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Performance Analysis of 16-QAM Scheme for HSDPA

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Abstract: 3G HSDPA High Speed Downlink Packet Access is an upgrade to the original 3G UMTS cellular system (3.5G) that provides a much greater download speeds for data. With more data being transferred across the downlink than the uplink for data centric applications, the upgrade to the downlink was seen as a major priority. Accordingly 3G UMTS HSDPA was introduced into the 3GPP standards as soon as was reasonably possible, the uplink upgrades following on slightly later. 3G UMTS HSDPA significantly upgrades the download speeds available, bring mobile broadband to the standards expected by users. With more users than ever using cellular technology for emails, Internet connectivity and many other applications, HSDPA provides the performance that is necessary to make this viable for the majority of users with the implementation of HSDPA, this technology can coexist on the same carrier as the current Release'99 WCDMA services. This will enable a smooth and cost-efficient introduction of HSDPA into the existing WCDMA networks. The driving force for high data rates are greater speed, shorter delays when downloading audio, video and large files which will be used in PDA's, smart phones etc. Further a user can download packet data over HSDPA, while at the same time having a speech call. HSDPA offers theoretical peak rates of up to 10MBps and in practice more than 2MBps.

Keywords- OFDM, MMSE,CFO,HSDPA,WCDMA.

I. INTRODUCTION

The wireless industry is currently facing many challenges. Mobile penetration has reached saturation point in many countries and revenue from voice is declining. So the mobile operators are looking for new opportunities to increase the revenue. The situation is similar with the fixed line operators and internet service providers. They are also looking for new opportunities to increase the revenue. Mobile operators are trying to increase their revenue by providing new services based on packet technology and are also looking for opportunities to substitute the fixed line services like PSTN and DSL with wireless services. On the other hand fixed line operators are also trying to flex their muscles in the wireless field. Technological developments like WLAN 802.11b, 802.16, cdma 2000 EV-DO have enabled the fixed line operators and alternate mobile operators to focus in the field of fast growing data communication. Technological developments like GPRS/EDGE/UMTS have helped mobile operators to increase their revenue by providing new data services to a certain extent. However, these technologies have not been able to reduce the cost of delivering per Mbyte of data to the end user to a level where GSM mobile operators can compete with the alternative technologies for a profitable business growth.

To enhance the competitiveness of UMTS new technological evolution for UMTS called HSDPA (High Speed Downlink Packet Access) has been standardized within 3GPP in release 5. HSDPA is to UMTS as EDGE is to GSM; a technology which acts as an upgrade to existing infrastructure, enhancing network performance without the CAPEX burden of overlaying an entirely new radio network. HSDPA provides a two-fold improvement in network capacity and boost data speeds up to 14Mbps/user. End user speeds of 2Mpbs are expected to be achievable - even higher under optimal network conditions. Shorter network latency and better response times are also enabled by the technology upgrade, allowing time-dependent applications, like live video streaming and multi-player gaming, to perform more effectively.

HSDPA will enable the mobile operators to:

- reduce costs / MByte by up to factor 2
- create rich and attractive new services for lucrative end-user segments
- unleash UMTS business to achieve its full potential
- counter the mobile operators using cdma 2000 EV-DO technology
- counter emerging access technologies like 802.xx and service provider using such technologies
- position as a mobile DSL Service Provider
- provide truly converged voice and data solution to the end user using single device anytime, anywhere

II. SYSTEM MODEL

Multiple-input multiple-output (MIMO) links exploit the spatial dimension and antenna arrays at both ends of a link to transmit multiple parallel streams in the same time and frequency channel [3,4]. The result is an extraordinary bandwidth-efficient approach to wireless communication, especially in multi-path environments. The figure below shows the general architecture used for MIMO.

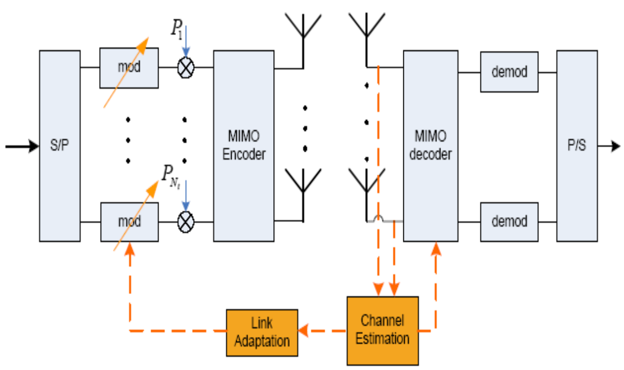

Fig1: Block diagram of MIMO System

The link adaptation is used to set the changes in the transmitter and modulator(AMC) depending up on channel condition which varies instantaneously with traffic and atmospheric conditions.

For Example, We consider the MIMO system with M transmit antennas and P receive antennas. It is assumed that the channel coherence bandwidth is larger than the transmitted signal bandwidth so that the channel can be considered as narrowband or flat fading. Furthermore, the channel is assumed to be stationary during the communication process of N symbols. The baud rate sampled received signal at receive antenna p can be written as

$$\mathbf{y}(k) = \mathbf{Hm}\ \mathbf{s}(k) \qquad (1)$$

where k is the symbol index, h,m is the complex-valued narrowband channel coefficient connecting transmit antenna m to receive antenna s(k) is the k^{th} transmitted symbol from transmit antenna m that takes value from the binary phase shift keying (BPSK) symbol set {−1, +1}, and np(k) is the complex-valued additive white Gaussian noise (AWGN) with $E[|np(k)|^2] = 2\sigma^2 n$.

The overall system can be described by the well-known MIMO channel equation as

$$\mathbf{y}(k) = \mathbf{H}\ \mathbf{s}(k) + \mathbf{n}(k), \qquad (2)$$

where $\mathbf{n}(k) = [n1(k)\ n2(k) \cdot\cdot\cdot\ nP\ (k)]^T$, $\mathbf{s}(k) = [s1(k)\ s2(k) \cdot\cdot\cdot\ sM(k)]^T$ is the transmitted symbols vector, $\mathbf{y}(k) = [y1(k)\ y2(k) \cdot\cdot\cdot\ yP\ (k)]^T$ is the received signal vector and **H** is the P ×M channel matrix with **H**(p,m) = hp,m.

In an AWGN (Additive White Gaussian Noise) channel the BER decreases (for various codes and modulation schemes) exponentially with the SNR . However, the average BER in a Rayleigh fading channel decreases only linearly with SNR. This indicates the severe degradation in performance caused by Rayleigh fading. This degradation can be partly mitigated by using multiple antennas at the transmitter and the receiver. For example if M antennas are used at the transmitter and P at the receiver, one can achieve the BER decay at a rate $SNR^{(-MP)}$ (called a diversity order of (M P) ([3], [4]. If the transmitter has CSI, even if not exact, it can be exploited to obtain further reduction of BER [2], [3], [4]. But the diversity order remains M P . It is generally believed to be the maximal diversity order one can achieve for a Rayleigh fading channel.

In the proposed scheme of MIMO transmissions, blind scheme depends only on the observation vector y(k) over a relative short length N of transmitted data sequence to perform joint data and channel estimation. Let us define the P × N matrix of received data and the corresponding M × N matrix of transmitted data as

$$\mathbf{Y} = [\mathbf{y}(1)\ \mathbf{y}(2) \cdot\cdot\cdot\ \mathbf{y}(N)] \qquad (3)$$

and

$$\mathbf{S} = [\mathbf{s}(1)\ \mathbf{s}(2) \cdot\cdot\cdot\ \mathbf{s}(N)]\ , \qquad (4)$$

respectively. Then the probability density function of the received signal matrix **Y** conditioned on the MIMO channel matrix **H** and the transmitted data matrix **S** can be written as

$$P(y/H,s)=\frac{1}{\left(2\pi\sigma_n^2\right)^N P^e}-\frac{1}{2\sigma_n^2}\sum_{k=1}^{N}\left\|y(k)-Hs(k)\right\|^2 \quad (5)$$

The estimation of the transmitted symbols **S** and the MIMO channel matrix **H** can be obtained by maximizing p(**Y**|**H**, **S**) over **S** and **H** jointly. Equivalently, the joint estimation can be obtained by minimizing the following cost function

$$J(s^\wedge, H^\wedge)=\frac{1}{P\times N}\sum_{k=1}^{N}\left\|y(k)-Hs(k)\right\|^2 \quad (6)$$

Namely , the joint channel and data estimation is obtained as

$$(s^\wedge, H^\wedge)=\arg\{\min_{s^\wedge\cdot H^\wedge} J(s^\wedge, H^\wedge)\} \quad (7)$$

Blind joint data and channel estimation for MIMO channels has an inherent permutation and scaling ambiguity problem. Scaling ambiguity refers to the fact that the detected data and the estimated channel matrix columns can only be resolved with a complex-valued factor. This scaling factor depends on the modulation scheme, and in the case of BPSK modulation, it takes the values from {+1,−1}.

One way of resolving this ambiguity is to employ a few pilot training symbols in Semi-Blind Channel estimators [**SBCE**] . We can further exploit this training to provide an initial channel estimate. This naturally leads to a semi-blind scheme, which also reduces the computational complexity considerably, in comparison with the pure blind technique. The proposed semi-blind method follows exactly the same methodology of the blind scheme , except that it uses a few pilot training symbols to initialize prior estimation. The least mean square estimated channel matrix is given as

$$\overline{H}_{LSCE}=Y_t S_t^H\left(S_t S_t^H\right)^{-1} \quad (8)$$

The proposed semi-blind method requires less computational complexity than the blind one and the number of training symbols N_T required is very small, as will be demonstrated in the simulation example.

a) Design considerations

In this section we present different channel estimators belonging to Space time coding and Spatial Multiplexing. We evaluate the combined effect of these estimators with semi-blind scheme to improve the BER of the system by utilizing Adaptive Modulation and Coding in the transmitting side. The estimators below are designed with both transmitter and receiver diversity i,e 2X2 MIMO for Rayleigh fading with BPSK modulation.

b) Design considerations:

We consider a fixed input sequence { $x_1,x_2,x_3,\ldots x_n$ }such as x_1 in the first time slot, x_2 in the second time slot, and so on and if we transmit successive symbols in the respective time slots we require only n/2 time slots .

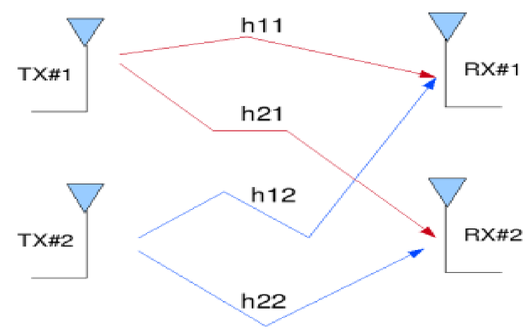

Fig2: 2×2 MIMO channel

The channel experience by each transmit antenna is independent from the channel experienced by other transmit antennas. For the i^{th} transmit antenna to j^{th} receive antenna, each transmitted symbol gets multiplied by a randomly varying complex number $h_{j,i}$. As the channel under consideration is a Rayleigh channel, the real and imaginary parts of $h_{j,i}$. are Gaussian distributed having mean $\mu_{hj,i}$ = 0 and variance $\sigma^2_{hj,i}$ =1/2 . On the receive antenna, the noise n has the Gaussian probability density function with

$$P(n)=\frac{1}{\sqrt{2\pi\sigma^2}}e^{\frac{-(n-\mu)^2}{2\sigma^2}} \quad (9)$$

with μ = 0 and $\sigma^2=\frac{N_0}{2}$.

The matrix representation of the MIMO is given as:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix}=\begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}+\begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (10)$$

Equivalently,

$$y = Hx + n \qquad (11)$$

To solve for x, we know that we need to find a matrix W which satisfies WH = I.

$$W = \left(H^H H\right)^{-1} H^H . \qquad (12)$$

Where,

$$H^H H = \begin{bmatrix} h^*_{1,1} & h^*_{2,1} \\ h^*_{1,2} & h^*_{2,2} \end{bmatrix} \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} = \begin{bmatrix} |h_{1,1}|^2 + |h_{2,1}|^2 & h^*_{1,1}h_{1,2} + h^*_{2,1}h_{2,2} \\ h^*_{1,2}h_{1,1} + h^*_{2,2}h_{2,1} & |h_{1,2}|^2 + |h_{2,2}|^2 \end{bmatrix}$$

c) BER for ZF equalizer:

In ZF equalizer the off diagonal terms in the matrix [$H^H H$] are non zero ,so that the interference caused by other input symbols is nullified. The channel for transmitting symbol from each spatial dimension (space is antenna) is a like a 1×1 Rayleigh fading channel. Hence the BER for 2×2 MIMO channel in Rayleigh fading with Zero Forcing equalization is same as the BER derived for a 1×1 channel in Rayleigh fading. The bit error rate is derived as,

$$P_b = 1/2\left(1 - \sqrt{\frac{E_b / N_0}{E_b / N_0 + 1}}\right) \qquad (13)$$

d) BER for ZF-SIC:

Using ZF equalization approach described above, the receiver can obtain an estimate of the two transmitted symbols x_1, x_2 , i.e.

$$\begin{bmatrix} \bar{x}_1 \\ \bar{x}_2 \end{bmatrix} = \left(H^H H\right)^{-1} H^H \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} . \qquad (14)$$

Take one of the estimated symbols (for example $\bar{x}_2$) and subtract its effect from the received vector y_1 and y_2, i.e.

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} y_1 - h_{1,2}\bar{x}_2 \\ y_2 - h_{2,2}\bar{x}_2 \end{bmatrix} = \begin{bmatrix} h_{1,1}x_1 + n_1 \\ h_{2,1}x_1 + n_2 \end{bmatrix} \qquad (15)$$

it is represented as $r = hx_1 + n$

The above equation is same as equation obtained for **receive diversity** case in which equalization symbol is given as:

$$\bar{x}_1 = \frac{h^H r}{h^H h} \qquad (16)$$

e) BER for ZF SIC with Optimal ordering

The received power at the both the antennas corresponding to the transmitted symbol x_1 is

$$Px_1 = |h_{1,1}|^2 + |h_{2,1}|^2 . \qquad (17)$$

The received power at the both the antennas corresponding to the transmitted symbol x_2 is,

$$Px_2 = |h_{1,2}|^2 + |h_{2,2}|^2 . \qquad (18)$$

If $Px_1 > Px_2$ then the receiver decides to remove the effect of $\bar{x}_1$ from the received vector y_1 and y_2 and then re-estimate $\bar{x}_2$.

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} y_1 - h_{1,1}\bar{x}_1 \\ y_2 - h_{1,2}\bar{x}_1 \end{bmatrix} = \begin{bmatrix} h_{1,2}x_2 + n_1 \\ h_{2,2}x_2 + n_2 \end{bmatrix} \qquad (19)$$

it is represented as

$$r = hx_2 + n \qquad (20)$$

f)BER for MMSE SIC with and without Optimal ordering.

Using the MMSE equalization, the receiver can obtain an estimate of the two transmitted symbols x_1, x_2, i.e.

$$\begin{bmatrix} \bar{x}_1 \\ \bar{x}_2 \end{bmatrix} = \left[H^H H + N_0 I\right]^{-1} H^H \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} . \qquad (21)$$

(i) With out optimal ordering: The receiver arbitrarily takes one of the estimated symbols, and subtracts its effect from the received symbol y_1 and y_2. Once the effect of $\bar{x}_2$ is removed, the new channel becomes a receiver diversity like SIMO.

(ii)With optimal ordering: whether we should subtract the effect of $\bar{x}_1$ first or $\bar{x}_2$ first, we find the transmit symbol which came at higher power at the receiver. The received power at the both the antennas corresponding to the transmitted symbols x_1 and x_2 are with reference to 12 and 13 respectively.

III. HIGH SPEED DOWNLINK PACKET ACCESS (HSDPA)

3G HSDPA High Speed Downlink Packet Access is an upgrade to the original 3G UMTS cellular system (3.5G) that provides a much greater download speeds for data. With more data being transferred across the downlink than the uplink for data centric applications, the upgrade to the downlink was seen as a major priority. Accordingly 3G UMTS HSDPA was introduced into the 3GPP standards as soon as was reasonably possible, the uplink upgrades following on slightly later. 3G UMTS HSDPA significantly upgrades the download speeds available, bring mobile broadband to the standards expected by users. With more users than ever using cellular technology for emails, Internet connectivity and many other applications, HSDPA provides the performance that is necessary to make this viable for the majority of users. [6][7] With the implementation of HSDPA, this technology can coexist on the same carrier as the current Release'99 WCDMA services.

The typical and theoretical data rates which are achieved with different technologies are shown below:

SYSTEM	GSM	GPRS	EDGE	3G (R99)	HSDPA
Typical max. data rate (kbit/s)	9.6	50	130	384	2048 (or more)
Theoretical max. data rate (kbit/s)	14.4	170	384	2048	14400

International Mobile Telecommunications-2000 (IMT-2000), better known as 3G or 3rd Generation, is a family of standards for mobile telecommunications fulfilling specifications by the International Telecommunication Union, which includes UMTS, and CDMA2000. The IMT-2000 third generation mobile standard enables mobile users to harness the full power of the Internet through efficient high-speed radio transmission, optimised for multimedia communications. The comparison and the upgrade of HSDPA with the 3G technology is shown below:

All the 3G standards has many benefits such as delivering high speed data:

- Up to 2 Megabits / second (indoors)
- Up to 384 kilobits / second (outdoors)
- Networks likely to be IP based
- Global roaming via terrestrial and satellite
- Customised services "Virtual Home Environment"

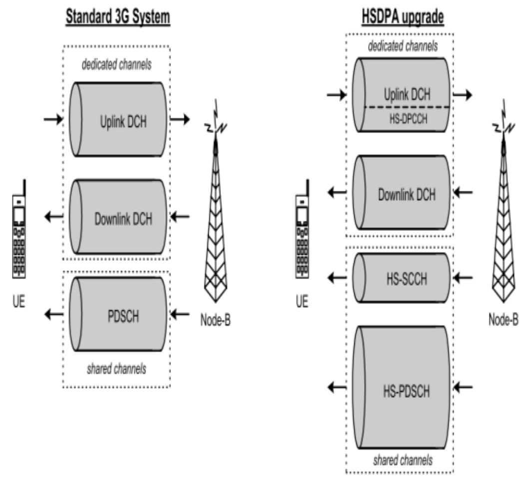

Fig3. 3rd GENERATION TECHNOLOGY

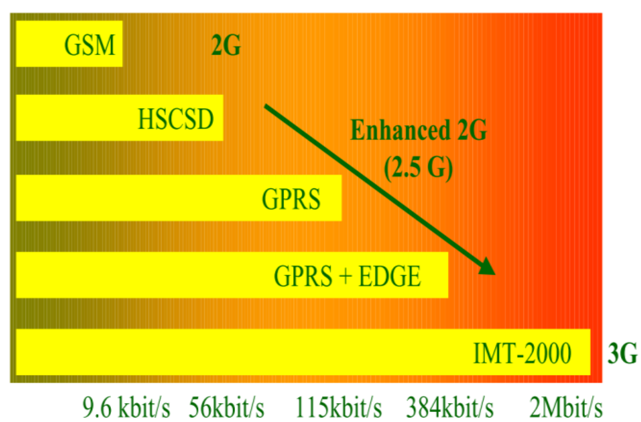

Fig4. Evolution of the 3rd generation technology:

a) HSDPA PRINCIPLE

HSDPA is based on different technological combinations. The major change in HSDPA than compare to the traditional telecommunication system is the introduction of new transmission channels for the user data, the High Speed (Physical) Downlink Shared Channel, HS-(P) DSCH. The air interface resources available on this channel is shared by multiple users. In

Node B there is an intelligent algorithm which decides the subscriber for the reception of the data packet at the desired time. This decision is reported to the subscribers via a parallel signalling channel, the High Speed Shared Control Channel, HSSCCH. In contrast to UMTS, where a new data packet can be transmitted at least every 10 ms, with HSDPA data packet transmission can occur every 2 ms.

Another major improvement in HSDPA is the use of an Adaptive Modulation and Coding (AMC) procedure. The messages regarding the channel quality is regularly sent by every subscriber to the Node B. Now the Node B selects a suitable modulation (QPSK and/or 16 QAM) and coding for the data packet, depending on the quality of the mobile radio channel, that offers suitable protection against transmission errors and that optimizes the use of resources on the air interface. The Node B can select from the modulation methods QPSK (Quadrature Phase Shift Keying) and 16QAM (Quadrature Amplitude Modulation). While QPSK is already being used in UMTS release 99, 16QAM provides high data rates specifically for HSDPA but also has high error rates than compared to QPSK.In order to achieve robust error free data transmission, HSDPA uses a protocol called HARQ (Hybrid Automatic Repeat Request). If a User Equipment (UE) receives a data packet with errors, it requests the data packet to be transmitted again. When the packet transmission is sent again, the Node B can select a different coding version that provides the subscriber with better reception of the packet (incremental redundancy). This coding version is often referred to as “redundancy and constellation version” or in short “redundancy version” (RV version).

b) HSDPA ARCHITECTURE:

The figure below illustrates the HSDPA architecture for both UE and the network

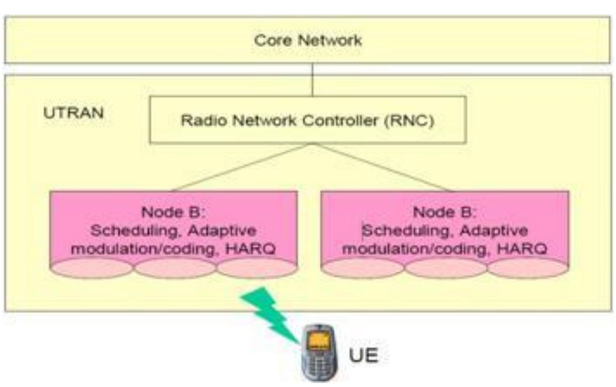

Fig5. ARCHITECTURE

c) MAC- hs:

In the Release 99 UTRAN architecture, the radio network controller (RNC) performs the scheduling and transport-format selections. Therefore for HSDPA, it is advantageous to move parts of the functionality from RNC to node B, thus forming a new Node B entity, MAC-hs. The responsibilities of MAC-hs are as follows:[13]

- Handling Scheduling
- HARQ
- Transmit Format (TF) Selection

Apparently, the Node B needs some upgrading to get enabled and use the different MAC-hs functionalities. There is one MAC-hs entity in the UTRAN for each cell supporting HS-DSCH. The transmission of data on the HS-DSCH is handled by the MAC-hs entity in the UTRAN. Furthermore, it is responsible for managing the physical resources allocated to HSDPA. MAC-hs receive configuration parameters from the higher layers.[13]

The functional entities included in MAC-hs are shown in the figure below:

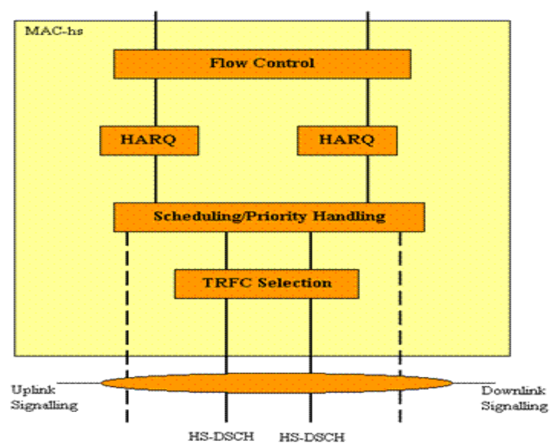

Fig6. MAC Layer

- **Flow control**: This is the companion flow control function to the flow control function for existing dedicated, common, and shared channels in RNC. This function is employed to limit layer 2 signaling latency and reduce discarded and retransmitted data as a result of HS-DSCH congestion.[13]
- **HARQ**: One HARQ (Hybrid Automatic Repeat Request) entity handles the hybrid

ARQ functionality for one user. One HARQ entity is capable of supporting up to eight HARQ processes of stop-and-wait HARQ protocols. [13]

- **Scheduling/Priority handling**: This function manages HS-DSCH resources between HARQ entities and data flows according to their priority. [13]
- **TFRC selection**: This is to select an appropriate transport format and resource combination (TFRC) for the data to be transmitted on HSDSCH.

IV. HSDPA in WCDMA UMTS

HSDPA is basically based on three different techniques. Out of which the most important one which enables data rates up to 10Mbps in the downlink is the fast link adaptation provided by the use of Adaptive Modulation and Coding (AMC). Fast Hybrid Automatic Repeat ReQuest (HARQ) mechanisms and fast scheduling facilitates support the efficient usage of the radio resources in adaptation to the instantaneous channel conditions and network loading. These techniques for the HSDPA are described in detail below.

HSDPA was designed to increase downlink packet data throughput of UMTS by means of different technical aspects behind the HSDPA concept which include:

1. Shared channel transmission

2. Adaptive Modulation and Coding (AMC)

3. Fast Hybrid Automatic Repeat Request (H-ARQ)

4. Fair and fast scheduling at Node B

5. Fast cell site selection (FCSS)

6. Short transmission time interval (TTI)

a) SHARED CHANNEL TRANSMISSION

Several new channels are introduced in the release 5. A new transport channel named High-Speed Downlink Shared Channel (HS-DSCH) is the primary radio bearer. For the associated signalling a channel called high-speed shared control channel (HS-SCCH) has been added in the downlink and in the uplink. The three new channels associated to the HSDPA structure are discussed in detail below:

b) HS-(P) DSCH Structure

The HS-PDSCH channel is one of the mapped physical channel by the HS-DSCH transport channel. This channel can map on one or more physical channels this type. The HS-PDSCH is always spread with spreading factor 16. One HS-DSCH transport block is transmitted in a transmission time interval (TTI) of 2 ms corresponding to 3 timeslots. The HS-DSCH transport blocks can be scheduled to the UE continuously if the user equipment allows it to do so, i.e. in every Transmission Time Interval or TTI. Less complex UEs corresponding to a lower UE category can only process data received in every second or even every third TTI. This is described by the so-called inter TTI distance parameter.[10][12][15]

An inter Transmission Time Interval distance of 1 equals continuous HS-PDSCH transmission in the case if data is available for transmission through the channel. QPSK or 16QAM are available as modulation scheme on the HS-PDSCH. Figure outlines the structure of the HS-(P) DSCH.

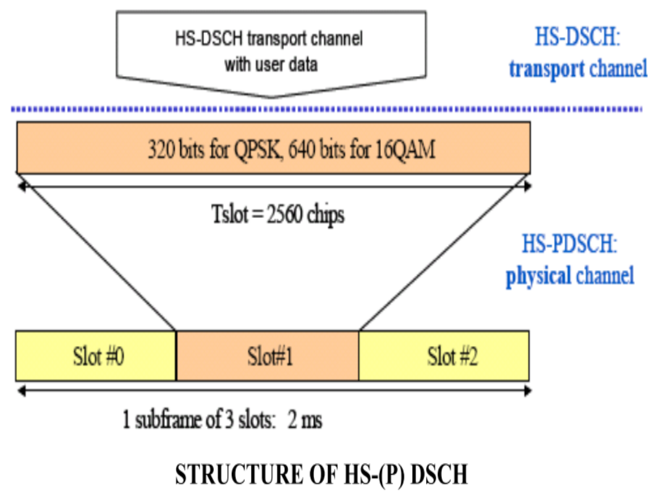

Fig7. Structure of HS-DSCH

c) HS-SCCH Structure

The HS-SCCH is the second important channel introduced in HSDPA, it is also called as a fixed rate downlink physical channel, spread with spreading factor of 128 unlike the previous mentioned channel above. A single User Equipment has to monitor up to 4 HS-SCCH channels. HSPDSCH modulation scheme information, transport block size information, HARQ process information, redundancy and constellation version, new data indicator. The figure for the HS-SCCH structure is shown below:

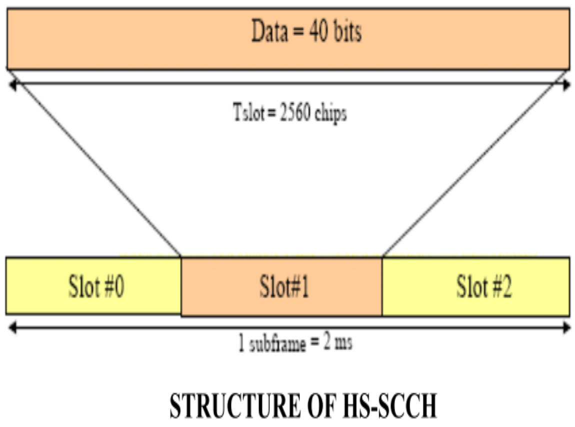

Fig8. Structure of HS-SCCH

The HS-PDSCH starts 2 timeslots after the start of the corresponding HSSCCH.

d) HS-DPCCH Structure

The HS-DPCCH is the third new channel introduced in the HSDPA architecture, this serves as an uplink physical channel which is used to carry control information such as, HARQ ACK/NACK and Channel Quality Information. The figure shown below outlines the structure of the HS-DPCCH.

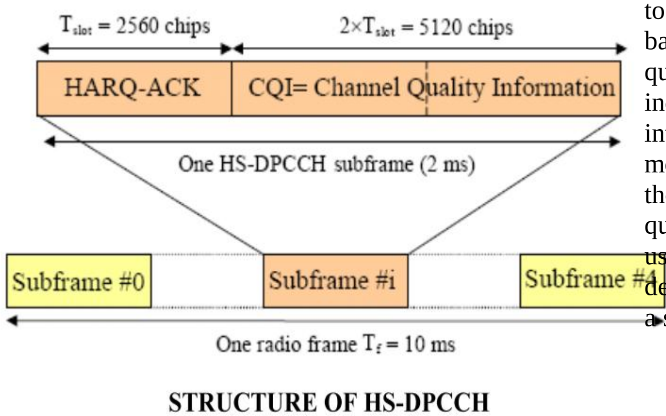

Fig9. Structure of HS-DPCCH

The Channel Quality Information consists of a CQI value. There are different CQI tables specified for different UE categories, reflecting the level of UE implementation complexity. The CQI values regularly reported by the UE are interpreted by the Node B as proposal how to format the HS-(P) DSCH. With this format, the resulting block error rate of the HS-DSCH is predicted by the UE to be below 0.1. The higher the CQI value, the more demanding the HS-DSCH transmission format, i.e. the better the radio link quality has to SDPA uses both the modulation techniques which are used in WCDMA, namely Quadrature Phase Shift Keying (QPSK) and under good radio conditions, an advanced modulation scheme, 16 Quadrature Amplitude Modulation (16 QAM). The benefit of 16 QAM is that four bits of data are transmitted in each radio symbol as opposed to two with QPSK. 16 QAM increases data throughput, while QPSK is available under adverse conditions. 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 is error correcting bits. The process of selecting and quickly updating the optimum modulation and coding rate is referred to as fast link adaptation.

V. QUADRATURE PHASE SHIFT KEYING (QPSK)

Sometimes known as quaternary or quadriphase PSK, 4-PSK, QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with Gray coding to minimize the BER twice the rate of BPSK. Analysis shows that this may be used either to double the data rate compared to a BPSK system while maintaining the bandwidth of the signal or to maintain the data-rate of BPSK but halve the bandwidth needed. Although QPSK can be viewed as a quaternary modulation, it is easier to see it as two independently modulated quadrature carriers. With this interpretation, the even (or odd) bits are used to modulate the in-phase component of the carrier, while the odd (or even) bits are used to modulate the quadrature-phase component of the carrier. BPSK is used on both carriers and they can be independently demodulated. The modulated signal is shown below for a short segment of a random binary data stream.[2]

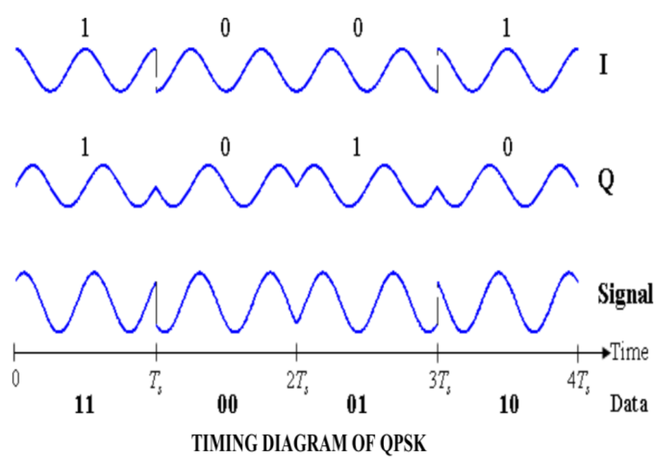

Fig10. Timing Diagram of QPSK

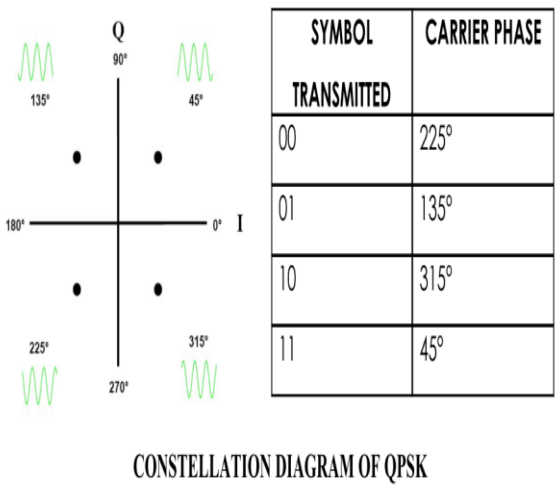

Fig11. Constellation Diagram of QPSK

a) ADAPTIVE CODING

Coding is the important mechanism in the physical channels of HSDPA such that error free transmission and robust transmission of data can take place to and from the user equipment. The HSDPA coding is based on the release 99, 1/3 turbo coding, the major criteria in this coding technique is the rate matching i.e.., puncturing od repetition of codes. The effective code rate is given as 1/4 – 3/4, which is theoritically 1/6 – 0.98. The coding mechanism is dynamically based on the quality of the radio link.[8]

Multiplexing and channel coding defines that the rate 1/3 turbo coding shall be used for HS-DSCH channel coding. In the following rate matching uses puncturing or repetition effective coding rates other than 1/3. [8]

Varying the code rate, the number of bits per code (and so the throughput) can be increased at the expense of reduced coding gain. The better the radio interface quality (Ec/Io) the higher the possible coding. [8]

b) FAIR AND FAST SCHEDULING AT NODE B

It allows the HS-DSCH channel to take advantage of favourable channel conditions to make best use of available radio conditions. Each UE periodically reports on the signal quality to Node B (Base Stations). That information is then used to decide which users will be sent data on the next 2ms frame and how much data can be sent to each user. A first approach for fair scheduling can be Round-Robin method where every user is served in a sequential manner so all the users get the same average allocation time. However, the requirement of high scheduling rate along with the large AMC availability with the HSDPA concept, where the channel is allocated according to the instantaneous channel conditions. Another popular packet scheduling is proportional fair packet scheduling. Here, the order of service is determined by the highest instantaneous relative channel quality. Since the selection is based on relative conditions, still every user gets approximately the same amount of allocation time depending on its channel condition. [10][12][15]

c) FAST HYBRID AUTOMATIC REPEAT REQUEST (H-ARQ)

Some data will inevitably be corrupted in transit to the device and will have to be retransmitted. With HSDPA, data retransmission may be handled “locally” by the base station improving response times compared to earlier UMTS networks (where only the more distant RNC could manage data retransmissions). HSDPA employs a “stop and wait hybrid automatic repeat request” (SAW HARQ) retransmission protocol between the base-station and the user device. With HARQ, each device checks the integrity of its received data in each relevant HS-DSCH TTI. If the data is correct, the device returns an “ACK” (acknowledging receipt of correct data) signal, in which case the base-station can move on to the next set of data. If the data is not successfully received, the device transmits an “NACK” (negative acknowledgement) and the base-station retransmits the corresponding data. With “soft combining” at the user device, the earlier set(s) of corrupted data can be combined with subsequently retransmitted data to increase the likelihood of correctly decoding valid data. [10][12][15]

The AMC uses an appropriate modulation and coding scheme according to the channel conditions. Even after AMC, we may land up with errors in the received packets due to the fact that the channel may vary during the packet is on the fly. An automatic repeat request (ARQ) scheme can be used to recover from these link adaptation errors. When the transmitted packet is received erroneous then the receiver requests the transmitter for the retransmission of that erroneous packet. The basic technique is to use the energy of the previously transmitted signal along with the new retransmitted signal to decode the block. There are two main schemes for H-ARQ, Chase combining and Incremental redundancy.

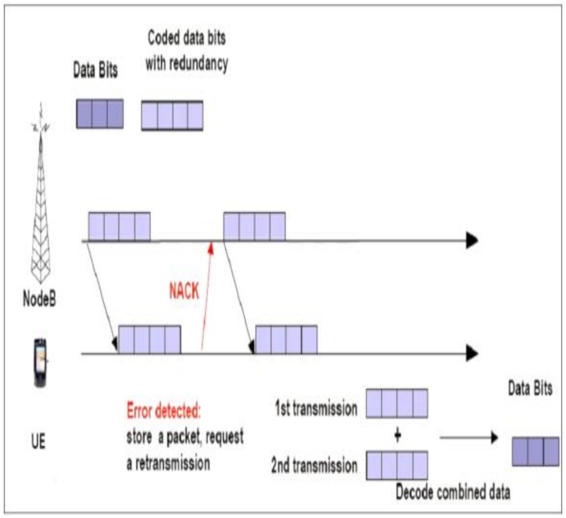

Fig12. CHASE COMBINING SCHEME

Incremental Redundancy is used to get maximum performance out of the available bandwidth. Here the retransmitted block consists of only the correction data to the original data that carries no actual information (Redundancy). The additional redundant information is sent incrementally when the first, second retransmissions are received with errors. It is advantageous as it reduces the effective data throughput/ bandwidth of a user and using this for another user. The main disadvantages are the systematic bits are only sent in the first transmission and not with the retransmission which makes the retransmissions non-self decodable. So, if the first transmission is lost due to large fading effects there is no chance of recovering from this situation. [10][12][15]

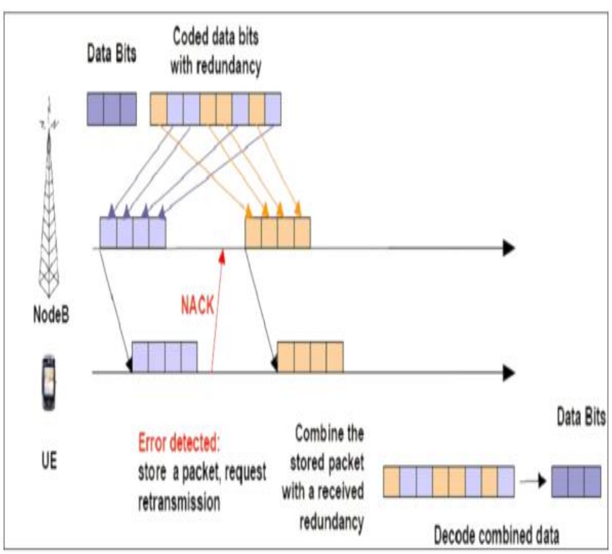

Fig 13. Incremental Redundancy

Although the HSDPA standard supports both chase combining and incremental redundancy, it has been shown that incremental redundancy performs almost always better than chase combining, at the cost of increased complexity, though.

d) FAST CELL SITE SELECTION (FCSS)

HSDPA does not use soft handover. This is because the AMC, H-ARQ and fast packet scheduling are techniques that require a constant one-to-one connection between the HSDPA mobile terminal and the BS. Thus hard handover, in which the destination BS is selected each time the cell changes, is needed. Since the only traffic supported by HSDPA is delay-tolerant data traffic soft handover is also not as necessary as when dealing with voice traffic. [10][12][15]

e) SHORTER TRANSMISSION TIME

The shorter time interval enables higher speed transmission in the physical layer, so that the system will be more reactive to changing link conditions and can reallocate capacity to users quicker. The details furnished so far gives the clear picture of HSDPA technology which is also termed as 3.5G or Turbo 3G. With many number of benefits in HSDPA, this technology will replace the current technologies such EDGE and GPRS. As mentioned above in the previous pages, HSDPA technology has number of key enhancements without which this technology would not work. From the various enhancements of this technology, my objective to work on will be the Adaptive Modulation and Coding (AMC) mechanism in HSDPA. AMC is the major and important part of the HSDPA as the higher data rates which are supposed to be the key advantage of HSDPA depends on this mechanism. The reason behind choosing this objective is because of its various advantages in the field of HSDPA. AMC is considered to be the heart of HSDPA technology as without which the high data rates would not be possible. The two main adaptive modulation techniques, which are used in HSDPA, and on which I will be working throughout the completion of my project are:

- Quadrature Phase Shift Keying (QPSK)
- 16 Quadrature Amplitude Modulation (16 QAM)

These two techniques are used in HSDPA under the variations of the radio conditions.

The simulation of these techniques can be done under many simulating software. I would be working on MATLAB latest version to simulate the above techniques. The selection of MATLAB simulator is because it is environment friendly. The details of this simulator is given in the methodology section later in this report.

VI. SIMULATION RESULTS

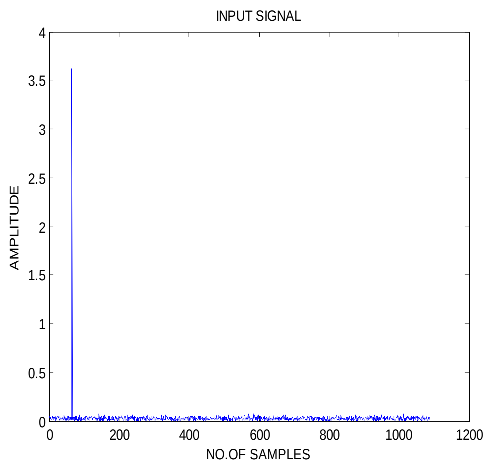

Fig14. Input Signal

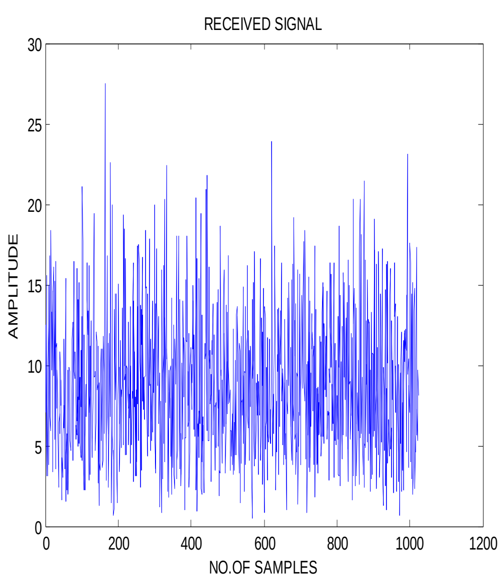

Fig15. Received Signal

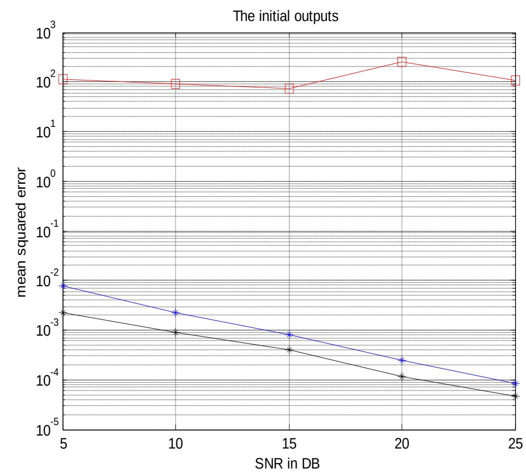

Fig16. SNR vs MSE without I/Q

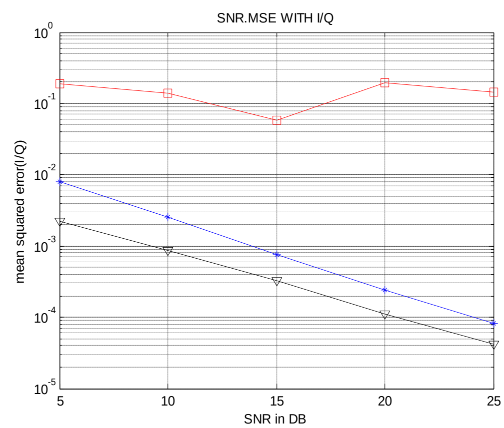

Fig17. SNR vs MSE with I/Q

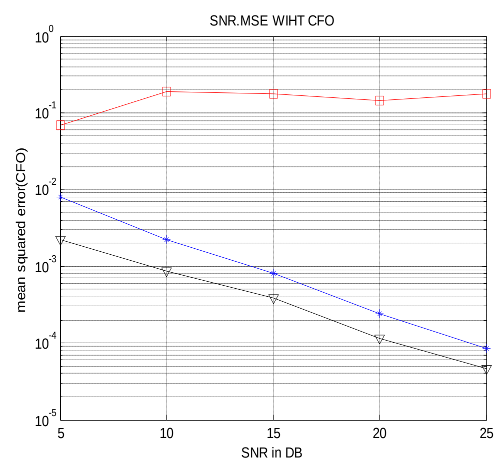

Fig18. SNR vs MSE with CFO

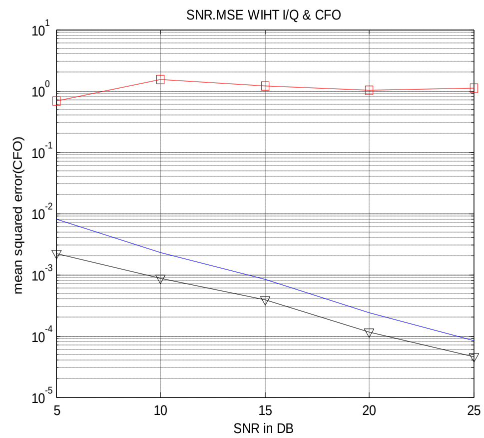

Fig19. SNR vs MSE with I/Q and CFO

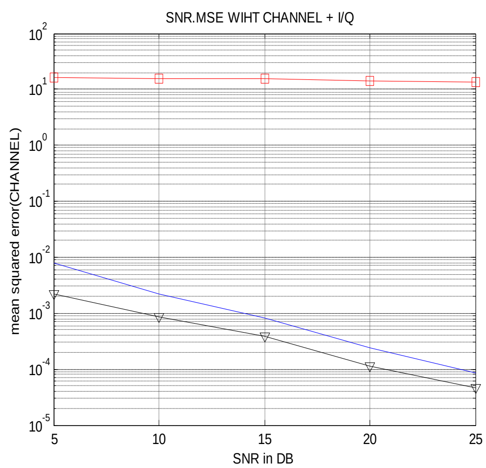

Fig20. SNR vs MSE with Channel and I/Q

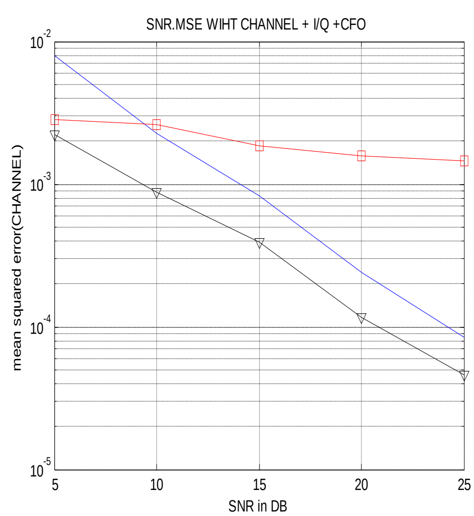

Fig21. SNR vs MSE wih channel , I/Q, CFO

VII.CONCLUSION

The details furnished in this report gives the clear picture of HSDPA technology and its important characteristics. By, now the I have studied the major part of HSDPA and its enhanced technologies using which the working of HSDPA is taken into consideration. As, already mentioned HSDPA has various advantages which will overcome the difficulties/disadvantages in the technologies which are already into existence such as GPRS and EDGE. These technologies were developed for the 2nd Generation of the mobile communications. HSDPA has many advantages when compared to these 2G technologies. The main and the important improvement/benefit from HSDPA is the high data rates which are not possible in the either of the two mentioned above. Theoretically HSDPA cal allow up to 14Mbps of downlink data, which is the key benefit of this technology. Out of the six enhancements given earlier in this report, the Adaptive Modulation and Coding is the important technique used in HSDPA which is used for the production of high data rates. This technique uses two types of modulations depending on the variations of the radio link.

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