HSDPA and beyond

> White Paper
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Introduction

1.1. Objective

According to Pyramid Research, as of January 2005, more than 16 million subscribers around the world use UMTS commercial services like video telephony, video and music on demand at speeds up to 384 kbps. The fact is that the radio access layer as specified in 3GPP Rel’99 enables high Quality of Service (QoS) with video telephony, for instance, but it does not manage the radio spectrum efficiently when dealing with “bursty” traffic. The continuous need for even better spectral efficiencies, improved user experiences and new services drove the standardization of new features defined in 3GPP Release 5 (Rel’5).

One of the key features defined in UMTS Rel’5 is High Speed Downlink Packet Access (HSDPA), which offers significantly higher data capacity and data-user speeds on the downlink compared to R’99 UMTS. This is possible through the use of a new downlink shared transport channel and a set of smart mechanisms such as very dynamic adaptive modulation and coding, a fast scheduler, and fast retransmissions implemented in the UMTS BTS. This new feature is fully Rel’99 backward compatible and can co-exist on the same RF carrier with R’99 UMTS traffic.

Broadband and convergence will radically change the way of communicating by providing seamless access to any kind of bandwidth-demanding services and will blend the boundaries between wireline operators, Internet service providers and wireless operators. Without waiting for the future, where high-speed wireless data uses new physical interfaces like MIMO/OFDM, wireless operators can accelerate their Return of Investment due to the high spectrum efficiency of HSDPA, which means higher capacity and coverage, and enables new services that would have not been economically viable otherwise.

1.2. Scope of this document

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.
1.3. **Audience for this document**

Network technology evolution, strategy planning

2. **Related documents**

2.1. **Applicable documents**

None

2.2. **Reference documents**

None

3. **What’s all the fuss with HSDPA?**

3.1. **Empowering UMTS networks with HSDPA**

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.

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.

Wireless operators have to squeeze the absolute most value from their investment, and as data traffic is expected to take off very quickly, there is a further need for higher spectrum efficiency compared to UMTS Rel’99. According to Forrester, revenues from
Wireless Emerging Services are forecasted to grow from $4 Billion in 2004 to $61 Billion in 2008 (CAGR 98%). The last business case created by Nortel shows an OPEX reduction of 37% due to the lower cost per megabyte (half the cost of UMTS Rel’99) with HSDPA.

HSDPA is the right answer to the 1xEV-DO offensive — already launched in March 2004 — and also the way to clearly position UMTS in the broadband area.

3.2. Triggering the data usage with HSDPA

HSDPA innovations compared to today’s UMTS include the increase in the range of applications available to the end user, enabling access to broader content due to the high-speed downlink transmission (because it is ~5x faster), and the increase of the data users per cell due to the better spectral efficiency (~10x more spectrally efficient). This will boost the use of applications by the end users, which will generate more revenues for wireless operators.

The usage increase of the Internet today is mainly due to the huge deployment of broadband solutions, making bandwidth a commodity and enabling richer content based on a friendly format using video, pictures, music and interactive gaming.

Looking back in history at what happened with the adoption of mobile services for voice provides a good example of what will happen with data. At the beginning of the ‘90s, it was believed that voice service would be dedicated for specific professional users like medicine, or a sales force on the road. Finally, instead of a niche application, wireless voice services are now widely spread all over the globe with more than three billion users. GSM and CDMA 1xRTT brought a first step towards freedom with the ability to provide a basic service — speech — everywhere with good quality and without any specific constraints for the user. Even at home, people are now using their mobile phone because the quality is equivalent to their fixed phone.

HSDPA will change wireless communications by delivering broadband in wireless access. This is the next big technological advancement needed to increase usage. It will boost usage in business sectors by providing a virtual office environment anywhere and it will also trigger usage by the consumer market by leveraging the end-user experience of fixed broadband.
Thanks to HSDPA, UMTS market growth will replicate what happened with fixed broadband access. The implications, both for businesses and for the consumer market, will be enormous.

The first trend will be for the business market, by extending Wireless LAN applications to everywhere, providing a virtual office to sales forces and all nomadic jobs. Indeed, HSDPA allows for broadband to be truly ubiquitous for the very first time without the inconvenience of looking for hot spots or wireless access points.

One of the most dramatic changes the telecom sector has faced in recent years has been the diminishing time lag between the corporate sector and the consumer market in their uptake for new technology. As far as the consumer market is concerned, HSDPA will blend the boundary between their fixed broadband access and their mobile services: HSDPA will provide the seamless access to all applications already used at home for entertainment like music and video downloads, multiplayer gaming and TV. HSDPA has a great opportunity to enter the triple play market by addressing residential access with a bundle offer for TV, Internet access and voice and mobile services.
In the same way GSM can be used at home, UMTS users will also use UMTS services at home due to the broadband capability of HSDPA. That’s why 100 percent of the access will be wireless in the very near future!

This is not a futuristic vision. This is what will be possible in 2005 with HSDPA as HSDPA has already been demonstrated by Nortel in January 2005 using a commercial infrastructure and a commercial chipset. HSDPA will blend the boundaries enabling consumers to access the same level of services everywhere as was the case with voice in the 1990s!

### 3.3. 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, 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.

![Figure 3 - Comparison between 1xEV/DO and HSDPA](image-url)

![Figure 4 - Spectrum efficiency between HSDPA and 1xEV/DO](image-url)
4. What is HSDPA?

4.1. A new radio Interface

HSDPA is a UMTS packet air interface (add-on solution on top of 3GPP R99/R4 architecture) that allows up to 3.6 Mbps peak data rate for a Category 6 Mobile per user with a classical Rake receiver and up to 14.4 Mbps peak data rate for a Category 10 mobile per user with advanced receiver solutions.

HSDPA terminals will co-exist with R99 terminals, but new terminals will be required to support HSDPA. As explained in the next session, there is no modification to the core network and traffic classes.

4.2. No core network impacts

It is important to note that HSDPA is a pure 3GPP Rel’5 access evolution without any core network impacts except for minor changes due to the higher bandwidth access. For instance, in the 3GPP Rel’5, the maximum throughput set into the signaling protocol has been increased from 2 Mbps to 16 Mbps in order to support the theoretical maximum limit of HSDPA data rate, which is 14.4 Mbps. This is why the signaling between the UTRAN, SGSN and GGSN need to be changed in order to support newly expanded QoS parameters (hence GTP protocol and Session Management layer changes).

4.3. HSDPA overview

Basically, HSDPA introduces a new common High Speed Downlink Shared Channel (HS-DSCH) shared by several users. In addition, it introduces enablers for the high-speed transmission at the physical layer like the use of a shorter TTI (2 ms), the use of adaptive modulation and coding, and the use of fast retransmission based on hybrid ARQ (HARQ) techniques. These key mechanisms are located within the UMTS BTS.

The scheduler has not been standardized in 3GPP and Nortel proposes a two stage scheduler integrating the subscriber’s differentiation. With this “packetized” air interface, more users are on a cell and the scheduler is more efficient by having more opportunity to deal with a constructive fading. This is the Multi-User Gain of the HSDPA scheduler.
### Key mechanisms of HSDPA

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Description</th>
</tr>
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</table>
| **New downlink shared transport channel**     | • HS-DSCH is shared by all users of a sector  
• HS-SCCH enables the UE to identify which codes of the HS-DSCH contain its data  
• DPCCH is responsible of Uplink signaling |
| **Fast link adaptation**                      | It enables to change modulation and coding format in accordance with variations in the channel conditions which leads to a higher data rate for users in favorable positions and reduced interference |
| **Adaptive modulation and coding**            |                                                                                                                                               |
| **Hybrid Automatic Request (HARQ)**           | HARQ retransmission protocol is implemented in MAC Layer instead of the RLC Layer, decreasing the delay associated with retransmissions. HARQ is placed in the Node B. |
| **Fast scheduling**                           | The Scheduler is placed in the Node B in order to quickly respond to the changes in channel conditions. A compromise between a Round Robin and a Max C/I scheduler will be used. |
| **Fast cell selection**                       | The scheduled nature of HSDPA makes it impossible to use a soft HO mechanism. A hard HO is used for HS-DSCH: the UE indicates the best cell which should serve it through uplink signaling. |

The TTI of 2 ms leads to a reduced round trip delay and a higher validity of the channel estimation.

**Figure 5 - Key mechanisms of HSDPA**

In many aspects, the new transport channel type HS-DSCH is very similar to the DSCH transport channel in R’99. As in DSCH, the HS-DSCH transport channel is associated to a dedicated DPCH channel (in the uplink for HS-DSCH, contrary to DSCH). The main difference from DSCH is that the scheduling with HS-DSCH is done at the Node B rather than the RNC.
The HSDPA functionality defines new channel types:
- HS-DSCH transport channel
- HSDPA Shared Control Channel (HS-SCCH)
- High Speed Dedicated Physical Control Channel (HS-DPCCH)

Basically, the downlink HS-DSCH channel is shared in a number of SF 16 codes and time. Within each 2 ms TTI, a constant spreading factor of 16 is used with a maximum of 15 parallel channels for the HS-DSCH. These channels may all be assigned to one user during the TTI, or may be split among several HSDPA users. There is no more power control with HSDPA and the High Speed Downlink Shared Channel 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.

![Figure 6 - Time multiplexing downlink channel with HSDPA](image)

The HS-DPCCH, UL signaling channel is of paramount importance as it provides Channel Quality Indicator (CQI), ACK and NACK. The CQI — based on the measurement of the CPICH power — reflects the Signal to Interference Ratio (SIR). Based on this CQI, the UMTS BTS may change every 2 ms the modulation, the coding and the number of codes during all the communication. Thanks to the real time knowledge (every 2 ms) of the radio conditions for each user, HSDPA matches the exact throughput to the radio bandwidth available for every user during the communication, which means higher average throughput and higher spectrum efficiency.
By taking the best of the radio spectrum in a real-time process, the adaptive modulation and coding enables “bursty” traffic, hence higher average throughput. This end-user experience will depend on the number of HSDPA users in the cell, but three to five times higher throughput is expected on the field with HSDPA. It also reduces the interference variation due to link adaptation based on variations in the modulation/coding scheme instead of variations of the transmit power.

This is the use of the 16 QAM modulation and the use of five SF16 codes that enable the 3.6 Mbps of throughput, which is the capability of a Category 6 Mobile. This modulation enables higher data rates as four bits are transmitted per symbol.
The main architectural shift with respect to R’99 is the introduction of an ARQ scheme for error recovery at the physical layer (which exists independently of the ARQ scheme at the RLC layer). This scheme can be defined as Multilink Stop-and-Wait, because it uses several ARQ protocols (up to eight) with window size of one in parallel. In addition, the error recovery scheme makes use of incremental redundancy by combining successive retransmissions of the same data unit (with possibly different coding and modulation scheme between the two).

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.
The RLC NACK is often routed to a centralized part of the network (accounting for the 80 to 100 ms round-trip time) where RNCs are located.

With HSDPA, thanks to HARQ in the UMTS BTS at the MAC-hs level, a NACK requires less than 10 ms for retransmission, which enables the recovery of erroneous frames before the TCP timer expires and leaves the TCP throughput unaffected. Basically, the mobile stores the first erroneous packet and will combine it with the retransmitted one.

Two combining schemes are supported with HSDPA: Chase combining where the BTS resends the same packet and Incremental Redundancy where the BTS provides additional coding by sending the parity bits in the retransmission. Chase combining and Incremental Redundancy are both mandatory in the HSDPA Terminal but the Incremental Redundancy requires more memory in the HSDPA Terminal and should be used only when using high coding rate. The BTS decides which combining technique should be used depending on the memory of the terminal and the data rate.

Figure 9 - TCP enhancements with the fast retransmission HARQ
Hence, HSDPA enables not only a higher download speed, but also more robust behavior of the TCP regarding bad radio conditions.

There is tremendous gain if the MAC has at least one retransmission; however, simulations show that the gain does not increase substantially if the number of retransmissions is more than two. This is due to the fact that after two transmissions, most of the packets are recovered and the third retransmission is hardly required.

If the fast ARQ fails to deliver a frame correctly even after retransmitting the maximum allowed number of times, then the responsibility is passed on to the RLC to retrieve the frame.

Regarding mobility, due to the time scheduling aspect of HSDPA, Fast Cell Selection is used instead of Soft Handover. The terminal indicates the best cell that should serve it on the downlink, through uplink signaling. Thus, while multiple cells may be members of the active set, only one of them transmits at any time, potentially decreasing interference and increasing system capacity.

### 4.4. HSDPA Terminals

HSDPA will require new terminals. However, they will be built in with R’99 terminals and will be compatible with WCDMA R’99 networks. A typical upgrade strategy for an operator will be to convert only a few cells with HSDPA while the remaining cells remain...
on R’99. Therefore, all terminals must support R’99 and HSDPA. The first terminal will be a data-card enabling 1.8 Mbps of peak data rate (Category 12) and 3.6 Mbps of peak data rate (Category 6).

The signaling downlink shared physical channel HS-SCCH carries the HSDPA-related controlling information to the HSDPA mobile, which monitors one or more HS-SCCHs according to its class to know when it should receive data. An example of the way data is transmitted to the different users on HS-PDSCH is described below.

![Figure 11 - Signaling monitoring by the HSDPA Terminal](image)

Up to 15 HS-PDSCHs could be allocated to HSDPA in a given cell and the terminal equipment can monitor up to 4 HS-SCCHs — each HS-PDSCH requires an SF16 code, and each HS-SCCH requires an SF128 code. The UE capabilities are standardized in 3GPP in terms of category, which depends on the number of channelization codes, the minimum inter-TTI interval and the support of the 16 QAM Modulation, described in the following table.
### 4.5. Transport evolution with HSDPA

As already explained in the previous section, HSDPA will provide higher spectrum efficiency thanks to the new shared downlink channel and enhanced mechanisms like adaptive modulation and coding, and the 16 QAM modulation when good radio conditions enable the use of the higher rate modulation. This leads to a more bandwidth-demanding access in terms of transmission between the UMTS BTS and the RNC. This impact on the throughput per UMTS BTS will depend on the mobile performances for HSDPA, which are characterized by the UE category.
5. Performances with HSDPA

We presented all the innovations that make HSDPA so efficient and we aim to provide the key performances with HSDPA thanks to Nortel’s experience and leadership in 1xEVDO, which is the HSDPA-like solution for CDMA2000.
5.1. Indoor vs. outdoor HSDPA solutions

In the indoor environment, the small cell size, the very good and controlled coverage, and low mobility lead to a very high spectrum efficiency and very high data rate per user. Even if the 16 QAM modulation is very sensitive to the radio conditions, this modulation will be used most of the time in an Indoor environment. In addition, there is a very low impact on PA power for HSDPA operation, which means the downlink throughput is not significantly impacted by the minimum power required for the signaling HS-SCCH channel.

However, when dealing with outdoor configurations, the broadband performances are much more challenging due to higher interference at the cell edge and larger cell size compared to indoor coverage for WLAN-type services.

Basically, there is a significant impact on PA power for HSDPA operation, i.e., lower downlink throughput due to required power for HS-SCCH. Therefore, HS-SCCH power control is required to reduce impact on HSDPA throughput as described below. Otherwise, more than 10 percent of the PA should be reserved for the HS SCCH Signaling channel.

Typically, as depicted on the above distribution, in an outdoor environment, the signal to interference ratio is less than -2 dB for more than 90 percent of the cell, which means a
minimum power of – 9 dB on HS-SCCH to guarantee a probability of error on the signaling downlink channel of one percent. This results in 12 percent of the PA.

As there is a linear relationship between the radio conditions of the terminal equipment and the power needed on the HS-SCCH signaling channel, it is possible to build a smart RF algorithm within the UMTS BTS. This is able to provide the right power for HS-SCCH to every user of the cell due to the CQI information. For example, with a reasonable error rate of two percent of HS-SCCH, a user reporting a CQI of 7 will require -12 dB of HS-SCCH Power and another user reporting a CQI of 12 will require only -19 dB of HS-SCCH Power.

5.2. Throughput per cell and throughput per user

The capability to change the modulation, the coding and the number of SF16 codes during the communication enables a higher average data rate and higher spectrum efficiency. But the support of a high number of SF 16 codes and the support of the 16 QAM modulation require very good radio conditions, i.e., high CQI. The following table specifies in the 3GP 25.214 the different transport format depending on the CQI reported by a Category 6 Mobile.

<table>
<thead>
<tr>
<th>CQI</th>
<th>0 to 6</th>
<th>7 to 9</th>
<th>10 to 12</th>
<th>13 to 14</th>
<th>15</th>
<th>16 to 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of HS-SCCH</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK</td>
<td>QPSK</td>
<td>QPSK</td>
<td>QPSK</td>
<td>QPSK</td>
<td>16-QAM</td>
</tr>
</tbody>
</table>

Figure 15 - Table of transport characteristics for Category 6 Mobile

The following pictures show that mobile capabilities really differentiate in good radio conditions and that without enhanced UE Receiver, the expected throughput per user is between 500 kbps and 1 Mbps.
When dealing with more than five SF16 codes, a classical Rake Receiver is not able to counter the Multiple Access Interferences and even if fast retransmissions enable the partial coping with Multiple Access interference, it leads to an asymptotic throughput of 2 Mbps.

5.3. Coverage

In most cases, wireless operators have already deployed a large number of UMTS BTSs by using RF dimensioning for 64-kbps services. It is very important to understand the impact of a migration towards HSDPA in terms of capacity and coverage.

Paradoxically, HSDPA enables a wider coverage than UMTS R’99 due to the adaptive modulation and coding and the fast scheduler in the BTS, which provides more granularity in term of radio and resource management.

Figure 16 - HSDPA throughput for different types of Mobile
At the cell edge, HSDPA is still able to deliver data while preserving the capacity of the neighbor cells. Even with Soft Handover for UMTS Rel’99, it is possible to provide a 384-kbps dedicated channel at the cell edge that would strongly impact all the capacity of sites involved in the Soft Handover. Nortel computed many simulations based on strong engineering experience in 1xEV/DO, and it has been shown that the migration towards HSDPA will not impact the current network design at 64 kbps.

Basically, this is the Dedicated Uplink Channel which will determine the HSDPA coverage. For a typical cell design based on 64 kbps (PS or CS), the impact is very limited and occurs only when the HS-DPCCH is effectively transmitted.

6. 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 3GPP Release 7.
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 radio-access technology is now under investigation in 3GPP RAN Working Group. Nortel demonstrated its leadership in the studies which have led up to the December 2004 agreement of the 3GPP Study Item on Evolved UTRA and UTRAN.

6.1. 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
- 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

6.2. MIMO

MIMO (Multiple-Input Multiple-Output) is also a very promising technology that will empower UMTS HSDPA networks by providing three times more throughput than HSDPA as illustrated below:
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.

6.3. 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.
As described on the following picture, OFDM splits the available bandwidth into many narrow band channels. The carriers for each channel are made orthogonal to one another, allowing them to be spaced very close together.

![Figure 19 - Principle of OFDM](image)

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 multi-path delay spread, as the delay spread must be very long to cause significant inter-symbol 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 inter-symbol 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.
Nortel is leading the 3GPP study for a new physical interface combining both MIMO and OFDM, and which promises a huge increase in HSDPA throughput with more than 40 Mbps within the 5MHz of bandwidth in the next five years.

7. Conclusion

Thanks to Nortel’s leadership in 1xEVDO, the HSDPA-like solution for CDMA 2000, and more than five years of UMTS development with a stable solution in commercial networks based on the fourth UMTS Release, Nortel will empower UMTS networks with a smooth and software-only migration path towards HSDPA.

First to market with HSDPA with end-to-end wireless HSDPA calls in November 2004 and trials starting in Q2 2005, Nortel enhances the end-user experience by delivering up to five times the UMTS data rate and two times the UMTS capacity. In addition, 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, Nortel’s R&D team is working to bring the future beyond HSDPA. Nortel innovations in MIMO and OFDM radio technology will allow the ability to cost-effectively add capacity to support the emerging broadband wireless era. Nortel has had an advanced MIMO-OFDM program in place since 2000 and achieved peak data rates of up to 300 Mbps in a realistic allocation of 20MHz radio channel.
8. Abbreviations and definitions

8.1. Abbreviations

OPEX: Operational Expenditure  
CAPEX: Capital Expenditure  
UE: User Equipment  
lub: Interface between the RNC and the Node B  
16QAM: 16 Quadrature Amplitude Modulation  
CQI: Channel Quality Indicator  
HARQ: Hybrid Automatic Repeat Request  
HSDPA: High Speed Downlink Packet Access  
HS-DSCH: High Speed Downlink Shared Channel  
HS-PDSCH: High Speed Physical Downlink Shared Channel  
HS-SCCH: Shared Control Channel for HS-DSCH
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