on two 5MHz carriers with 64QAM. In the uplink, Enhanced CELL_FACH supports Enhanced Uplink functionality and, in addition, improved Layer 2 has been introduced in the uplink direction. Various HSPA enhancements in Rel-8 are [13]:

MIMO with 64QAM Modulation in Downlink: Rel-8 combines MIMO and 64QAM modulation (two features in Rel-7) to boost the peak downlink rate over a single 5MHz carrier to 42Mbps.

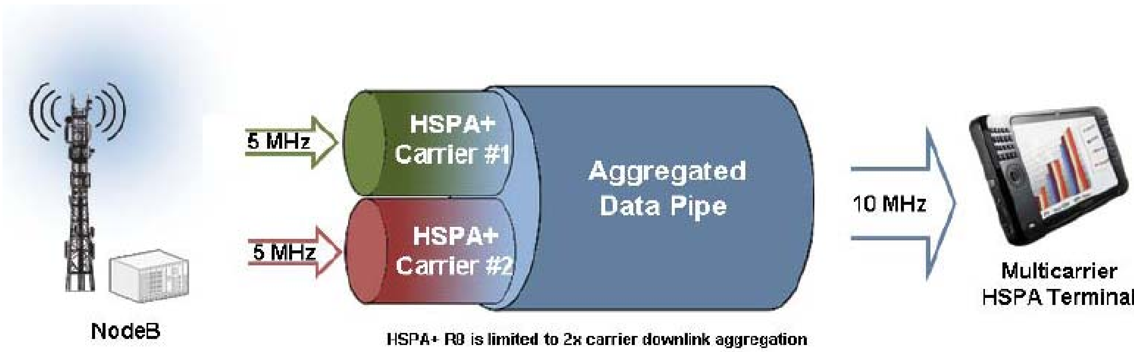

Figure 10: Multicarrier Further Enhances the Broadband Experience [1].

The term MIMO refers to the use of more than one transmit antenna in the base station and more than one receive antenna in UEs. The transmitter chain for the standardized MIMO scheme applies separate coding, modulation and spreading for up to two transport blocks transmitted over two parallel streams, thereby doubling the achievable peak rate in the downlink. The UE radio propagation conditions determine how many streams (one or two) will be transmitted [13].

In Rel-7, 16QAM is the highest-order modulation used in combination with MIMO. Therefore, four bits can be transmitted per modulation symbol, resulting in a peak rate of 28Mbps. The upgrade to 64QAM in Rel-8 allows six bits to be transmitted per symbol, which increases the peak rate by 50% to 42Mbps. To the greatest possible extent, the introduction of MIMO with 64QAM modulation reuses the protocol changes introduced in Rel-7 for MIMO and 64QAM respectively [13].

Dual-Carrier Operation in Downlink: In deployments where multiple downlink carriers are available, the new multicarrier operation offers an attractive way of increasing coverage for high bit rates. Rel-8 introduces dual-carrier operation in the downlink on adjacent carriers. This technique doubles the peak rate from 21Mbps to 42Mbps without the use of MIMO – it doubles the rate for users with typical bursty traffic; therefore, it also doubles the average user throughput, which translates into a substantial increase in cell capacity (see figure 10) [13].

A dual-carrier user can be scheduled in the primary serving cell as well as in a secondary serving cell over two parallel HS-DSCH transport channels. All non-HSDPA-related channels reside in the primary serving cell, and all physical layer procedures are essentially based on the primary serving cell. Either carrier can be configured to function as the primary serving cell for a particular user. As a consequence, the dual-carrier feature also facilitates an efficient load balancing between carriers in one sector. As with MIMO, the two transport channels perform hybrid automatic repeat request (HARQ) retransmissions, coding and modulation independently. A difference compared to MIMO is that the two transport blocks can be transmitted on their respective carriers using a different number of channelization codes [13].

In terms of complexity, adding a dual-carrier receiver to UEs is roughly comparable to adding a MIMO receiver. Because the two 5MHz carriers are adjacent, they can be received using a single 10MHz radio receiver, which is already be available if the UE is LTE-capable [13].

Enhancements to Common States: Users should always be kept in the state that gives the best trade-off between data rate availability, latency, battery consumption and usage of network resources. As a complement to the data rate enhancements made to the dedicated state (CELL_DCH), 3GPP has also made significant enhancements to the common states (URA_PCH, CELL_PCH and CELL_FACH). Rel-7 introduces HSDPA mechanisms in the common states in order to improve their data rates, latency and code usage. Rel-8 introduces corresponding enhancements in the uplink, allowing base stations to configure and dynamically manage up to 32 common E-DCH resources in each cell.

This enhancement improves latency and data rates for keep-alive messages (for example, from VPN or messenger applications) as well as web-browsing events, providing a seamless transition from E-DCH in common state to E-DCH in dedicated state. As a further improvement of the CELL_FACH state, Rel-8 introduces discontinuous reception (DRX), which significantly reduces battery consumption. Therefore, UEs can remain in CELL_FACH for long periods of time. DRX is now supported in all common and dedicated states [13].

HSPA+ (3GPP Release-9)

HSPA has a strong evolution path beyond HSPA+ R8. The definition of HSPA+ Rel-9 has already been initiated in early 2009 with focus on multicarrier enhancements. The combination of MIMO and multicarrier in 10 MHz would enable 84 Mbps in HSPA+ Rel-9 . Uplink multicarrier is also a Rel-9 candidate that would increase the uplink data rates to 23 Mbps, with similar benefits as downlink multicarrier within the limit of the device transmit power [1].

HSPA+ Rel-8 allows aggregation within the same spectrum band only, but future enhancements may also target the aggregation across bands, even with large RF separation, allowing operators to better leverage all their spectrum assets. Aggregation of up to four downlink carriers are also being considered, enabling 84 Mbps peak data rates in 20 MHz (without MIMO) [1].

Evolved Multicarrier Operation in Downlink: Following the introduction in Rel-8 of dual-carrier operation in the downlink, 3GPP is now discussing operation on multiple 5MHz carriers. Multiband operation of multiple carriers allows a single user to simultaneously aggregate and use the spectrum distributed over different bands. This gives operators greater flexibility when using available spectrum.

Increasing the number of carriers that UEs receive from two to four doubles the peak rate and achievable user throughput (see figure 11). For bursty traffic, this translates into substantially greater capacity, either as a larger number of users at a given data rate, or as a higher data rate for a given number of users. To substantially boost spectral efficiency, 3GPP is studying the combination of dual-carrier operation and MIMO with 64QAM in the downlink, thereby doubling the peak data rate to 84Mbps. Similarly, they are studying the combination of MIMO, 64QAM and up to four downlink carriers to support peak data rates of more than 100Mbps [10].

Multicarrier Operation in Uplink: The enhanced data rates in the downlink call for improved data rates in the uplink. Introducing support for dual carrier operation in the uplink will double the peak rate to 23Mbps while keeping UE complexity at a reasonable level. Initial investigations indicate that available bandwidth limits performance more than the UE transmit power. Therefore, by making use of greater bandwidth for data transmission, operators can distribute interference over two carriers. In summary, uplink multicarrier operation increases availability as well as coverage of high data rates in the uplink [10].

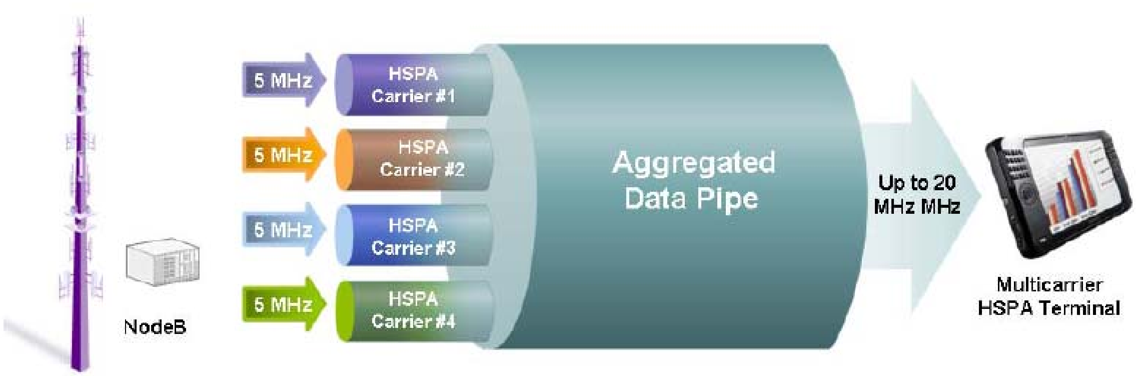

Figure 11: Multicarrier Aggregation of up to Four Carriers [1].

CONCLUSION

The success of mobile broadband is driving the demand for higher data rates and greater cell capacity. There are a number of different broadband access technologies available today. For operators, technology choices made now will influence operations for many years to come. HSPA is a proven mobile broadband technology that is already deployed in over 200 commercial networks. It is built on the firm foundation of the 3GPP family, offering the carrier-grade voice services users expect and the broadband speeds they desire [4].

The industry is evolving HSPA through 3GPP Releases. HSPA+ is the name of the set of HSPA enhancements that are defined in 3GPP beyond Release 6 (Rel-6). The enhanced downlink (HSDPA) was defined in Rel-5 and the enhanced uplink (HSUPA) was defined in Rel-6. HSPA+ further enhances the mobile broadband experience by providing up to 28 Mbps peak data rates in the downlink (DL) in Rel-7, and up to 42 Mbps in Rel-8 [1].

HSPA+ is the natural and most economical evolution from HSPA, allowing WCDMA/HSPA operators to make the most efficient use of their existing assets and investments in network, spectrum and devices at a lower cost. HSPA+ is backward compatible, allowing for a gradual introduction of devices and a smooth, cost-efficient and simple network upgrade to existing HSPA nodes. HSPA+ enables operators to offer mobile broadband and voice services at an even lower cost. HSPA+ further enhances the end-user experience through lower latency, extended talk time through VoIP, and an improved "always-on" experience [1].

HSPA has a strong evolution path beyond HSPA+ Rel-8. The definition of HSPA+ Rel-9 has already been initiated in early 2009 with focus on multicarrier enhancements. The combination of MIMO and multicarrier in 10 MHz would enable 84 Mbps in HSPA+ Rel-9. Uplink multicarrier is also a Rel-9 candidate that would increase the uplink data rates to 23 Mbps, with similar benefits as downlink multicarrier within the limit of the device transmit power [1]. In summary, HSPA Evolution gives operators a cost-effective way of migrating mobile broadband access toward 4G.

REFERENCES

1. Qualcomm Incorporated. 2009. "HSPA+ for Enhanced Mobile Broadband". Retrieved from http://www.qualcomm.com/common/documents/white_papers/HSPAPlus_MobileBroadband_021309.pdf

2. UMTS Forum. 2009. "Mobile Broadband Evolution: The Roadmap from HSPA to LTE". http://www.umts-forum.org/component/option,com_docman/Itemid,12/

3. [3gamericas. 2009. "Global Wireless Technology Forecast by Informa Telecoms & Media, WCIS+". May, 2009. Retrieved from http://www.3gamericas.org/index.cfm?fuseaction=page&pageid=1008

4. Ericsson. 2009. "HSPA, the Undisputed Choice for Mobile Broadband". Retrieved from http://www.ericsson.com/technology/whitepapers/hspa_Rev_b.pdf

5. Ericsson. 2009. "Technical Overview and Performance of HSPA and Mobile WiMAX". Retrieved from http://www.ericsson.com/technology/whitepapers/hspa_and_mobile_wimax.pdf

6. Total Telecom. 2009. "Global Mobile Broadband Subscribers up 84% to 186m". Informa Telecoms & Media. Retrieved from http://www.totaltele.com/view.aspx?C=0&ID=444112

7. 3gamericas. 2008. "All Roads lead to LTE: The Mobile Broadband Future: HSPA+ and LTE". www.3gamericas.org/documents/3g_america.pdf

8. Ericsson. 2009. "Mobile Broadband: The Path is Clear". Retrieved from http://www.ericsson.com/broadband/facts_opinions/pdf/mb_the_path_is_clear.pdf

9. Ergen, M.. 2009. *Mobile Broadband: Including WiMAX and LTE*. Springer: Berkeley, CA.

10. Ericsson. 2009. "Continued HSPA Evolution of Mobile Broadband". Retrieved from http://www.ericsson.com/ericsson/corpinfo/publications/review/2009_01/files/HSPA.pdf

11. GSMA. 2009. "How to Realize the Benefits of Mobile Broadband Today". Retrieved from http://hspa.gsmworld.com/upload/news/files/13022009113831.pdf

12. 3gamericas. 2008. "EDGE, HSPA, LTE: Broadband Innovation". Retrieved from http://www.3gamericas.org/documents/EDGE_HSPA_and_LTE_Broadband_Innovation_Rysavy_Sept_2008.pdf

13. 3gamericas. 2009. "The Mobile Broadband Evolution: 3GPP Release 8 and Beyond HSPA+,

SAE/LTE and LTE – Advanced". http://3gamericas.org/documents/3GPP_Rel-8_Beyond_02_12_09.pdf

14. 3gamericas. 2007. "UMTS Evolution from 3GPP Release 7 to Release 8, HSPA LTE/SAE". Retrieved from http://www.3gamericas.org/documents/UMTS_Rel-8_White_Paper_12.10.07_final.pdf

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