

Performance of MIMO-OFDM Transmission System on Wireless Networks

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Abstract-A detailed study of the performance of MIMO-OFDM transmission on WLAN physical layer specified in IEEE 802.11n, Wi-MAX (IEEE 802.16-2009) physical layer specified in 802.16 and LTE downlink physical channel (PDSCH) has been carried out using MATLAB Simulink. The WLAN and Wi-MAX system incorporates Convolution coding with 1/2 and 2/3 rated codes. The LTE incorporates Turbo coding with 1/2 and 2/3 rated codes. Orthogonal Frequency Division Multiple (OFDM) accesses uses adaptive modulation technique such as QPSK, 16-QAM and 64-QAM, on the physical layer of WLAN, Wi-MAX and LTE and the concept of cyclic prefix that adds additional bits at the transmitter end. The Error Rate (BER) derived from simulation results show that the implementation with interleaved Convolution coding and Turbo coding under QPSK modulation technique is found to be highly efficient for WLAN, Wi-MAX and LTE wireless network system. The Implementation of MIMO-OFDM multiplexing on WLAN networks with QPSK modulation at BER $\sim 10^{-3}$ dB, exhibits significant improvement in SNR ~ 2.75 dB, Wi-MAX network SNR ~ 3.75 dB and LTE network SNR ~ 7.55 dB. The improvement of SNR ~ 4.8 dB displayed between the MIMO-OFDM implementation on WLAN and LTE network can be attributed to the Turbo coding techniques adopted in LTE networks.

Keywords-Multiple Input Multiple Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM), Phase Shift Keying (PSK), Quadrature Amplitude modulation (QAM), Bit Error Rate (BER), Signal to Noise Ratio (SNR), Line-of-Sight (LoS), Forward Error Correction (FEC), Wireless Local Area Network (WLAN), Worldwide interoperability for Microwave Access (Wi-MAX), Long Term Evaluation (LTE), Subscriber Station (SS), Base Station (BS).

I. INTRODUCTION

In this new information age, high data rate and strong reliability features out wire-less communication systems and is becoming the dominant factor for a successful deployment of commercial networks. MIMO technology is one among being used in broadband systems that exhibit frequency-selective fading and Inter-Symbol Interference (ISI).

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MIMO system realize the spatial diversity and spatial multiplexing at the same time and consequently obtain both the spatial diversity gain and spatial multiplexing gain leading to an enormous capacity enlargement. The improvement can be even greater by combination with other technology such as OFDM. Effectively, OFDM transforms a frequency selective channel into parallel flat-fading sub channels i.e., the signals on the subcarriers undergo narrowband fading. Hence by performing MIMO transmission and detection per subcarrier, MIMO can be applied in broadband communication. Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM), a new wireless broadband technology, has gained great popularity for its capability of high rate transmission and its robustness against multipath fading and other channel impairments [14]. In radio, MIMO is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency or to achieve a diversity gain that improves the link reliability and reduced fading. Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution, Wi-MAX and HSPA+ [2].

Conventional high-speed broadband solutions are based on wired-access technologies such as Digital Subscriber Line (DSL). This type of solution is difficult to deploy in remote rural areas, and furthermore it lacks support for terminal mobility. Mobile Broadband Wireless Access (BWA) offers a flexible and cost-effective solution to these problems. The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium. A further goal was the redesign and simplification of the network architecture to an IP-based system with significantly reduced transfer latency compared to the 3G architecture. The LTE wireless interface is incompatible with 2G and 3G networks, so that it must be operated on a separate wireless spectrum [19].

The present study involves implementation of MIMO system with OFDM multiplexing and modulation

techniques for digital signal transmission on WLAN, Wi-MAX and LTE networks. For WLAN, IEEE 802.11n standard is considered, for Wi-MAX IEEE 802.16-2009 is considered. The performance of the WLAN, Wi-MAX and LTE combined with MIMO-OFDM is determined by computing the Signal to Noise Ratio (SNR), Bit Error Rate (BER) for a given data rate in a communication system using MATLAB Simulink.

II. MULTIPLE INPUT MULTIPLE OUTPUT (MIMO)

The multiple input multiple output channel technology is aimed to increase the capacity in the wireless communication network. With the invention of MIMO, the technology seems to gain popularity as it is being implemented in the current commercial wireless products and networks such as broadband wireless access systems, Wi-MAX, 3G networks, etc. Figure 1 shows a line of sight (LOS) antenna setup of a MIMO system.

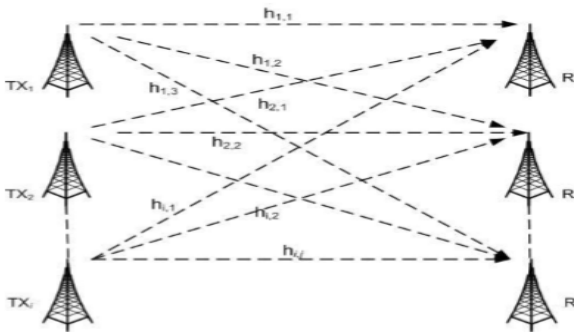


Figure 1 A generalized MIMO wireless communication system

The main idea behind MIMO is that, the sampled signals in spatial domain at both the transmitter and receiver end are combined so that they form effective multiple parallel spatial data streams which increase the data rate. The occurrence of diversity also improves the quality that is the bit-error rate of the communication [6, 13].

To derive the channel characteristics, MIMO system transmits specified and known training signals regularly from all transmitters of the system and these transmitted signals are received at the receiver. Based on the received signals, the receiver calculates the characteristics of all channel paths from each transmitted antenna to each receiving antenna. In order to prove that MIMO work, the transmitted signal X has to be solved from the group of equations in equation (1), assuming that the system is noise free and line of sight (LOS). If the transmitted signal is represented to be X, the received signal Y and the channel characteristics matrix is W_c , then $Y = X W_c$ --- (1).

If the channel matrix has N rows as many as there are transmitting antennas with index i, then transmitted signal vector is written as $X = [x_1, x_2, \dots, x_N]$. Also if the channel matrix has M columns, as there are receiving antennas with index j, then the received signal vector is $Y = [y_1, y_2, \dots, y_M]$. These vectors are extended later to matrixes by inserting K samples into each column. The channel matrix contains path characteristics h_{ij} as

$$W_c = \begin{pmatrix} h_{1,1} & h_{1,2} & \dots & h_{1,M} \\ h_{2,1} & h_{2,2} & \dots & h_{2,M} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N,1} & h_{N,2} & \dots & h_{N,M} \end{pmatrix}$$

III. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

OFDM is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers which are orthogonal to each other and can be thought of as a large number of low bit rate carriers transmitting in parallel. All these carriers transmitted using synchronized time and frequency, forming a single block of spectrum, to ensure that the orthogonal nature of the structure is maintained. As a modulation format, OFDM is very flexible in that it can be easily scaled to meet the needs of a particular application. For applications like VOFDM, the lack of ISI also greatly simplifies the implementation of diversity reception. BWIF (uplink), 802.11a and Hyperlan/II are unique in that the OFDM is pulse modulated. While the specifics of BWIF are proprietary, the impact on WLAN products is the need for special synchronization techniques [5, 10].

IV. IMPLEMENTATION OF MIMO-OFDM ON WLAN NETWORK (IEEE 802.11N)

The model shown in figure 2 represents an end-to-end baseband model of the physical layer of a WLAN according to the IEEE 802.11n standard. This model contains various components that model the essential features of the WLAN 802.11n standard. The top row of blocks contains the transmitter components while the bottom row contains the receiver components. The model supports data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The model also illustrates adaptive modulation and coding over a dispersive multipath fading channel, whereby the simulation varies the data rate dynamically [9, 11].

Random binary data is generated by Random Integer block (variable rate data source). This randomly generated data is then modulated by modulator bank (QPSK, 16-QAM and 64-QAM modulations are incorporated). This modulated data is converted to OFDM symbols and again modulated by OFDM modulator. Pilot signals and training symbols (preambles) are used for time synchronization (to avoid ISI) and frequency synchronization (to avoid inter-carrier interference, ICI, caused by Doppler shift). Zero padding blocks append zeros to the specified dimension if it is not available at the input of IFFT block. The cyclic prefix, which is transmitted during the guard interval, consists of the end of the OFDM symbol copied into the guard interval, and the guard interval is transmitted followed by the OFDM symbol. Ultimately it decides the number of subcarriers to be used [12, 15].

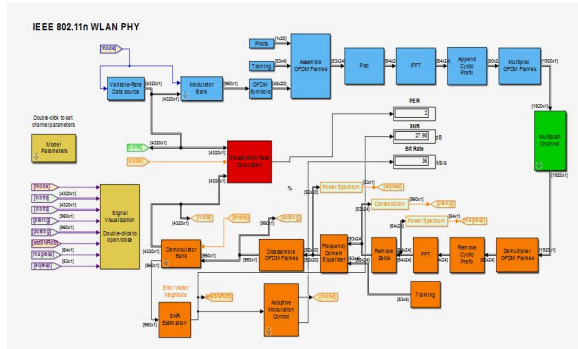


Figure 2 IEEE 802.11n WLAN PHY

Now OFDM frames are multiplexed and transmitted through the multipath channel. After passing through the channel the data first demultiplex the OFDM frames and then demodulated by the OFDM demodulator which consists of remove Cyclic Prefix, FFT, remove Zero Pad blocks in sequence. Cyclic prefix which is attached to OFDM signal before transmission is to be removed by removing Cyclic Prefix block. Then FFT will process the data to get the data same as that of input given to the IFFT block. After this, zero padding is removed. Now demodulator is used to demodulate this data to obtain random binary data transmitted by the random integer generator block [18, 20].

V. IMPLEMENTATION OF MIMO-OFDM ON WI-MAX NETWORK (IEEE 802.16-2009)

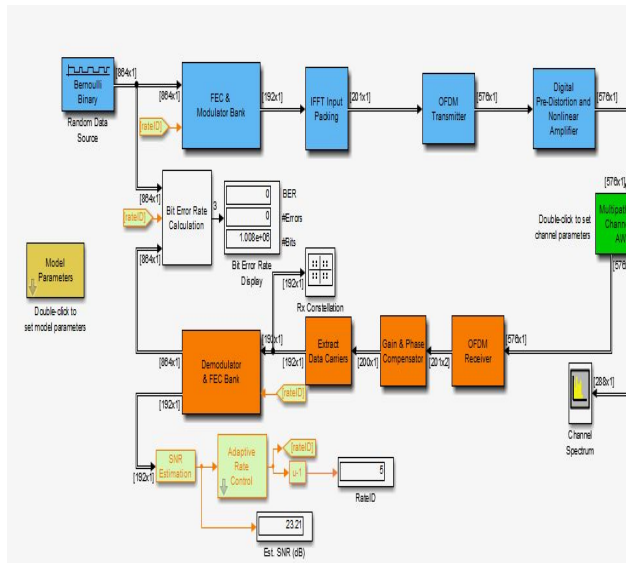


Figure 3 IEEE 802.16 Wi-MAX

IEEE 802.16 Wi-MAX NETWORK

The simulation model shown in figure 3 is an end-to-end baseband model of the physical layer of a wireless metropolitan area network (Wi-MAX), according to the

IEEE 802.16-2009 standard. More specifically, it models the OFDM-based physical layer, called Wireless MAN-OFDM, supporting all of the mandatory coding and modulation options. It also illustrates Space-Time Block Coding (STBC), an optional transmit diversity scheme specified for use on the downlink. Finally, it illustrates the use of digital pre-distortion, a technique for extending the linear range of a nonlinear amplifier [1, 7, 17].

VI. IMPLEMENTATION OF MIMO-OFDM ON LTE NETWORK

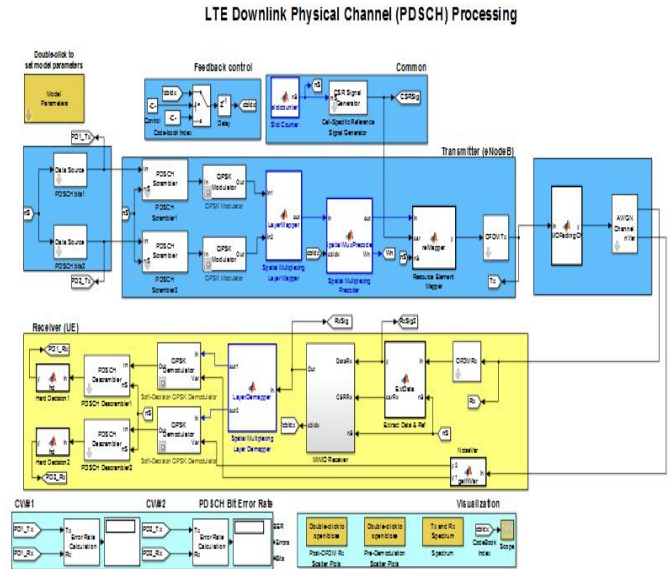


Figure 4 LTE Downlink Physical Channel

The simulation model of LTE is as shown in figure 4. A physical channel corresponds to a set of time-frequency resources used for transmission of a particular transport channel. The source data bits (transport channel encoded bits) are scrambled by a bit-level scrambling sequence. Downlink data modulation converts the scrambled bits into complex modulated symbols. The set of modulation schemes supported include QPSK, 16QAM and 64QAM, corresponding to two, four, and six bits per modulation symbol respectively. We can select the different modulation schemes using the PDSCH modulation type parameter in the simulation. The LTE Encode function combines the transmit diversity layer mapping and precoding as per the LTE Standard. This function uses complex notation for signals and employs the OSTBC Encoder System to implement the space-frequency block coding specified for LTE. The complex-valued time-domain OFDM signal per antenna is generated from the fully populated resource grid, via using the OFDM Modulator System. The simulator uses the MIMO Channel to model the Rayleigh fading over multiple links. OFDM receiver undoes the unequal cyclic prefix lengths per OFDM symbol in a slot and converts back to the time- and frequency-domain grid structure, using the OFDM Demodulator System. Channel Estimation when

selected, employs least-squares estimation using averaging over a subframe for noise reduction for the reference signals, and linear interpolation over the subcarriers for the data elements. Transmit Diversity (TD) combining for the multiple transmitted signals are folded into the TD Combine function which, similar to the encoder, uses complex notation for signals and employs the OSTBC Combiner. The combined data stream is further demodulated and descrambled to get the received data bits [3, 19].

VII. RESULTS AND DISCUSSIONS

The simulation results of the performance of 2x2 MIMO-OFDM system on WLAN physical layer, Wi-MAX physical layer and LTE for different digital modulation techniques namely QPSK, 16-QAM and 64-QAM are derived using MATLAB Simulink. The BER values as a function of SNR are determined for WLAN network for different modulation schemes to study their relative performances with digital modulation. The SNR values are determined as a function of BER for QPSK, 16-QAM and 64-QAM modulation schemes. Figure 5 shows the BER performance of WLAN network derived as a function of SNR for 2x2 MIMO-OFDM multiplexing system for different modulation schemes.

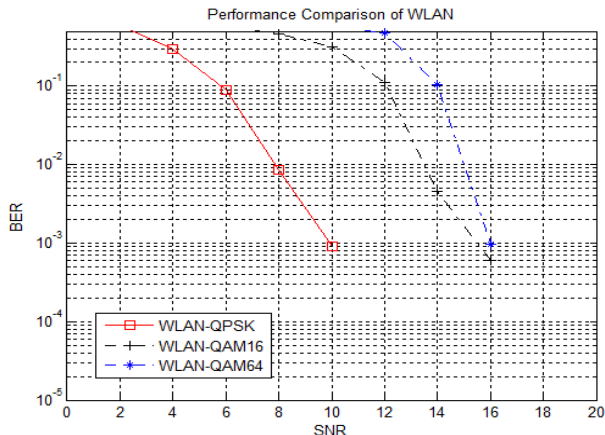


Figure 5 SNR Vs BER performance analysis on WLAN network for different modulation schemes

It is evident in figure 5 that the BER values decreases as SNR increases for different modulation schemes. The figure indicates that implementation of MIMO-OFDM system on the WLAN network for QPSK modulation at BER $\sim 10^{-3}$ dB, depicts an SNR ~ 10 dB, 16-QAM modulation SNR ~ 16 dB is achievable. The simulation results of 2x2 MIMO-OFDM system at BER $\sim 10^{-3}$ dB for QPSK modulation, the SNR is found to be lowest ~ 10 dB and between QPSK and 64-QAM modulation there is a large improvement in SNR ~ 6 dB. The results suggest that, the 2x2 MIMO-OFDM implementation with QPSK modulation is very efficient on WLAN networks.

The BER values as a function of SNR are determined for Wi-MAX network for different modulation schemes to study their relative performances for digital modulation. The SNR values are determined as a function of BER for QPSK, 16-QAM and 64-QAM modulation schemes.

Figure 6 shows the BER performance of Wi-MAX network derived as a function of SNR for 2x2 MIMO-OFDM multiplexing system for different modulation schemes.

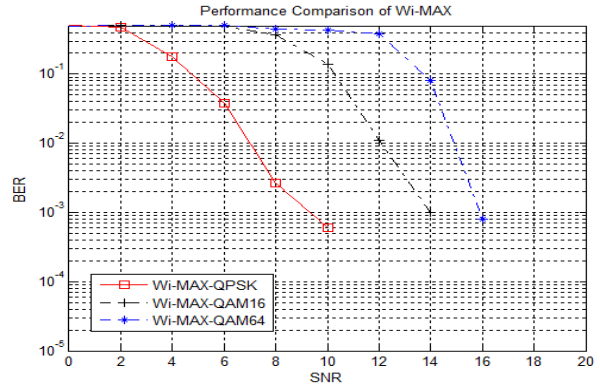


Figure 6 SNR Vs BER performance analysis on Wi-MAX network for different modulation schemes

It can be seen in figure 6 that the BER values decreases as SNR increases for different modulation schemes. The figure indicates that for MIMO-OFDM system at BER $\sim 10^{-3}$, the Wi-MAX network depicts that for QPSK modulation SNR ~ 9.1 dB, 16-QAM modulation SNR ~ 14 dB and 64-QAM modulation SNR ~ 15.7 dB is achievable. The simulation results of 2x2 MIMO-OFDM system at BER $\sim 10^{-3}$ dB for QPSK modulation, the SNR is found to be lowest ~ 9.1 dB and between QPSK and 64-QAM modulation there is a large improvement in SNR ~ 6.6 dB. The results of the simulation studies suggest that, the 2x2 MIMO-OFDM implementation with QPSK modulation is more efficient on Wi-MAX networks.

The BER values as a function of SNR are determined for LTE network for different modulation schemes to study their relative performances for digital modulation. The SNR values are determined as a function of BER for QPSK, 16-QAM and 64-QAM modulation schemes. Figure 7 shows the BER performance of LTE network derived as a function of SNR for 2x2 MIMO-OFDM multiplexing system for different modulation schemes.

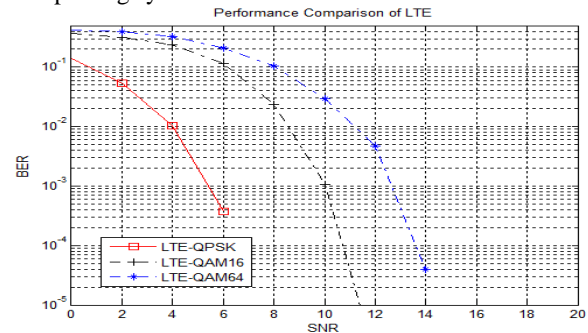


Figure 7 SNR Vs BER performance analysis on Wi-MAX network for different modulation schemes

It can be seen in figure 7 shows that the BER values decreases as SNR increases for different modulation schemes. The figure indicates that for MIMO-OFDM

system at BER $\sim 10^{-3}$ dB, the Wi-MAX network depicts that for QPSK modulation SNR ~ 5.2 dB, 16-QAM modulation SNR ~ 10 dB and 64-QAM modulation SNR ~ 12.8 dB achievable. The simulation results of 2x2 MIMO-OFDM system at BER $\sim 10^{-3}$ dB for QPSK modulation, the SNR is found to be lowest ~ 5.2 dB and between QPSK and 64-QAM modulation, there is a large improvement in SNR ~ 7.6 dB. The results of the analysis suggest that, the 2x2 MIMO-OFDM implementation with QPSK modulation is very efficient on LTE networks.

A detailed comparison of the SNR performance of 2x2 MIMO-OFDM system implementation on WLAN, Wi-MAX and LTE networks as a function of BER for QPSK modulation is shown in figure 8.

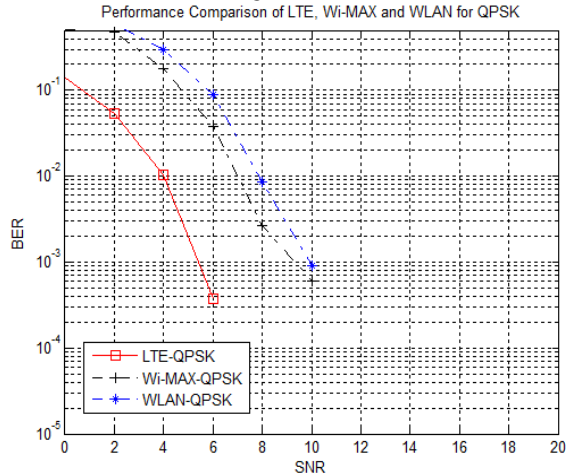


Figure 8 SNR Vs BER performance analysis for QPSK on different networks

It is evident from figure 8 that the BER values decreases as SNR increases for all the three networks. The figure indicates that at BER $\sim 10^{-3}$ dB, the WLAN shows that the SNR ~ 10 dB, Wi-MAX shows SNR ~ 9.1 dB and LTE shows the SNR ~ 5.2 dB are achievable for QPSK modulation. Further the figure shows that there is a large improvement in SNR ~ 4.8 dB between WLAN to LTE networks. The SNR values are being lowest ~ 5.2 dB for 2x2 MIMO-OFDM system implemented on LTE network suggest that, the LTE networks are most efficient for MIMO-OFDM implementation with QPSK modulation. The SNR performance of 2x2 MIMO-OFDM without and with implementation on the WLAN, Wi-MAX and LTE networks for QPSK modulation at BER $\sim 10^{-3}$ dB has been compared in table 1

Table-1- Comparison of MIMO Systems with and without implementation network, SNR Values for QPSK modulation technique for BER $\sim 10^{-3}$ dB

NETWORK	WLAN SNR(dB)	Wi-MAX SNR(dB)	LTE SNR(dB)
WITHOUT MIMO-OFDM ON NETWORK IMPLEMENTATION	12.75	12.75	12.75
WITH MIMO-OFDM ON NETWORK IMPLEMENTATION	10	9.1	5.2
DIFFERENCE	2.75	3.75	7.55

It is clearly evident from the Table 1 that at BER $\sim 10^{-3}$ dB the simulation results show that implementation of MIMO-OFDM transmission on WLAN networks for QPSK modulation there is significant improvement in SNR ~ 2.75 dB. Similarly the implementation on Wi-MAX networks shows an improvement in SNR ~ 3.65 dB. The implementation on LTE networks shows an improvement in SNR ~ 7.55 dB. The result of the analysis indicates that the 2x2 MIMO-OFDM system implementation on WLAN, Wi-MAX and LTE networks offers better SNR performance for higher data rate transmission.

The SNR values derived at BER $\sim 10^{-3}$ dB for the 2x2 MIMO-OFDM implementation on the WLAN, Wi-MAX and LTE networks for different coding schemes and modulation techniques are summarized in table 2.

Table-2 Comparison of SNR values for WLAN, Wi-MAX and LTE for different modulation techniques at BER $\sim 10^{-3}$

CODING TECHNIQUE USED	NETWORKS / MODULATION	QPSK SNR (dB)	16-QAM SNR (dB)	64-QAM SNR (dB)
Convolution coding	WLAN (IEEE 802.11n)	10	15.5	16
Reed-Solomon with Convolution coding	Wi-MAX (IEEE 802.16-2009)	9.1	14	15.7
Turbo coding	LTE	5.2	10	12.8

It is clearly evident from the Table 2 that at BER $\sim 10^{-3}$ dB, the SNR values increase with increasing modulation from QPSK to 64-QAM modulation are consistent with theoretical considerations. Further the table shows that implementation of the MIMO-OFDM transmission on LTE networks for QPSK modulation shows lowest SNR ~ 5.2 dB compared to other networks. The LTE implementation of MIMO-OFDM network indicates a large improvement in SNR ~ 4.8 dB compared to WLAN network. The MIMO-OFDM implementation on the three networks indicates that the SNR values are very sensitive

to the coding techniques. The lowest SNR ~5.2 dB values and the better SNR performance displayed by LTE network compared to WLAN and Wi-MAX networks can be attributed to the efficient Turbo coding schemes adopted by LTE networks.

VIII. CONCLUSIONS

It can be concluded from the results presented that,

1. The simulation results of MIMO-OFDM implementation on network indicates that the SNR at BER 10^{-3} dB increases from QPSK to 64-QAM modulation in accordance with the modulation theory. The results depicts that QPSK modulation exhibits lowest SNR values.
2. The MIMO-OFDM system implementation on WLAN network for QPSK modulation shows that at BER $\sim 10^{-3}$ dB, the lowest SNR values ~ 10 dB and improvement in SNR ~2.75 dB.
3. The MIMO-OFDM system implementation on Wi-MAX network for QPSK modulation show that at BER $\sim 10^{-3}$ dB, the lowest SNR values ~9.1 dB and improvement in SNR ~3.65 dB.
4. The MIMO-OFDM system implementation on LTE network for QPSK modulation shows that at BER $\sim 10^{-3}$ dB, the lowest SNR values ~ 5.2 dB and improvement in SNR ~7.55 dB.
5. The implementation of 2x2 MIMO system on LTE networks QPSK modulation at BER 10^{-3} dB shows an improvement of SNR ~ 4.8 dB compared to WLAN networks.
6. The larger improvement seen in SNR ~ 4.8 dB for LTE networks can be attributed to the Turbo coding adopted in LTE networks.

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REFERENCES

[1] MojtabaSeyedzadegan and Mohamed Othman, "IEEE 802.16: WiMAX Overview, WiMAX Architecture," International Journal of Computer Theory and Engineering vol. 5, no. 5, 2013, pp. 784-787.

[2] S. Pitschajah, V. Erceg, D. Baum, R. Krishnamoorthy and A. Paulraj, "Modeling of multiple-input multiple-output (MIMO) radio channel based on outdoor measurements conducted at 2.5GHz for fixed BWA applications," in Proc. Int. Conf. Communications, 2008.

[3] Prof. LajosHanzo, Dr. Yosef (Jos) Akhtman and Dr. Li Wang, "MIMO-OFDM for LTE, Wi-Fi and WiMAX Coherent versus Non-coherent and Cooperative Turbo-transceivers," 2011. ISBN 978-0-470-68669-0

[4] Manal Al-bzoor and KhaledElleithy, "Wimax Basics From Phy Layer To Scheduling And Multicasting Approaches," International Journal of Computer Science & Engineering Survey (IJCSES) Vol.2, No.1, Feb 2011

[5] HardeepKaur and M L Singh, "Bit Error Rate Evaluation of IEEE 802.16 (WiMAX) in OFDM System," International Journal of Computer Applications, 10-13, February 2012 pp 40(12). Published by Foundation of Computer Science, New York, USA

[6] H. Weingarten, Y. Steinberg, and S. Shamai, "The Capacity Region of the Gaussian Multiple-Input Multiple-

Output Broadcast Channel," in IEEE Trans. Inform. Theory, vol. 52, no. 9, Sep. 2006,pp. 3936-3964.

[7] Gazi Faisal Ahmad Jubair; "Performance Evaluation of IEEE 802.16e (Mobile WiMAX) in OFDM Physical Layer", ME Thesis of Blekinge Institute of Technology 2009.

[8] K. Etemad, "Overview of Mobile WiMAX Technology and Evolution." in IEEE Communication. Mag., vol. 46, no. 10, Oct. 2008, pp. 31-40.

[9] S. Yang, and F. Kaltenberger, "MIMO Algorithms for Wireless LAN,"Proceedings Wireless Congress, Munich, Germany, October 2005.

[10] Yunho Jung, Jiho Kim, Seongjoo Lee, Hongil Yoon, and Jaeseok Kim,"Design and Implementation of MIMO-OFDM Baseband Processor for Wireless MANs", IEEE Transactions on circuits and systems-II Express Briefs, vol. 54, No. 7, July 2007.

[11] Carl Eklund, et.al. "Wireless MAN: Inside the IEEE 802.16 Standard for Wireless Metropolitan Area Networks," IEEE Press, 2006.

[12] Allert van Zelst, and Tim C. W. Schenk, "Implementation of a MIMO OFDM-Based Wireless LAN System", IEEE Transaction on Signal Processing, VOL.52, No. 2, Feb 2004, Pages 483-494.

[13] Katalinic, R. Nagy and, R. Zentnerl, "Benefits of MIMO Systems in Practice:Increased Capacity, Reliability and Spectrum Efficiency," in 48th InternationalSymposium ELMAR, Zadar, Croatia, June 2006.

[14] H. Bölcskei, "MIMO-OFDM wireless systems: basics, perspectives, and challenges," IEEE Wireless Communications, vol. 13, no. 4, Aug. 2006, pp. 31-37.

[15] A. Zelst and T. Schenk, "Implementation of a MIMO OFDM-based wireless LAN system," IEEE Trans. Axoustics, Speech and Signal Processing, Vol. 52, No. 2, Feb. 2004, pp 483-494.

[16] J. G. Andrews, A. Ghosh, R. Muhamed, "Fundamentals of WiMAX: Understanding Broadband Wireless Networking," Prentice Hall PTR, Feb, 2007.

[17] A. G. R. G. Hanna and A. H. Zekry, "Development of WiMAX physical layer building blocks,"Third International Conference on Intelligent Systems Modeling and Simulation2012, pp. 537-541.

[18] V. K. Jain D. Divakaran, "Channel Estimation for a New High Performance MIMO STC-OFDM WLAN System", IEEE Communications Letters, Vol. 6, June 2010.

[19] Christoph Spiegel, Jens Berkmann, Zijian Bai, Tobias Scholand, Christian Drewes, "MIMO Schemes In UTRA LTE, A Comparison", IEEE 2008, pp 2228-2232, 2008.

[20] Hsin-Lei Lin, Robert C. Chang, "Implementation of Synchronization for 2x2 MIMO WLAN System", IEEE Transactions on Broadcasting, Vol. 52, No. 14, December 2012.



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