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Analysis of the effect of Modulation Techniques, Spreading Codes and Turbo Codes for HSDPA under Different Channel Conditions

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ABSTRACT: *HSDPA (High Speed Downlink Packet Access) is gaining popularity because of its capability of delivering higher data rate transmission with minimum latency then the GSM (global system for mobile communications) and 2.5G GPRS (general packet radio service) systems. The stated improvements are in corporated by the application of multi-codes and adaptive modulation and coding techniques combining the two in proper way gives the best data rate for the available channel conditions. The latest release of HSDPA (release 11) facilitates the selection of QPSK, 16-QAM and 64-QAM as modulation technique, orthogonal variable spreading factor (OVSF) as spreading codes and turbo codes with various code rates. Because of great impact of these factors on the selection of best data rate according to channel conditions in this paper we experimented with other available options for the modulation techniques, spreading codes and turbo codes for multipath fading channel conditions to achieve the most efficient combination for achieving the optimum data rate at particular channel conditions.*

Keywords: *W-CDMA (Wideband Code Division Multiple Access), HSDPA, Turbo Codes, Fading Channel.*

I. INTRODUCTION

HSDPA enables the provision of a high bit data rate services with increased channel capacity and provided a suitable platform for the high speed networks, at lower investment. The efficient use of radio resources is realized by the shared channel concept of HSDPA. This supports high especially bursty non real time traffic such as variable rate and packet switched data.

The initial release of HSDPA (Release 5) allow maximum data throughput of approximately 14 Mbps, which is achieved by the introduction of 16-QAM and higher code rates. These physical layer Changes are almost achievable especially for line-of- Sight (LOS) conditions. The enhance data rate in different releases of HSDPA is achieved by employing adaptive modulation and coding technique (AMC) which provides flexibility to select best modulation technique and coding rate best suitable for the channel conditions hence makes the system more robust even under adverse multipath fading conditions.

Because of enormous demand for high speed data rates services the continuous research for the further improvement of the HSDPA is required in every aspect of the system from protocol to physical layer designing. In this paper we are mainly focusing on the physical layer modifications and analyzing the impact of the various modulation techniques, spreading techniques and coding rates which can provide the useful information about the optimum selection strategy for AMC.

II. LITERATURE REVIEW

This section presents a review on the some of the most relative work in the same field. Frank Brouwer et al [1] analyzed integration of HSDPA (High-Speed Downlink Packet Access) link-level simulation results into network-level simulations for Enhanced UMTS their link-level simulation model all physical layer features of the 3GPP standards from generation of transport blocks, turbo coding, rate matching, spreading, scrambling to modulation. Similarly at the receiver side, all complementary blocks were designed, with soft-decision demodulation, and a turbo decoder using the MAP (Maximum A Posteriori) algorithm with 8 iterations. They also using fading channel model with CQI (Channel Quality Indicator) selection technique. The overall model described is accurately approximates the practical performance of HSDPA. Hermann Buddendick et al [3] presented a dynamic W-CDMA system level simulator extended to enable the simulation of packet switched services with special focus on HSDPA. The complete simulation system contains traffic sources that create sequences of packets for each active User Equipment (UE), models the protocol stack and provides the possibility to collect performance indicators, e.g. sector packet data throughput, page throughput, and packet delays, in different scenarios for offline analysis. A cross-layer design is proposed by Xin Wang et al [4] for quality-of-service (QoS) guaranteed traffic. The proposed design jointly exploits the error-correcting capability of the truncated automatic repeat request (ARQ) protocol at the data link layer and the adaptation ability of the adaptive modulation and coding (AMC) scheme at the physical layer to optimize system performance for QoS guaranteed traffic. The queuing behavior induced by both the truncated ARQ protocol and the AMC scheme is analyzed with an embedded Markov chain. Analytical expressions for performance matrics such as packet loss rate, throughput, and average packet delay are derived. Using these expressions, a constrained optimization problem is solved numerically to maximize the overall system throughput under the specified QoS constraints.TNL Congestion Control Impact on the HSDPA Performance is presented by Thushara Weerawardane et al [5].Their proposed work focuses to analyze the effect of congestion at the Iubinterface on the HSDPA performance. The 3GPP (3rd Generation Partnership Project) Rel. 5 specifications highlight two congestion detection mechanisms which are based on the frame sequence number (FSN) and the Delay Reference Time (DRT) fields of HSDPA data frame. In addition to these, a third congestion detection mechanism based of Checksum of HSDPA data frame is considered. Vasileios M. Kapinas et al [8] proposed a generalized framework for handling Multiple-Input Multiple-Output (MIMO) schemes defined within the context of the Third Generation Partnership Project (3GPP) physical layer specifications. They introduce the Transmit Matrix (TRAM) concept that can include as special cases several MIMO systems (e.g. transmit diversity, spatial-multiplexing, etc.) regardless of the presence or not of a feedback channel their approach is based on the adoption of a novel measure called Necessary Transmit Information (NTI) and on its one-to-one correspondence with the TRAM. The last allows for a convenient alternative representation of a TRAM-based MIMO system model and serves the straight forward construction of NTI-codebooks for a wide range of transmission schemes.

III. THE PHYSICAL LAYER STRUCTURE OF HSDPA

The new HSDPA Physical channels are described as:

HS-PDSCH or High Speed Physical Downlink Shared Channel: This is a downlink channel which is both time and code multiplexed. The channelization codes have a fixed spreading factor, SF = 16. Multi-code transmissions are allowed that translates to UE being assigned multiple channelization codes in the same TTI, depending on the UE capability. The same scrambling code sequence is applied to all the channelization codes that form the single HS-DSCH CCTrCH. If there are multiple UE's then they may be assigned channelization codes in the same TTI (multiplexing of multiple UE's in the code domain).

HS-DPCCH or High Speed Dedicated Physical Control Channel: This is an uplink channel that carries the Acknowledgements of the packet received on HS-PDSCH and also the CQI (Channel Quality Indication). The CQI estimates have to be transmitted by the UE every 2.0 ms frame. This information is very important as it ensures reliability and impacts power capacity.

HS-SCCH or High Speed Shared Control Channel: The HS-SCCH is a fixed rate (60 kbps, SF=128) downlink physical channel used to carry downlink signaling related to HS-DSCH transmission. This provides timing and coding information thus allowing the UE to listen to the HS-DSCH at the correct time and using the correct codes to allow successful decoding of UE data.

Adaptive Modulation and Coding (AMC): HSPDA standard ensures that highest possible data rate is achieved for all users regardless of whether they are close to the base station or far off. This is done using ACM. For HS-DSCH, the transport format, including the modulation scheme and code rate, can be selected based on the downlink channel quality. The selection of transport format is done by the MAC-HS located in Node B and is based on channel quality feedback reported by the UE. The spreading factor cannot change but the coding rate can change between 1/4 and 3/4. The higher coding rate reduces the number of errors. Also the standards support multi-codes. This means that up to 15 codes can be allocated to a UE.

Hybrid Automatic Repeat Request (HARQ): In case of ARQ, the receiving system on receipt of data checks the CRC. If the CRC is the same as that received in the message ACK is sent back to the sender. In case if CRC does not match then NACK is sent back and the packet discarded. In case of HARQ, this method of CRC checking is improved based on the following two things.

Chase Combining: In this when an error is detected in CRC, NACK is sent back but the packet is not discarded. It is stored. In case the re-transmitted packet is again erroneous then the previous and current packet is combined in an attempt to recover from errors. Each time the packet is resent, the same scheme is applied. Eventually the error will be either resolved or maximum number of retries is reached. In that case higher layer protocols will deal with the error.

Incremental Redundancy (IR): IR is similar to Chase combining but the redundant information that was not transmitted earlier is also included to improve the chances of reception without errors or with enough errors removed so as to allow combining with the previously stored packet and resolve the errors.

Fast Cell Site Selection (FCSS): When the UE moves between the cells, it is possible that it would be served by different cells. Hence the UE will construct a list of Active Set (the term Active Set is incorrect and the term that will be used eventually is "Eligible Set") Cells that it can use at any one time. The mobile will indicate on HS-DPCCH as to which one is the best cell for DL transmission. The serving cell then decides the modulation and coding scheme to be used for the mobile and in addition may code multiplex multiple mobiles within that HSDPA frame. To simplify this procedure, it is further subdivided into Intra-Node B FCS and Inter-Node B FCS.

The complete structure of the physical layer for the HSDPA is shown in figure 1. This is a downlink channel which is both time and code multiplexed. The channelization codes have a fixed spreading factor, SF = 16. Multi-code transmissions are allowed that translates to UE being assigned multiple channelization codes in the same TTI, depending on the UE capability. The same scrambling code sequence is applied to all the channelization codes that form the single HS-DSCH. If there are multiple UE's then they may be assigned channelization codes in the same TTI (multiplexing of multiple UE's in the code domain).

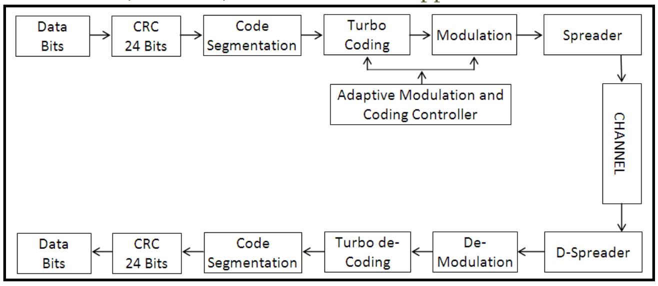

Figure 1: Block Diagram of HSDPA Physical Layer

In the first stage of the transmitter 24 bits CRC is appended to the input data after which the data is segmented into the proper block size for performing the turbo coding at the rate decided by the AMC based on the feedback which is then pass through the modulator, the modulation can be the QPSK, 16-QAM or 64-QAM which is also decided by AMC and depends upon feedback and at last the spreading is performed by using Orthogonal variable spreading factor (OVSF) with spreading factor (SF) of 16. After spreading the data is transmitted using radio waves which is then pass through the channel which produces abnormality (such as noise addition or fading, depending upon the environment conditions) on the signals pass through it. Now these signals are received at the receiver and at this end the inverse operations of transmitter side is performed to recover the data. The values used for the system are Fixed Spreading Factor of 16 for HS-DSCH, QPSK 16 QAM and 64 QAM Modulation, Static TTI Length of 3 Time Slots = 2ms, Fixed CRC of 24 bits, Error Correction using 1/3 to 3/4 Turbo Coding.

IV. TURBO CODES

The turbo codes are represents a class of high-performance forward error correction (FEC) codes initially proposed in 1993 which were the first practical implementable error control codes that achieve Shannon’s bound to within 0.5 dB of signal-to-noise ratio. Because of such capability the turbo codes are used in 3G and (space) satellite communications and other applications where reliable information transfer with bandwidth or latency constrained are required.

A turbo coder is the parallel concatenation of a number of RSC (recursive systematic convolution) coders. The number of RSC coders depends upon the required performance, complexity and overhead. The working of the coder can be visualized by the figure 2 which shows the structure of turbo coder with two RSC coders. The input to the second decoder is an interleaved (Randomly Permutated) version of the input x, thus the outputs of coder 1 and coder 2 are time displaced codes generated from the same input sequence. The input sequence is only presented once at the output (y direct passing line). The outputs of the two coders may be multiplexed into the stream hence giving a rate R=1/3 code, or they may be punctured (sequentially selected by both coders) to give a rate R=1/2 code.

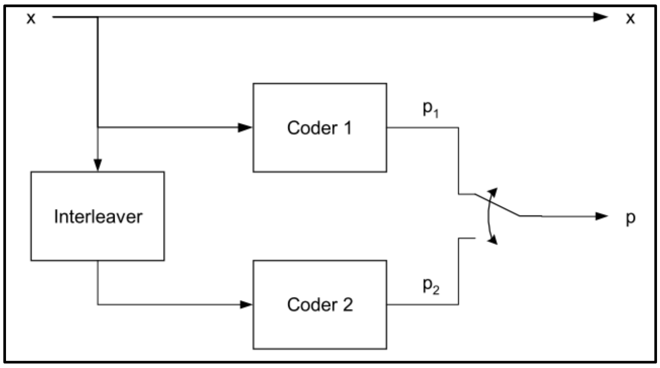

Figure 2: Structure of Turbo Encoder

Since the turbo coder is a complex combination of convolution encoder the decoding process also an extension of convolution decoder which generally utilizes two main concepts 1.Maximum A Posteriori (MAP) and 2. Soft Output Viterbi Algorithm (SOVA). MAP looks for the most likely symbol received; SOVA looks for the most likely sequence. Both MAP and SOVA perform similarly at high Eb/No. At low Eb/No MAP has a distinct advantage, gained at the cost of added complexity.

V. ORTHOGONAL VARIABLE SPREADING FACTOR (OVSF) CODES

These are the spreading codes required for the Code Division Multiple Access (CDMA) shown in figure 3, where in each transmitted signal is spread over a broad spectral range, using one of the codes from the codes set called users code. User’s codes are to be carefully chosen so that they must have mutual orthogonally.

These codes are derived from an OVSF code tree, and each user given a different, unique code. An OVSF code tree is a complete binary tree, reflects the construction of Hadamard matrices.

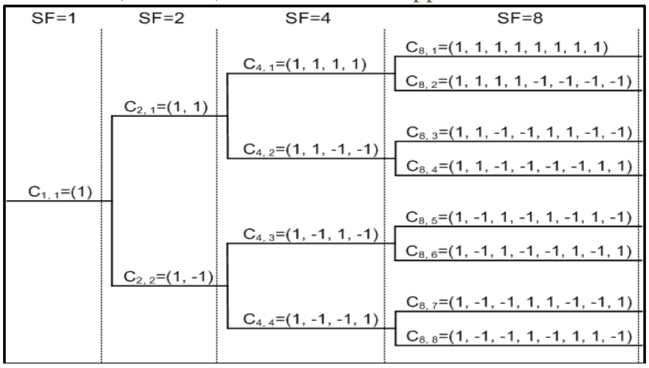

Figure 3: OVSF code tree structure

VI. SIMULATION RESULTS

For the analysis of the system performance and scope the simulation of the HSDPA is performed for different channel conditions and with different system configurations and the simulated results are presented for each scenario.

Channel Conditions: Multipath Rayleigh Fading
Number of Paths = 4
Path Gains = 0,-1,-1,-3 dB
Path Delay = 0, 1e-7, 1.5e-7, 1.2e-6 seconds
Additive Wight Gaussian SNR: Varying from -10 to 10 dB
Spreading Codes: Orthogonal Codes Arranged and Numbered in Three Different Ways as shown in table 1, 2, and 3.

Finally the simulation is performed for the 20 Physical Layer Transport Blocks (TB) and the size of TB is calculated as follows:

$$Block\ Size\ (bits) = \frac{ChipRate}{SF * \left(\frac{1}{TTI}\right)} * BitsPerSymbol * ECR * NumOfCodes$$

Where:

ChipRate = 3.84 MHz
TTI = Transmission Time Interval = 2 ms
SF (Spreading Factor) = 16
Bits Per Symbol = Depends upon Modulation technique
ECR = Effective Coding Rate = Depends upon Turbo Coder
Num of Codes = Number of Multi-codes Allowed

TABLE 1: ORTHOGONAL CODES ARRANGEMENT 1

1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1
1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1
1	1	-1	-1	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1
1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1
1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	1	1	-1	-1
1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1	1	-1
1	-1	1	-1	1	-1	1	-1	-1	1	-1	1	-1	1	-1	1

TABLE 2: ORTHOGONAL CODES ARRANGEMENT 2

1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1
1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1
1	1	-1	-1	-1	-1	1	1	-1	-1	1	1	1	1	-1	-1
1	1	-1	-1	1	1	-1	-1	-1	-1	1	1	-1	-1	1	1
1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1
1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1
1	-1	-1	1	1	-1	-1	1	-1	1	1	-1	-1	1	1	-1

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TABLE 3: ORTHOGONAL CODES ARRANGEMENT 3

1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1
1	-1	-1	1	1	-1	-1	1	1	-1	-1	1	1	-1	-1	1
1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1
1	-1	1	-1	-1	1	-1	1	1	-1	1	-1	-1	1	-1	1
1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1	1	1
1	-1	-1	1	-1	1	1	-1	1	-1	-1	1	-1	1	1	-1
1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
1	-1	1	-1	1	-1	1	-1	-1	1	-1	1	-1	1	-1	1

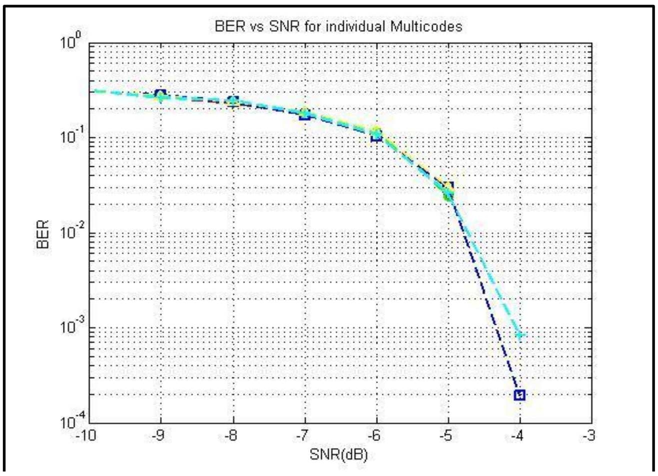

Figure 4(a): BER vs SNR plot for each user when Orthogonal Codes Arrangement 1 is used.

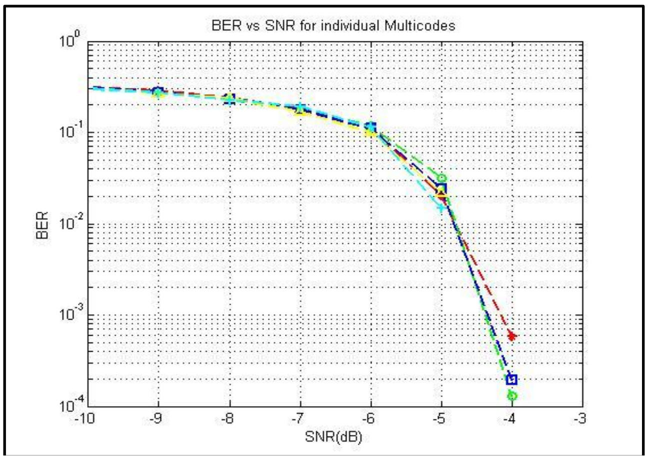

Figure 4(b): BER vs SNR plot for each user when Orthogonal Codes Arrangement 2 is used.

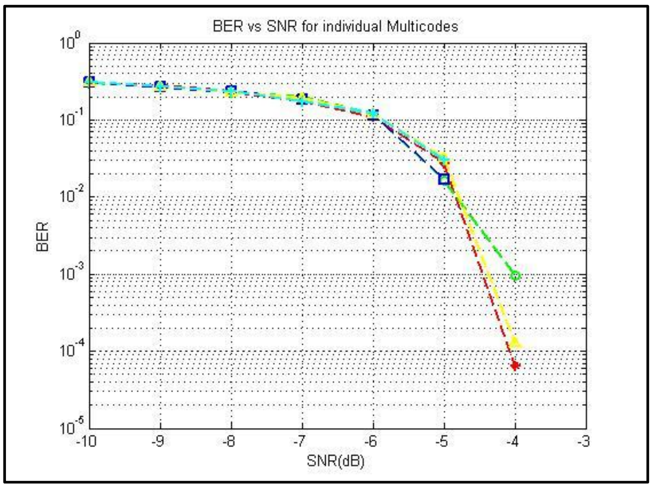

Figure 4(c): BER vs SNR plot for each user when Orthogonal Codes Arrangement 3 is used.

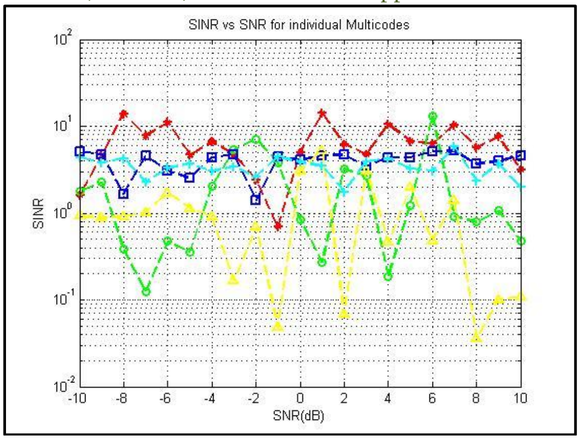

Figure 5(a): SINR vs SNR plot for each user when Orthogonal Codes Arrangement 1 is used.

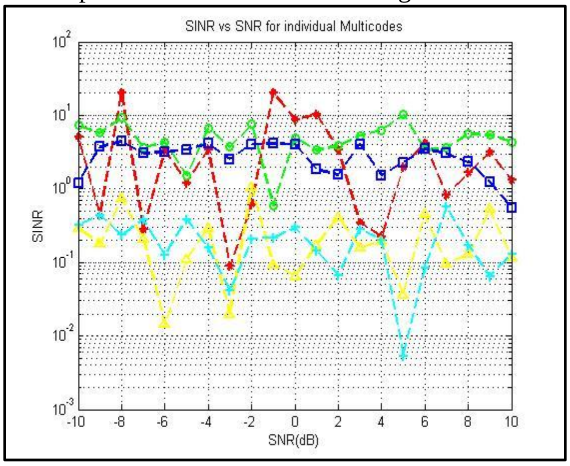

Figure 5(b): SINR vs SNR plot for each user when Orthogonal Codes Arrangement 2 is used.

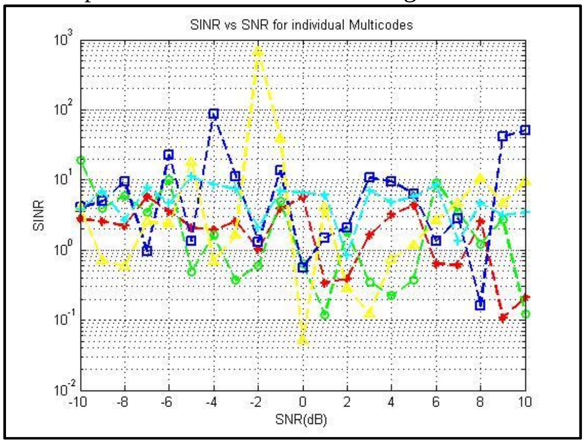

Figure 5(c): SINR vs SNR plot for each user when Orthogonal Codes Arrangement 3 is used.

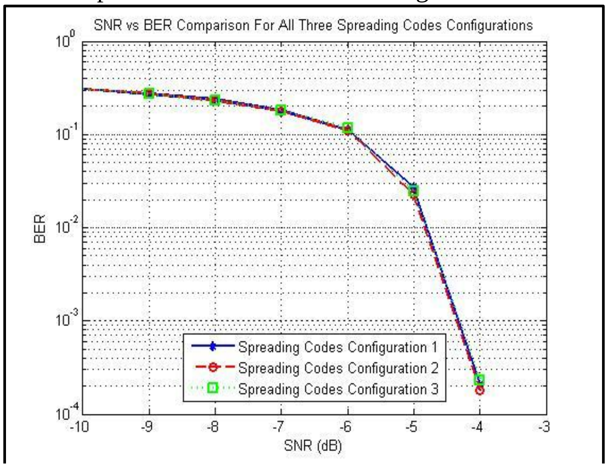

Figure 6: Average BER for all users for each configuration of orthogonal codes.

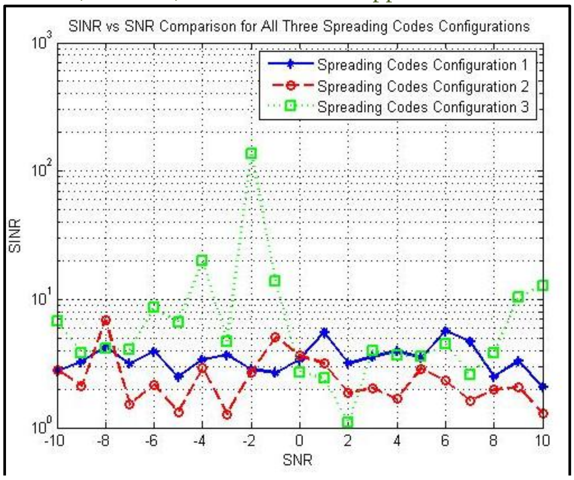

Figure 7: Average SINR for all users for each configuration of orthogonal codes.

The SNR vs BER and the SINR vs BER plot shown for each Orthogonal Codes Arrangement presents that each users BER is slightly different than others even in same operating condition this is because some combination of orthogonal codes produces less interference in fading channel conditions while others are not (as shown in figure 7 that the configuration 3 gives the best SINR then others) even though they are drawn from the same code set.

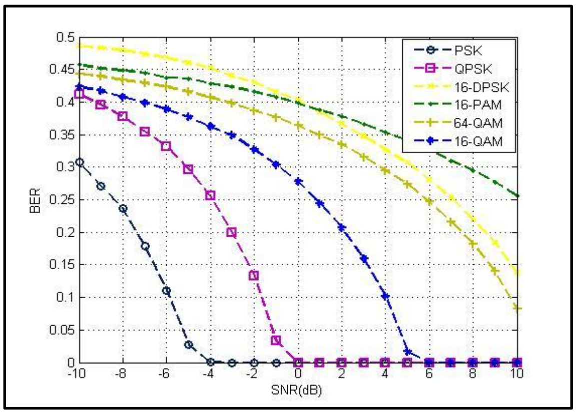

Figure 8: Comparison of the BER performance for different modulation techniques.

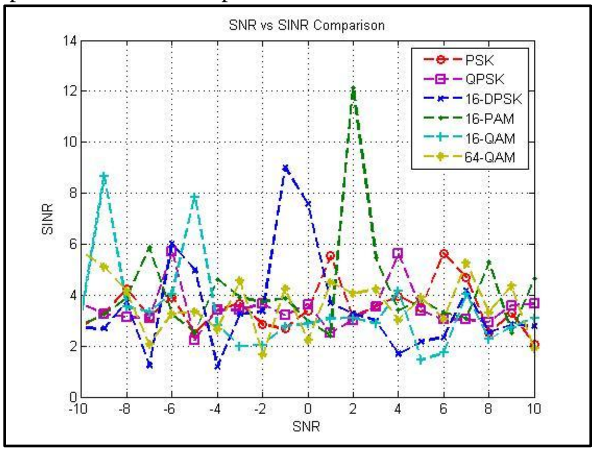

Figure 9: Comparison of the SINR performance for different modulation techniques.

From the figure 8 and 9 it can be concluded that the 16-QAM is an optimum solution for lower BER better data rate and SINR.

VII. CONCLUSION

In this paper a detailed analysis of the performance of different modulation technique is performed the main objective of the paper was to get the optimum configuration for HSDPA system which not only provide higher data rate but also work under the noisy environment conditions, we also wants to investigates the reduction in SINR (signal to interference ratio) because of improper functionality of orthogonal spreading codes caused by noise and fading effect of channel. After the analysis of simulation results we can say that the proper selection of orthogonal code set from all available codes can reduce the SINR and hence improve the BER performance during the study it is also found that some modulation techniques also helps in improving SINR depending upon channel conditions. Considering all these scenarios finally we found that the 16-QAM provides an optimum solution for BER, SINR and Data Rate.

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