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Performance Analysis of Advanced Physical Layer Techniques in Evolved EDGE

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Abstract: Following the worldwide success of GSM/EDGE, the 3GPP is in the process of standardizing EDGE Evolution that will be a step further in improving performance, efficiency and other capabilities. Evolved EDGE delivers data rates comparable to 3G networks, using the same GSM spectrum. With EDGE Evolution service performance can be improved, thus enabling more efficient devices and wider range of multimedia applications. Evolved EDGE has been designed with utmost consideration to minimize the impact on the existing hardware infrastructure of GSM/EDGE. This work is an effort to recognize the prospects of Evolved EDGE and assess the impact of advanced physical layer techniques such as OFDM (Orthogonal Frequency Division Multiplexing), QAM (Quadrature Amplitude Modulation), MIMO (Multiple Input Multiple Output) and Turbo Codes. The entire physical layer structure has been implemented using the latest standards of 3GPP Release-7. Moreover the technologies like OFDM, Turbo Codes and MIMO have also been implemented and integrated with Evolved EDGE. A detailed study has been conducted using the MATLAB model of evolved EDGE Transceiver in AWGN, Rayleigh and Ricean fading channels. The results have shown that employing various advanced techniques helps to achieve significantly higher data rates and efficiency.

Key words: GSM/EDGE Evolution, Evolved EDGE, OFDM, QAM, MIMO, Turbo Codes

INTRODUCTION

The widespread use of the Internet and rapid increase in multimedia applications has put enormous demands for providing higher data rates and low latency packet mode services on mobile communication systems. GSM was designed to provide voice and data in circuit-switched mode. However, this mode was not efficient for the support of data traffic. Moreover, standard GSM supported user data rates of up to 13 Kbps. Therefore, the need existed for a more efficient packet based data services at higher data rates. This need resulted in the development of GPRS (General Packet Radio Service) and EDGE (Enhanced Data rates for GSM Evolution) (Timo Halonen *et al.,* 2003). GPRS is an overlay on top of GSM that caters for a wide range of packet-oriented applications and enables Internet Protocol (IP) connectivity.

EDGE defines a new radio access technology to achieve higher bit rates. The enhancements defined in EDGE are basically in the physical and data link layers for efficiently providing the required higher bit rates. EDGE reuses existing GSM/GPRS infrastructure including carrier bandwidth and TDMA structure (Furuskar *et al.,* 1999). EDGE has been able to provide support for a number of moderate data rate applications in packet mode such as wireless internet and e-mail, etc. However, there are efforts to evolve EDGE and this makes good sense from an economic point of view. It is clear that the cost to upgrade to UMTS will be much higher than evolving EDGE. This is due to the fact that most of the enhancements are software oriented. Further, long-term capital investments are much less than up gradation to a new system. Moreover, there are issues in allocation of spectrum for newer radio technologies such as UMTS/HSPA and LTE.

Evolved EDGE will provide a smooth transition to UMTS HSPA in terms of gradually improving user experience and service connectivity. In spite of the fact that GSM and EDGE are highly advance systems, the efficiency can further be enhanced by using advanced radio technologies (Navratil, 2006). As the share of GSM is about 85% of the world cellular market, higher data rates and increased system capacity in the form of Evolved EDGE are highly beneficial to both customers and operators as these will allow additional services to be introduced to this large base of users without heavy investments by the operators (3G Americas, 2008). In this work, the performance of advanced physical layer technologies such as higher order modulation, multiple antenna based spatial multiplexing and enhanced channel coding are studied and their impact on the

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performance is evaluated using simulation modeling.

The paper is organized as: Section I provides brief background information on the GSM evolution to Evolved EDGE. In Section II, the simulation model of an Evolved EDGE transceiver with advanced physical layer techniques is presented. Section III provides the simulation results and discussion and Section IV concludes the work.

I. GSM Evolution to Evolved EDGE:

Today, most GSM networks support GPRS and EDGE which are extensions of the GSM and reuse existing GSM infrastructure including carrier bandwidth and Time Division Multiple Access (TDMA) structure. GSM/GPRS/EDGE networks are already serving many applications very well, but still there is a need to further evolve EDGE capabilities. From a network operators point of view it is more economical than switching to UMTS. As most enhancements are software based, major portion of the existing infrastructure will not be changed. Because of this less capital investment is required for this upgrade. Evolved EDGE aims to offer higher data rates and system efficiency (3G Americas, 2008).

With the introduction of Evolved EDGE (Enhanced Data rates for Global Evolution), GSM (Global System for Mobile Communications) and other current cellular systems can be evolved to deliver higher data rate services that enable wireless access to Internet and other data networks. Evolved EDGE enables support of 3G applications with existing GSM network infrastructure and affords a seamless integration with 3G. Typical user bit-rates of 1 Mbit/s and a latency of 100 ms are being targeted in Evolved EDGE systems. Thus, Evolved EDGE can manage four times as higher traffic than GPRS. This will result in increased use of mobile data services, better customer satisfaction and higher revenues for the operators. 3GPP has standardized Evolved EDGE for further enhancing performance and coverage of GSM/EDGE involving higher data rates and very low latency of the order of 100ms (3GPP, 2006).

One of the main enhancements in Evolved EDGE is the use of higher order modulations such 16QAM and 32QAM. For EDGE, 8PSK modulation was introduced that resulted in an increase of three times in physical layer data rate as compared with GSM which uses GMSK modulation. With 16QAM and 32QAM in Evolved EDGE, the physical layer bit rate improves by a factor of four and five times respectively over GMSK. Another major change in Evolved EDGE is the higher symbol rate of 325 ksps as compared to that of 271 ksps in EDGE. This combined with higher-level modulation translates into very high bit rate at the air interface of Evolved EDGE (Navratil, 2006). Further enhancements include the use of turbo coding and better HARQ process. Turbo coding provides more robust error protection and HARQ results in faster retransmissions and highly adaptive error control overhead (3G Americas, 2008; GPP, 2006).

Some of the 3G technologies can be integrated with Evolved EDGE to achieve 4G equivalent results without even changing the frequency spectrum. These advanced techniques are OFDM (Orthogonal Frequency division Multiplexing), MIMO (Multiple Input Multiple Output) and Turbo Codes (3GPP TS 05.02; Berrou and Glavieux, 1996). Some of the important features of Evolved EDGE include multiple downlink carriers, higher-order modulations in both uplink and downlink, advanced algorithms for data latency reduction and mobile station diversity techniques. The introduction of these technologies will provide higher capacity, increased reliability, enhanced coverage and superior mobility management and wireless multimedia services.

Evolved EDGE comes with numerous advantages like increase in data rates, spectral efficiency and latency reduction. Further, Evolved EDGE allows coexistence of legacy mobile stations as both older and newer mobile stations can share the same radio resources. The combination of an increase in mean and minimum data rates and a decrease in latency makes it an efficient network. Therefore, Evolved EDGE aims to achieve 4G equivalent data rates and efficiency while reusing the GSM frequency with minimal up gradation of existing infrastructure.

II. Simulation Model for Evolved EDGE Transceiver:

The block diagrams of an Evolved EDGE transceiver is depicted in Figure-1. A number of logical channels and the associated transport services are defined at the physical layer. The logical channels are categorized into traffic and control channels. Traffic channels are needed to transport user information such as encoded speech or data. On the other hand, control channels carry signaling/synchronization data. 3GPP Release 7 specifies a Flexible Layer One (FLO) in as shown in Figure-2 (3GPP, 2006). In order to cater to the requirements of emerging Internet Multimedia Subsystem (IMS), FLO has specified a parameterized physical layer that is easily configurable and highly optimized (Timo Halonen *et al.,* 2003).

The FLO is responsible for the following (3GPP, 2006):

- Error control coding using FEC (Forward Error Correction) involving error detection and correction of transmitted information
- Rectangular interleaving of a radio block over eight consecutive bursts
- Processes involving detection of physical link congestion.

In FLO, a flexible and adaptive framework is defined so that instead of fixed coding schemes, these can be specified and optimized at time of call setup. Transport channels (TrCHs) from Layer 1 carry data in the form of transport blocks (TB) from Layer 2. A data flow with a specific QoS is associated with each transport channel. However, several transport channels may be multiplexed within a radio packet. For downlink transmissions, transport blocks (TB) are sent from L-2 (Layer 2) to L-1 (Layer 1) and vice versa for the uplink communications (3GPP, 2006).

A Transport Format (TF) defines the configuration of a transport channel that specifies the CRC (Cyclic Redundancy Check) size and input block size. L-3 (Layer 3) specifies the transport format with parameters values for satisfying the QoS of the particular data flow being transported over the traffic channel. Transport Format Combinations (TFC) defines combination of various Transport Formats used by a data flow and a Transport Format Combination Indicator (TFCI) is used to inform the receiver which TFC is currently being used. TFC is specified for each radio packet. The processing of a transport block corresponding to active transport channels involves at the first stage CRC attachment followed by channel coding and rate matching. These transport channels are then multiplexed. Afterwards TFCI mapping and interleaving is performed. After interleaving, bursts of coded bits are ready to be sent over the radio medium using Burst formatter (Timo Halonen *et al.,* 2003; 3G Americas, 2008; 3GPP, 2006).

A. Basic Transceiver Design:

The brief description of each of the processing blocks involved in the design of a basic transceiver model is as follows;

Speech Processing:

Speech processing is achieved using a Wideband AMR codec, specified in the 3GPP specifications. For the AMR-WB codec, the range of frequencies being considered is from 50 Hz and 7000 Hz. While for AMR-NB, codec for the narrowband speech, the frequency range is between 150 Hz and 3500 Hz. The quality of speech is dependent on the range of frequencies of the codec. For speech that is natural and the intelligible, the AMR-WB codec is the primary choice. The quality provided by the AMR-WB codec renders it more suitable for high-quality audio applications. This codec has nine different bit rates that vary between 6.60 kbps to 23.85 kbps (Timo Halonen *et al.,* 2003; 3GPP, 2006).

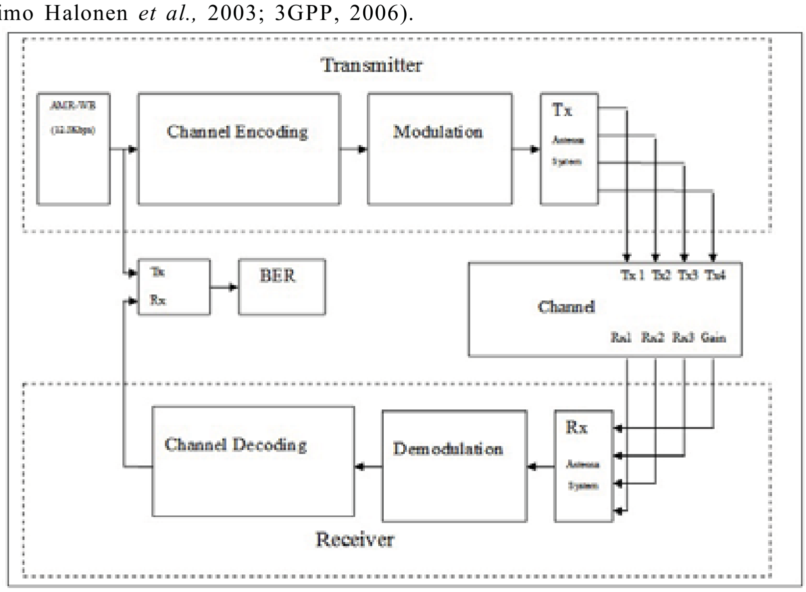

Fig. 1: Evolved EDGE Transceiver Block Diagram

CRC Attachment (Block Coder):

In this stage, parity bits are generated for a block of data, known as CRC (cyclic redundancy check) coding. This permits for error detection for the data block and provides the first level of protection against channel impairments and is dubbed as external protection. For each transport block, the CRC block coding is optionally used and the level of coding specified by L-3 (0, 6, 12 or 18 bits). A fixed CRC polynomial is used for each transport channel to generate the parity bits corresponding to a transport block (Timo Halonen *et al.,* 2003; 3GPP, 2006).

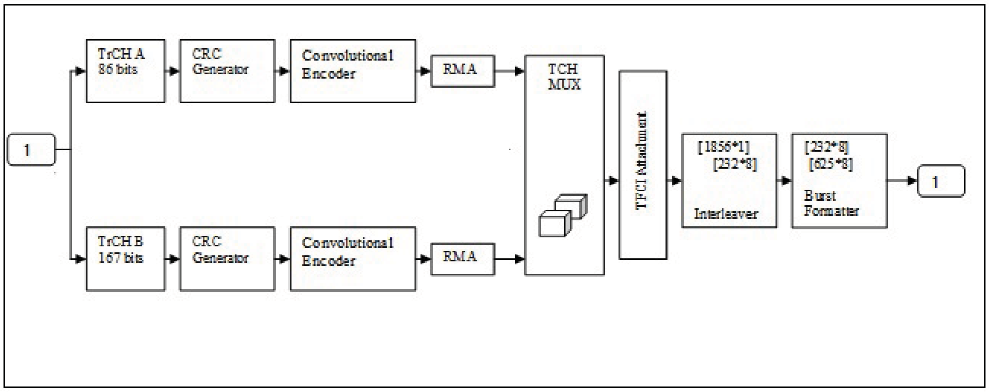

Fig. 2: Evolved EDGE Flexible Layer One (FLO) Architecture

Channel Coding:

In order to correct the transmission errors caused by the radio channel, further redundancy is applied in addition to the block coding. This is generally called as internal protection and is normally based on the Convolutional codes. This process is also known as FEC (Forward Error Correction). In Phase-1, a 1/3 rate non-recursive Convolutional code (3, 1, 3) with a constraint length of 7 is employed for each coded block similar to EDGE (Zangi *et al.,* 1998).

Rate Matcher:

This function involves repetition or puncturing of the coded bits of an encoded block, known as rate matching. As the number of bits a transport channel can carry varies at different transmission times, the transport block size changes dynamically. Therefore, bits in a given block need to be repeated or punctured so that bit rate matches to the channel bit rate after TrCH multiplexing. For each TrCH, a rate matching attribute (RMA) is specified by the Layer-3. After rate matching, the encoded blocks are designated as radio frames. The rate matching generates a radio frame per encoded block (3GPP, 2006).

Transport Channel Multiplexer:

In this stage, the radio frames from active traffic channels are concatenated to provide a Coded Composite TrCHs (CCTrCH) (3GPP, 2006).

TFCI Mapper:

TFCI mapping involves the decoding of TFCI so that the receiver can obtain the information about the active TFC. This provides the knowledge of transport formats of the various transport channels to initiate the decoding process (Timo Halonen *et al.,* 2003). A stronger level of coding is needed to protect the TFCI similar to that for a traffic channel (3GPP, 2006).

Interleaver:

Interleaving spreads the content of one traffic block across several TDMA timeslots to ensure that only some of the data from each traffic block is contained within each burst (Zangi *et al.,* 1998). So when a burst is not correctly received, the loss does not affect overall transmission quality because the error correction techniques are able to interpolate for the missing data. In this case radio frames are interleaved over 8 bursts diagonally and the input stream of 1856 bits at the interleaver is converted it into 8 coded words of 232 symbols. A flexible process of interleaving is used in the sense that it employs 20-ms rectangular or 40-ms diagonal blocks and further this can be applied to both full-rate or half-rate channels (3GPP TS45.912, 2006).

Burst Formatter:

Each burst carries 156 symbols which is a combination of information and signaling symbols. Due to the unwanted presence of fading in channel, it is really difficult to detect transmitted signal therefore training sequence is required to estimate channel, optimize reception and reduce ISI (3GPP, 2006).

Modulation:

The modulation used the in basic transceiver model is 8-PSK as in EDGE.

B. Integration of Advanced Techniques:

The basic transceiver model is further enhanced with the introduction of advanced physical layer techniques. This involves use of more efficient Turbo Codes (Berrou and Glavieux, 1996) which provide better error correction/protection than Convolutional Codes. Similarly, with the introduction of OFDM and QAM, the data throughput is increased while ISI is contained as well (Navratil, 2006; Arslan *et al.,* 2001). Thirdly, with the use of MIMO Antenna systems (3G Americas and Nortel, 2005), both the transmitter as well as receiver diversity is employed in addition to throughput enhancement. These three techniques are actually compulsory for 4G systems; however these have been explored for the Evolved EDGE transceiver while using the same GSM frequency spectrum. These techniques are presented concisely in the following;

Turbo Codes:

Two identical Recursive Systematic Convolutional (RSC) codes are concatenated in parallel to form a fundamental turbo coding encoder. The RSC encoder is obtained from the (conventional) Convolutional encoder by feeding back one of its encoded outputs to its input. An RSC tends to produce codeword with increased weight relative to a non recursive encoder. This results in fewer codeword with lower weights and this leads to better error performance. In Turbo coding, the blocks are of 16K bits length. This large length is responsible for effectively randomizing the information sequence going into the second encoder. The longer the length, the better would be its correlation with the message from the first encoder.

Turbo decoders use a method called Maximum Likelihood Detection or MLD. Turbo code decoding is initiated with the computation of “a posteriori probabilities” (APPs) for each transmitted bit of data. The data-bit value that was selected corresponds to the maximum a posteriori (MAP) probability for that data bit. For decoding when a corrupted code-bit block is received, the process of decision making with APPs allows the MAP algorithm to find out the most likely information bit that has been transmitted at each bit time. For turbo decoding serial concatenated decoding scheme is used. The performance of serially concatenated structure is better than the parallel concatenated decoding scheme due to the ability to share information between the concatenated decoders (3GPP, 2006; Berrou and Glavieux, 1996).

Higher Order Modulation (OFDM and QAM):

Introduction of advanced modulation schemes and a higher symbol rate (in fact, higher carrier bandwidth), the average and peak bit-rates and spectrum efficiency can be optimized. Taking advantage of localized coverage circumstances, higher order modulation can achieve optimal performance. Therefore, very high data transfer rates are enabled at various geographical locations and times based on the channel conditions (Arslan *et al.,* 2001). The use of OFDM with 16QAM, 64 QAM instead of 8-PSK modulation increases the bit-rates and results in improved robustness against interference.

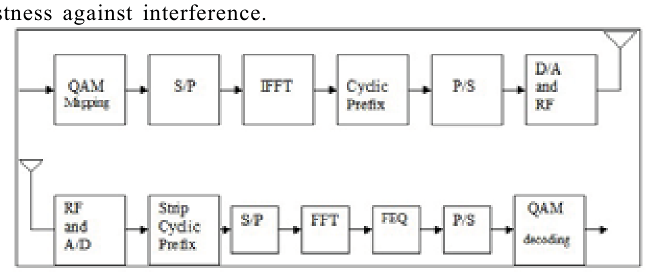

Fig. 3: An OFDM Modulator/Demodulator

First of all the input stream is encoded using QAM Modulator then afterwards this broadband channel is divided into numerous sub-channels. Each of these sub-channels is individually processes through Inverse Fast Fourier Transform (IFFT) which creates the output signal that is actually a time domain OFDM signal. Then cyclic prefix is added to its front for protection of symbol. Since OFDM has numerous carriers so this procedure is applied to each carrier. However these procedures which mitigates the effects of link fading and inter symbol interference, the bandwidth is increased. After that, all the sub-channels are superimposed to make a composite signal that is ready for transmission. At the demodulator end the composite signal is again divided into sub-channels. Then these sub-channels undergo a process where cyclic prefix are removed from each carrier to obtain perfectly periodic signals so that Fast Fourier transform (FFT) can be applied to get symbols on each carrier. The result of FFT is a frequency domain signal (Navratil, 2006; 3GPP, 2006).

In case of 16 QAM modem the single output stream of 5000 bits coming from the burst formatter was divided into 8 sub-channels. Each sub-channel got 768 bits to be modulated by QAM Encoder. The output after encoding was 192 symbols which after the addition of tail bits became 256 symbols. These symbols were passed to IFFT which converted them into time domain. Afterwards cyclic prefix was added which gave the final outcome of 320 symbols. Each Sub-channel gives 320 symbols so the composite signals give the output of 320x8=2560 OFDM symbols.

In case of 64 QAM modem the single output stream of 5000 bits coming from the burst formatter was divided into 5 sub-channels. Each sub-channel got 1000 bits to be modulated by QAM Encoder. The output after encoding was 192 symbols which after the addition of tail bits became 256 symbols. These symbols were passed to IFFT which converted them into time domain. Afterwards cyclic prefix was added which gave the final outcome of 320 symbols. Each Sub-channel gives 320 symbols so the composite signals give the output of 320x5=1600 OFDM symbols (Arslan *et al*., 2001).

MIMO Antenna Systems:

At the transmitter, an input symbol sequence is encoded using orthogonal space-time block code (OSTBC). The input symbols are mapped block-wise and the output codeword matrices are concatenated in the time domain. If (T x 1) is an input symbol length then after encoding the coded word would be (T/R) x (N), where N is number of transmitter antennas and R is the symbol rate. The OSTBC Encoder followed by the 16 QAM OFDM Modulator encodes 2700 symbols using the Encoding Algorithm for 3 transmit antennas and of rate 3/4. The output of this block is a 3600x3 matrix whose entries on each column correspond to the data transmitted over one antenna. Five different encoding algorithms are supported by the OSTBC (orthogonal space-time block code) Encoder (Alamouti, 1998).

At the receiver end, the received signal is combined with the channel estimate by the OSTBC Combiner combines signal to obtain the soft information of the encoded symbols. The estimate for the first symbol period per codeword block is used by the combining algorithm because he channel estimate may not remain constant during transmission of the codeword. At the receiver end we receive a 3600x3x2 matrix which contains the normalized gains of the 3 transmitter antennas that goes into the channel estimator and a 3600x2 matrix which is the data received by the 2 receiver antennas. The OSTBC Combiner decodes the received coded word using Combiner Algorithms for 3x2 MIMO system and outputs is a 2700 matrix which goes into the 16-QAM Demodulator. Further, five different computation algorithms for combining are supported by the OSTBC (orthogonal space-time block code) Combiner Block (Alamouti, 1998).

C. Channel Models:

A mobile radio channel is characterized by continuously varying transmission condition and a statistical approach is used for channel modeling. In this work, AWGN (Additive White Gaussian Noise) is used as a reference channel model. Wireless channels are characterized by fading phenomenon. The rapid variation due to fast fading are superimposed on to the slow variations of the local mean signal. For the fast-fading characterization of radio channels, Rayleigh or Ricean distributions are often used. Further, A MIMO channel model is needed in case MIMO antennas are used.

AWGN Channel:

This channel is characterized by the fact that the user signal is corrupted by thermal noise. The thermal noise could be associated with the physical channel itself and the hardware components in the link, transmitter and receiver as well. AWGN model is most commonly used reference for simulation based analysis of communication link performance.

Multipath Rayleigh Fading Channel:

This type of fading involves multiple indirect paths between transmitter and receiver, without any distinctive dominant path (such as an LOS path or any other distinct indirect-path or multipath).The Rayleigh fading model is more suited to outdoor short term propagation phenomenon. This model is representative of the wireless radio channel that is being typically applies to present day cellular mobile communication systems.

Multipath Ricean Fading Channel:

The Ricean fading is similar to Rayleigh fading except that there is a direct LOS component or as a minimum a dominant component in the signal that reaches the receiver. The Ricean model fits well with indoor short term propagation.

MIMO Channel:

The fading channel is a subsystem based implementation. It uses the Multipath Rayleigh Fading Channel to simulate the flat Rayleigh fading sub channel from transmitter antenna to the receiver antenna. The Maximum Doppler shift (Hz) parameter of the Multipath Rayleigh Fading Channel block is set to 30. The reason for using this value is to make the MIMO channel behave like a quasi-static fading channel, i.e., it keeps constant during one frame transmission and varies along multiple frames.

III. Simulation Results and Analysis:

This work focuses on assessing the impact of various advanced physical layer techniques introduced in Evolved EDGE using the simulation model as described in Section III above. For this purpose, a number of simulation scenarios have been considered that enable analyzing the impact of the various technologies under variety of channel conditions as embodied in AWGN, Rayleigh, Ricean and MIMO channel models.

Important simulation parameters include: Symbol Rate: 1.2 mega symbols per second, input signal power: $1e^{-3}$ and Eb/No variations: 1-15dB. Bit Error Rate (BER) is being used as a performance measure in this study and we have estimated BER values as function of Eb/No. Various scenarios being considered in this study are as below:

- Comparison of Modulation Schemes
- Impact of OFDM Configurations
- Impact of MIMO Configurations
- Comparison of Propagation Effects
- Impact of Turbo Codes Configuration

Comparison of Modulation Schemes:

In this scenario, an analysis using different modulation schemes like 8 PSK, 16-QAM and 64-QAM is carried out with Additive White Gaussian (AWGN) channel. It can be seen from Figure-4 that with the introduction of QAM modulation schemes, higher BER values for same Eb/No value are experienced. However, this is compensated by the fact that higher peak throughput per timeslot is achieved due to larger number of bits per symbol using QAM, thus making the transmission more efficient. This also reduces the data session airtime, allowing radio resources to be released more quickly for the same data transfer. It can also be seen that for Eb/No values less than 5dB, the BER values vary slightly for PSK and QAM schemes. At Eb/No values greater than 5dB, the BER variations are increasing but the higher data rate is compensating for it. In essence, it is basically a trade-off between the data throughput and the BER.

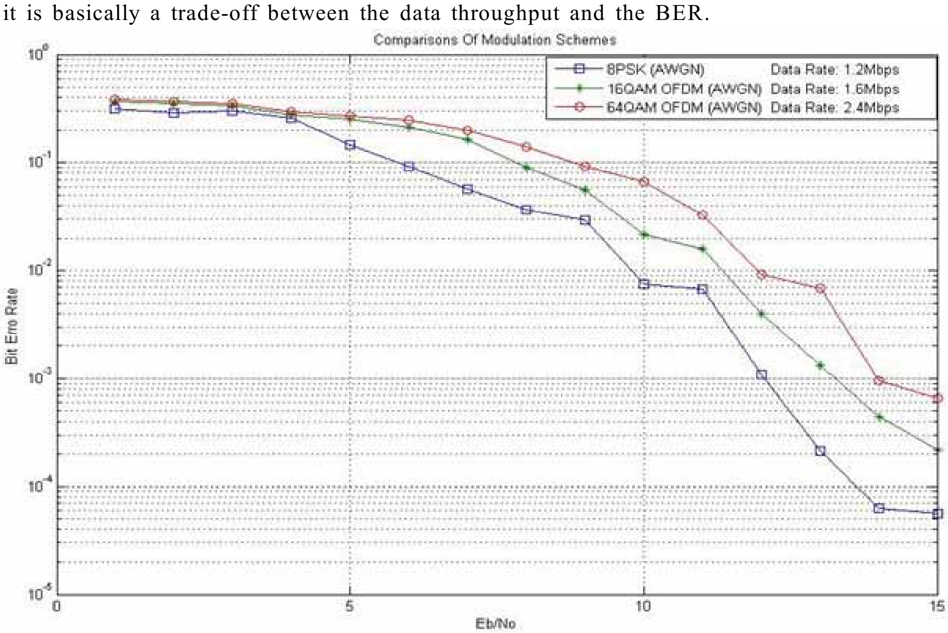

Fig. 4: Comparisons of Modulation Schemes

Impact of OFDM Configurations:

In this scenario, we carried out an analysis using different OFDM configurations of 16-QAM OFDM & 64-QAM OFDM Modem in Additive White Gaussian (AWGN) channel. From the results shown in Figure-5, it is clearly depicted that the introduction of a 16-QAM OFDM modem has made the transceiver more efficient. At an Eb/No value of 14dB, the 16-QAM OFDM Modem is 16 % more efficient than a simple 16-QAM modem. The introduction of a 64-QAM OFDM modem reduces BER values for given Eb/No as shown in Figure-6. The introduction of a 64-QAM OFDM modem has made the transceiver more efficient. At an Eb/No value of 14dB, the 64-QAM OFDM Modem is 18 % more efficient than a simple 64-QAM Modem.

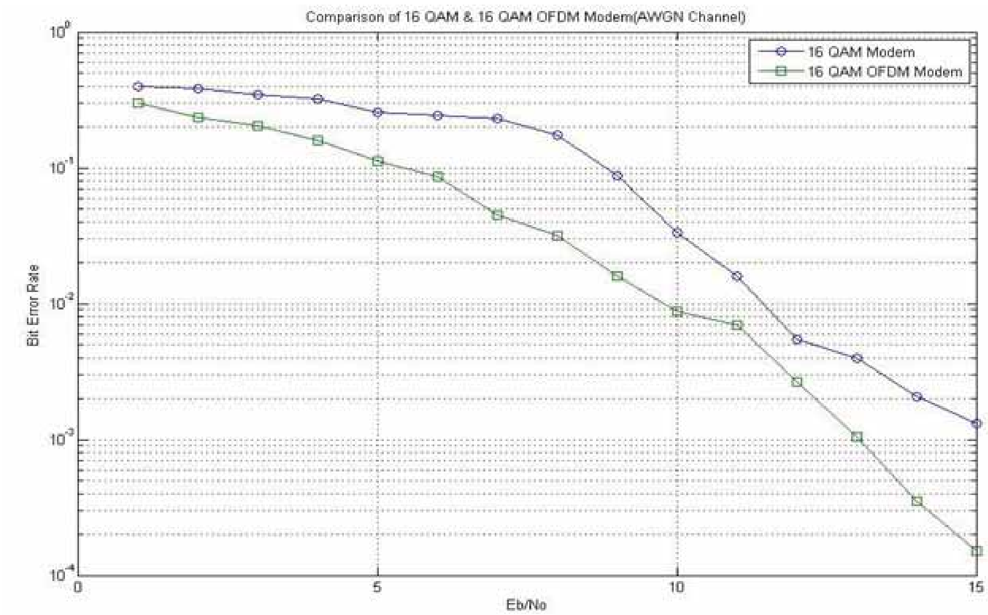

Fig. 5: Comparisons of 16 QAM & 16 QAM OFDM Modem (AWGN)

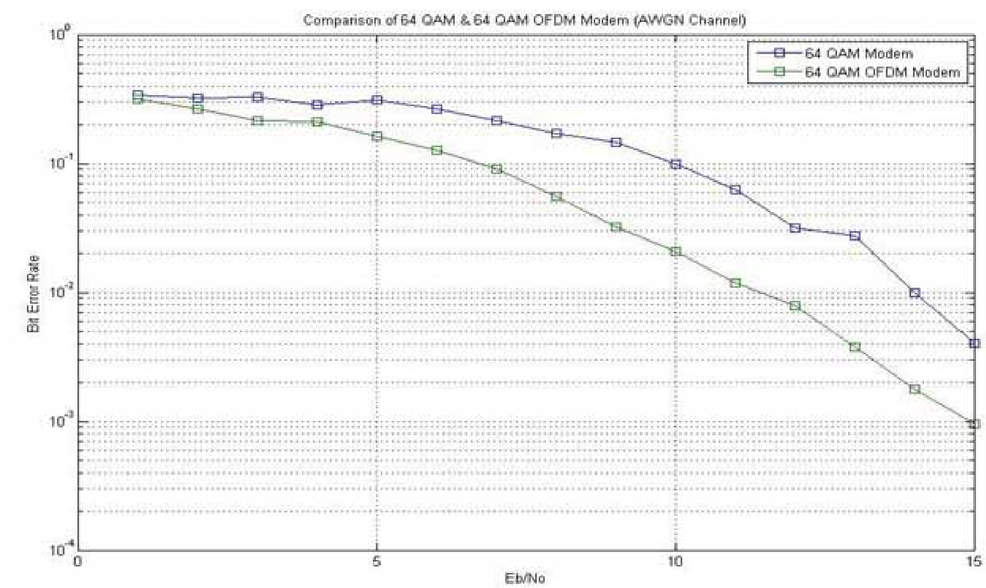

Fig. 6: Comparisons of 64 QAM & 64 QAM OFDM Modem (AWGN)

Performance of OFDM/QAM in Fading Environment:

Figure-7 depicts the comparative performance of 16-QAM-OFDM and 64-QAM-OFDM in AWGN and Ricean fading channels. It is seen that in both cases, higher SNR is required for the Ricean channel as compared to AWGN. For example, for 16-QAM-OFDM, about 8dBs higher SNR is needed to achieve a BER of 10-3 in the Ricean channel. Similarly, for 64-QAM-OFDM, the BER degrades by an order of magnitude (e.g., 10dB and 15dB) for the Ricean channel as compared to AWGN.

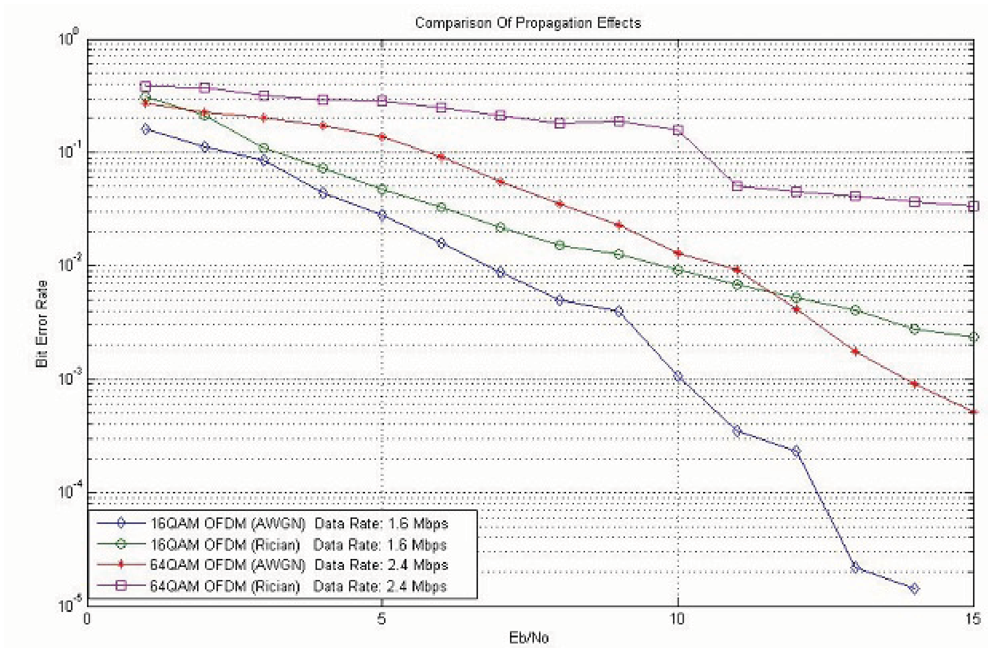

Fig. 7: Comparison of Propagation Effects

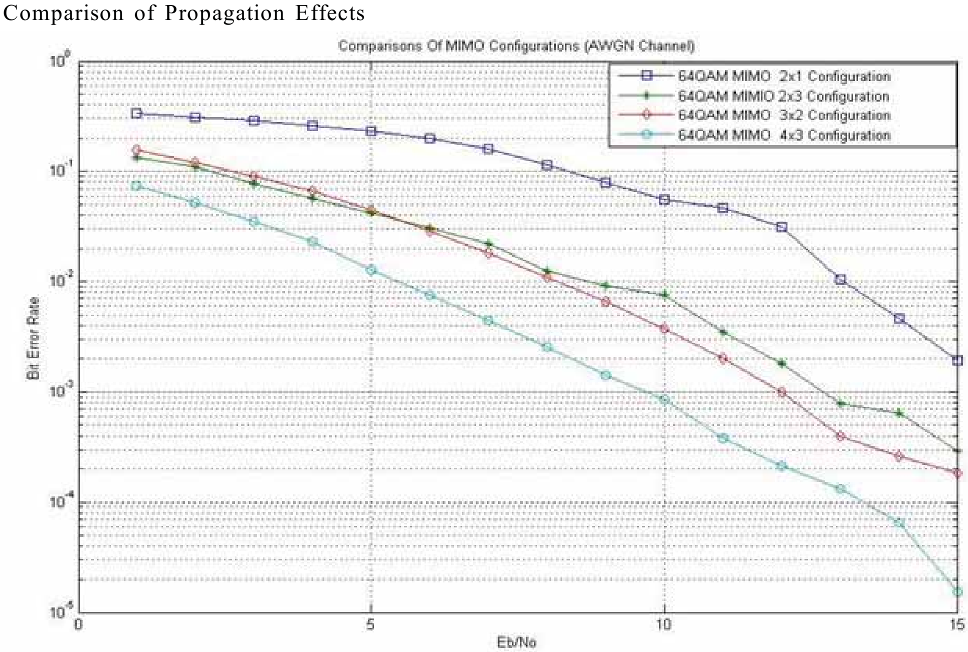

Fig. 8: Impacts of MIMO Configurations

Impact of MIMO Configurations:

In this scenario, an analysis using different Multiple–Input Multiple–Output (MIMO) configurations is carried out in a multi-path Rayleigh fading channel. In this case, the number of transmitter and receiver antennas is varied with 64-QAM OFDM modulation. Alamouti codes along with the OSTBC codes have been implemented (Alamouti, 1998). The MIMO configurations are all in diversity mode. As in diversity mode multiple paths are being used to transmit the same data, so the basic aim is to achieve lower BER values. In diversity mode the probability of error is inversely proportional to diversity gain. As shown in Figure-8, we can see that BER measurements for 4x3 MIMO are better than the rest of the schemes like 2x1MIMO, 2x3

MIMO and 3x2 MIMO. As diversity gain of 4x3 MIMO is highest among all the other configurations, so the BER values are the lowest for it. The diversity gain of 2x3 MIMO and 3x2 MIMO are same so their BER values are not much varying. For a 2x1 MIMO configuration, the probability of error is highest.

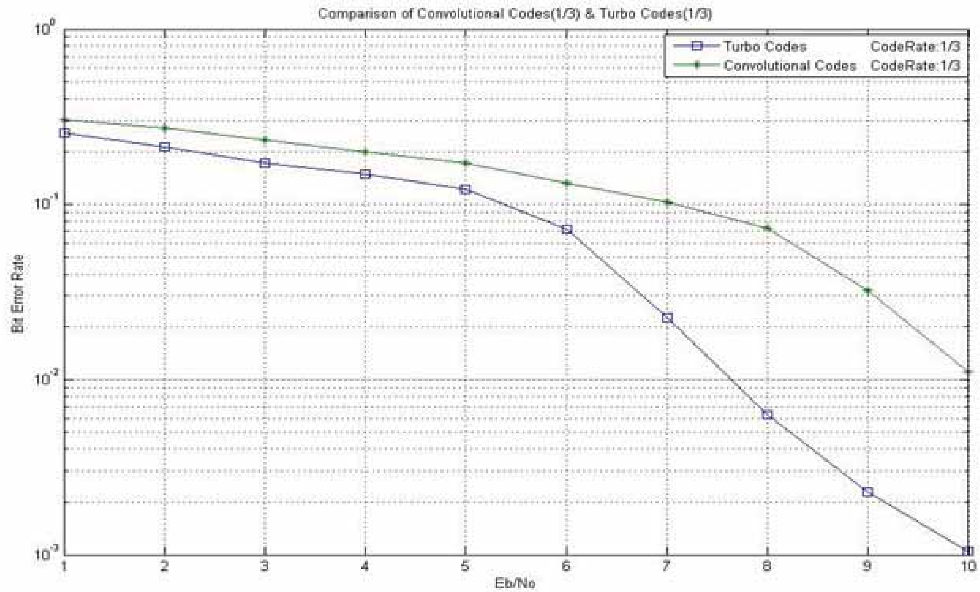

Fig. 9: Comparison of Convolutional Code (Rate: 1/3) and Turbo Code (Rate: 1/3)

Impact of Turbo Codes:

In this scenario, the impact of advanced coding technique such as Turbo Codes with Code Rate: 1/3 [k=1; n=3] is evaluated. For reference, performance is compared with Convolutional Codes using same code rate of 1/3. The channel model used is AWGN channel. The turbo codes achieve better performance with refinement of concatenated coding structure and iterative decoding. It is observed in Figure-9 that Turbo Codes result in better performance by reducing the error rates, specifically for Eb/No values of 6 dBs and higher. For example, at Eb/No value of 8 dB, error rate improves by more than ten times.

IV. Conclusions:

In this work, we have analyzed the impact of various advanced physical layer techniques that are being integrated in Evolved EDGE Transceiver for achieving efficiency and higher data rates. The introduction of higher order modulation schemes can provide us with much higher data rates with slightly high BER values. As GSM/EDGE deploys adaptive modulation so the new 16-QAM and 64-QAM with OFDM will provide user with high rates depending on the radio conditions. The need of higher bit rates, better utilization of bandwidth and immunity against multi-path propagation effects have emphasized the importance of OFDM in current wireless communication systems. Evolved EDGE performance can be dramatically increased by introducing, not only Transmitter diversity but also the Receiver diversity. We showed that MIMO 4 x 3 configurations with diversity mode is much more efficient than a SISO system. More over the replacement of Convolutional codes with Turbo codes is further increasing the efficiency of Evolved EDGE Network. From a network operator's point of view, with Evolved EDGE an operator will be able to significantly enhance the value of their existing GSM/GPRS/EDGE system as well as the spectrum it is deployed in. The increase in the data rates offered with this upgrade provide a much better complement for the speeds of HSPA, allow mobile users to more seamlessly enjoy their services while moving around. From a user's point of view, a user can have excellent battery life (handset needs one radio for GSM/GPRS/EDGE/Evolved EDGE), they can roam and enjoy services across the globe. From implementation point of view upgrade to Evolved EDGE is almost risk free and can be scheduled as part of normal operational upgrades of either the base station software alone or together with base station hardware.

REFERENCES

Alamouti, S., 1998. "A Simple Transmit Diversity Technique for Wireless Communications," IEEE JSAC, 16(8): 1451-1458.

3G Americas, 2008. "The Case for Evolved Edge", Report; Available at http:\\www.3gamaericas.com

Arslan, H., J.F. Cheng and K. Balachandran, 2001. "Evolution of EDGE to Higher Data Rates using QAM", in proceedings VTC, Atlantic City, NJ, USA.

Berrou, C. and A. Glavieux, 1996. "Near Optimum Error Correcting Coding and Decoding: Turbo-Codes," IEEE Trans. on Communications, 44: 1261-1271.

Furuskar, A. *et al*., 1999. "EDGE: Enhanced Data Rates for GSM and TDMS/136 Evolution", IEEE Personal Communications Magazine.

3G Americas and Nortel, 2005. "MIMO-OFDM Performance Analysis".

3GPP TS 05.02: "Digital Cellular Telecommunication System (Phase 2+); Multiplexing and Multiple Access on the Radio Path", http://www.3gpp.org.

Navratil, D., 2006. "Higher Order Modulations and GSM/EDGE Radio Access Network Evolution", IEEE VTC-Spring Melbourne, Australia.

Nortel Networks, 2006. "Nortel's GSM/EDGE Radio Access Network (GERAN) Evolution".

Timo Halonen, Javier Romero, Juan Melero, 2003. "GSM, GPRS and EDGE Performance, Evolution towards 3G/UMTS", John Wiley & Sons Ltd., Second Edition.

3GPP TS45.912, 2006. Third Generation Partnership Project, "Feasibility Study for Evolved GSM/EDGE Radio Access Network (GERAN)", Version 7.0.0, 2006.

Zangi, K., A. Furuskar and M. Hook, 1998. "EDGE: Enhanced Data Rates for Global Evolution of GSM and IS-136," Proceedings of Multi-Dimensional Mobile Communications.