Open Access
Full Length Article

ORIGINAL ARTICLE

A Measurement Study of Cooperative Network on WiMAX Technology using BICM LDPC with iterative Decoding Technique

Hamid Hussain[1], Usman Masud[2], Tausif Zahid[3], Muhammad Zahid[4]

[1,2]Department of Electronic Engineering, University of Engineering and Technology, Taxila
[3,4]Department of Electrical Engineering, Riphah International University, Lahore

ABSTRACT

Wireless technology can be split into two major portions, mobile and fixed wireless infrastructure (Wireless Local Loop). Today, the demand for mobile systems is increasing with the passage of time from voice to higher data rate services. It is difficult to make mobile systems trustworthy for the services that practice a very high digital bandwidth such as triple play (Telephone, Cable TV and Internet), MIMO systems are used in 4G technology for high data rate services. A network is designed with the cooperation surrounded by the involved nodes to accomplish substantial improvement in the capacity of the entire system keeping improved Quality of Service (QoS). Cooperative networks can be used to minimize signal degradation and power reduction in most of the networks. Here, WiMAX LDPC technique is used in cooperative networks. Numerous models of fading channels have been utilized to examine the health of the communication system. The channel capacity approaching coding method LDPC with the help of BICM is used to measure the performance with the main focus to analyze the performance measurements of WiMAX (IEEE 802.16).

Keywords: WiMAX, Quality of Service, Bandwidth, Cooperative Networks

Author`s Contribution	Address of Correspondence	Article info.
[1,2] Manuscript writing, Data Collection Data analysis, interpretation, Conception, synthesis, ,[3,4]planning of research, and discussion	*Tausif Zahid tausif. zahid@riphah.edu.pk*	*Received: March 09,2019 Accepted: November 16,2019 Published: December 30,2019*

Cite this article: *Hussain H, Masud U, Zahid T, Zahid M. A Measurement Study of Cooperative Network on WiMAX technology using BICM LDPC with iterative decoding technique. J. Inf. commun. technol. robot. appl.2019; 10(2):1-8*

Funding Source: *Nil*
Conflict of Interest: *Nil*

INTRODUCTION

The importance of wireless communication cannot be neglected from the last decade due to mobility and easy access [1], [2]. Third and fourth Generation systems (3G and 4G) have been introduced due to technological progress from wired communication to high bandwidth wireless communication [3], [5]. Data and bandwidth capacity are the key areas of concern for wireless communication research. High data rate technologies have occupied the outdated wireless communication system and WiMAX is one of these access systems [6], [11], [24]. As known well the three key parts of a telecommunication system are,

- Access
- Switching/Core
- Transport/transmission

The main focus area here is an access layer, which is being subjected to maximum research due to the demand for hi- speed data. 3G and 4G systems have a significant change in the access part/layer due to the large data requirement of the customer. CDMA, OFDMA, and similar techniques are examples of high data rate access. Some services need higher bandwidth to minimize user data services related issues.

Video conferences and further connected services having part of value-added services require additional throughput and seamless service data sending to end consumers. To enhance the bandwidth of access part of the system, 3G and 4G systems are employed. Soft switches and optical fiber systems are used in the core and transport layer that has a large data rate or bandwidth.

This is important to maintain Quality of Service (QoS) in a wireless access network. Factors (3R) that are used to check the quality are listed below.

- Range of signal
- Rate (Data Rate)
- Reliability

Profound investigation demonstrates that frequency band channel effectiveness desired to be upgraded to enhance the above-mentioned factors (3R). As per preceding information, this is recommended that when a remote channel is to a great degree recurrence, it suits essentially to perform on Inter-Symbol Interference (ISI), Fading and Noise strength. This is necessary to specify that multipath phenomena can't be eliminated, and these lines are used as an advantage rather than seen in CDMA technology. The time lapse must be considered, when a signal arrives at the receiver from various areas [4], [8], [13]. A substantial number of clients are being taken care of by better services. The demand cycle is shown in figure no Fig. 1.

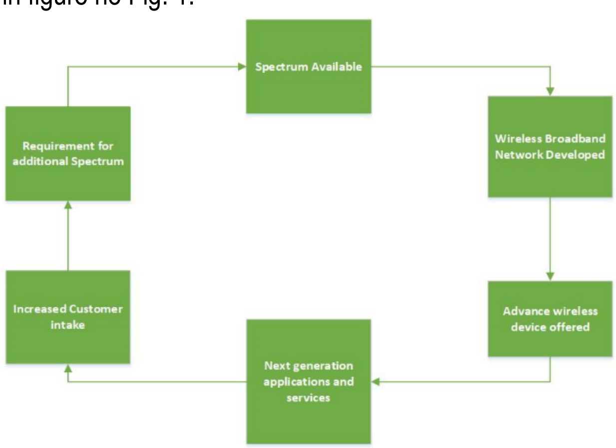

Figure 1. Demand Cycle

More up to date, latest technologies are IP based. Optical fibers are used at the transport layer, Soft Switches (SS) are utilized at the center layer striving to achieve the growing demand of users for multiple services [7]. OFDMA is used at the access layer for efficient use of Transport and Core capacity sing Smart in 4G and 3G systems. 4G systems have numerous highlights which empowered them to emerge by different advancements with highest data rate approximately up to 100 Mbps for more mobility such as mobile connectivity capable of one Gbps and short mobility like local area wireless link. Tractability for organizing web and security issues has upgraded the QoS issues. The systems that are being utilized. for the organization course of action are consolidated and can be achieved from wherever to assign the services to the customers. Public-Private systems are associated, and real globalization is achieved. Due to more throughput at the access layer, rapid access, and information exchange end up conceivable. A concise advancement of different system evolution is displayed in fig. 2

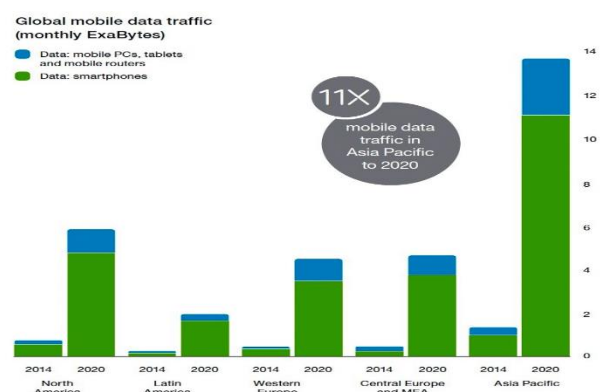

Figure 2. Ericson Mobility report [1]

At the user end, hand-off and expansion are very simple as compared to ancient technologies. After adding OFDM with TDMA/FDMA for enhanced spectral performance, OFDMA delivers better outcomes [17]. Enhancing the number of users in an access system for BB services, Multi-path attenuation, and frequency seductiveness can be minimized with this technique.

OFDMA is the type of advanced access technology and utilized for high digital data rate applications. Fading can be reduced by using above technology for high capacity 3G and 4G cellular applications. In OFDMA technology, using multiple antennas at transmitting and receiving end outcomes best practice which is basically employed in MIMO applications [12]. Signal to noise ratio (SNR) means channel efficiency, increases with enhancement of antennas at both Mobile station and at the Base Station in cellular network. Cooperative networks adopt this concept virtually this idea was presented by Nosratinia and Hunter in 2002 [14]. The use of single antenna, Cooperative communication is best answer for spatial diversity enhancement and antenna gain that results in a low cost array of antennas. The study on cooperative networks range was presented by Van der Meulen [15]. Info interrelated to channels with relays have been incorporated for the use of cooperative communication. Cooperative communication which is used among neighboring relay nodes which was presented by Gamal [16]. Several sources and relays station sends an identical signal (image) to receiving station. It works as a virtual antenna array. The antenna array between channel paths functions as a system for exchange of information. Concept of cooperative network is given in Fig. 3

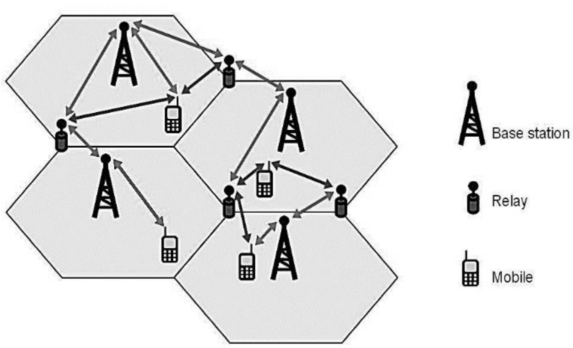

Figure 3. Concept of Cooperative Networks

LITERATURE REVIEW

A. OFDMA

This is the most prominent procedure for communication that accomplishes more throughput and flexibility for channel attenuation. It effectively makes utilization for spectrum regardless of the loss of frequency. Furthermore, noise factors and fading, which results in unified communication are also minimized with this technology in an efficient way. It requires a high capacity communication equipment which may be able to produce frequency, increasing OPEX. Splitting a frequency spectrum into discrete spectral outlines are called orthogonal frequencies. Every slot having a peak of frequency, that isn't intruded by spectral slot right adjacent to it. The spectral channel is getting split into sub-carriers and every carrier carries a fraction of data. Every sub carrier (having a small data rate) is modulated in a way that sub-carrier adjacent to it, is distinct and easily separated at receiving side.

B. LDPC

Low-Density Parity Check Code can be used for error correction coding which functions for getting Shannon limit. First presented by Rober G Gallager in 1960 [17],[18]. Research continued to explore coding in 1990 utilizing mapping codes using iterative coding. LDPC coding is utilized to enhance the performance of BER to achieve the Shannon limit. This method is like turbo codes used for error rectification. LDPC is trustworthy and has many benefits on turbo coding technique which are:

- BER performance is better
- Greater error correction
- Uses Trellis coding due to simple than turbo coding

C. Coding methods and Modulation

To achieve efficient use of available bandwidth, these are employed for getting coding gain. When bandwidth is not consumed in an appropriate way, the data rate decreases [21]. This is called a coded modulation. Modulation of analog functions and coding of digital functions are performed separately due to independent functions. Integration of the above two systems in one function, called trellis code modulation and utilized in band-limited slots.

D. Hamming Distance

This is necessary to elaborate on the concept of Hamming distance before describing error finding and error rectification in digital transmission. It can be defined as “the number of distinguished bits between two vectors”. In the case of no variation, the distance will be null. The overall count of deviations is the distance in between two-bit vectors. This Euclidian distance relates to actual no of the analog system whereas hamming distance is binary and utilized in coding [10]. Using coded modulation, a very high spectral efficiency is accomplished that contains Block

Coded Modulations. An alternative method is Trellis Coded Modulation. Using innovative designs, enhanced coding gain is generated for the execution of TCM, preparing of simplicity in coding and decoding is essential. Both have two main flaws that bound their uses. TCM and BCM have a significant effect on AWGN channels, however, their performance reduces in fading channels [22], [23]. For this compensation, a dominant binary coding is needed. For this purpose, signal power is enhanced to get the desired gain and BICM technology is utilized [19],[20]. Interleaving between modulations and encoding is done using bit interleaving for saving power with great spectral efficiency [22]. Fading can be divided into Small Scale Fading (SSF) and Large-Scale Fading (LSF). Here, abrupt variations in amplitude and phase of receiving signal is deviated within a minute time interval or traveling distance, named as SSF. SSF has a very small time and distance variations [23], is the reason for constructive and destructive interference for the received signal from diverse routes. Signal strength of combined signal fluctuates arbitrarily and cause signal amplitude variations. Following parameters badly disturb the SSF are, roaming speed of source and destination, multi-path propagation, and relative speed of objects between the source and destination [23].

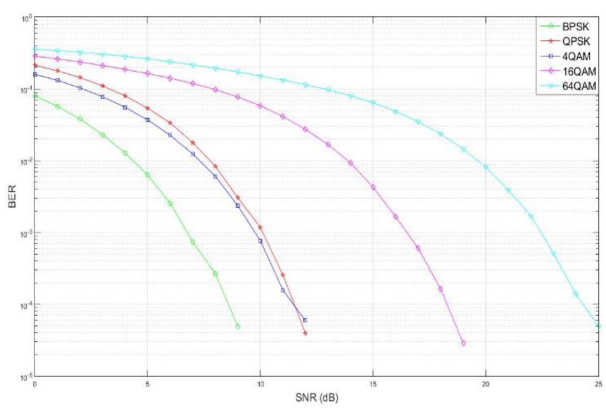

Figure 4. BER in OFDM Communication System

E. Small Scale Fading

This type of fading has two types, and these are frequency selective and flat. If linear phase response is greater than the bandwidth of transmitted signal and bandwidth of channel has a steady gain, then signal received faces the flat fading. When the transmitted signal has low bandwidth in comparison to the channel bandwidth, the signal at receiving end effects on amplitude variations due to a variant gain of the channel over time formed due to multi path propagation of the signal.

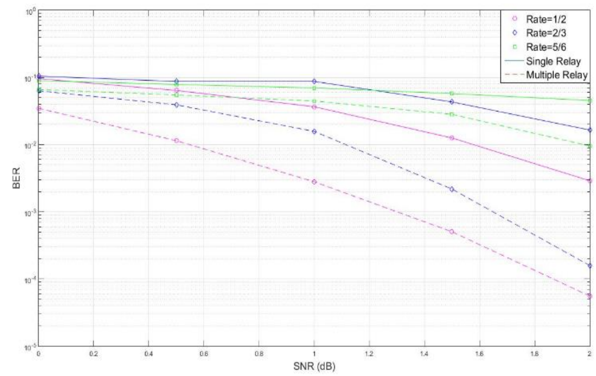

Figure 5. Performance comparison of multiple relays with single relay

F. Large Scale Fading

This fading effect is also known as slow fading and it appears due to variations in amplitude of the signal and huge distance between transmitter and receiver. The overall signal strength is the important limitation in LSF for specific separation between the sender side and receiver side. It shows the average path loss in the system along with a distance between the transmitter side and the receiver side.

RESULTS

MATLAB is used for analysis in two steps. In the first step, analysis of OFDM in AWGN channel utilizing Coded Modulation Library. For the second stage, the communication system is then simulated on Cooperative Networks using WiMAX LDPC. Performance is basically the Bit Error Rate (BER) of different Modulation arrangements, no. of Relays,Coding rate and dissimilar fading channels together with free space path loss influence below modulation schemes have been incorporated in simulation separately for assessment at last.

- BPSK
- QAM
- QPSK
- 16-QAM
- 64-QAM

The initial analysis is performed for the OFDM system using the AWGN channel, avoiding the use of encoding method and cooperative systems. Then performance is observed through MATLAB based results with multiple modulation schemes utilized in the OFDM system with BER vs SNR for each modulation. The OFDM analysis is established on the WiMAX standard (IEEE 802.16e) for Mobile. In this system, 2048 FFT (size) is utilized which provides a bandwidth of up to 20 MHz. Data subcarriers are used for suitable transmission, pilot carriers for the multiple numbers of channels assessment and synchronization management of communication system. For guard band, null sub-carriers are used, and DC carrier does not transport any information.

In Fig. 4 the OFDM communication system performance using 2048-FFT shows the AWGN fading channel with no use of any cooperative networks and encoding. Here, it is observed that high order modulation systems are less efficient than low order modulation systems. It shows fewer BER values with Low SNR. BPSK modulation system shows BER is 10-4 at when SNR is 8 dB, while 64-QAM shows the same BER with 24 dB SNR. Here approximately 16 dB more gain is achieved in BPSK than the 64-QAM system. Even though, high order modulation systems show greater data rate. However, for an efficient and reliable communication system, low order modulation systems are better. In both QAM and QPSK, BER results are identical as they show the BER having 10-4 with 12 dB SNR.

A. LDPC BER analysis with multiple coding rates

LDPC coding is utilized as a subsection of the QPSK signal for better channel capacity and BER. Different coding parameters are

1. Coding Rate with single Relay:

- Single Relay with 1/2 rate of coding
- Single Relay with 2/3 rate of coding
- Single Relay with 5/6 rate of coding

2. Coding Rates with multiple Relay:

- 1/2 coding Rate
- Multiple Relay with 2/3 coding Rate

Multiple Relay with 5/6 coding Rate

For performance enhancement, BICM-ID system is utilized with QPSK. Here Relays have been utilized to Amplify and Forward (AF) in cooperative networks. Using one and multiple relays, different LDPC coding rates are discussed for both one and multiple Relays coding rates. In Fig. 5, several relay performances are improved than one relay. Several relays provide a low bit error rate than the individual relay. This concludes that the increase in the number of relays, the performance may increase as well. Similarly, with low SNR value, ½ coding rate shows a lower bit error rate than 2/3 and 5/6 coding. Several relay performances are the best with code rate 1/2, which performs trustworthy communication having bit error rate value 10-4 with very small signal to noise approximately near to 1.9 dB. Alternatively, code rate of 5/6 shows very little performance with one relay.

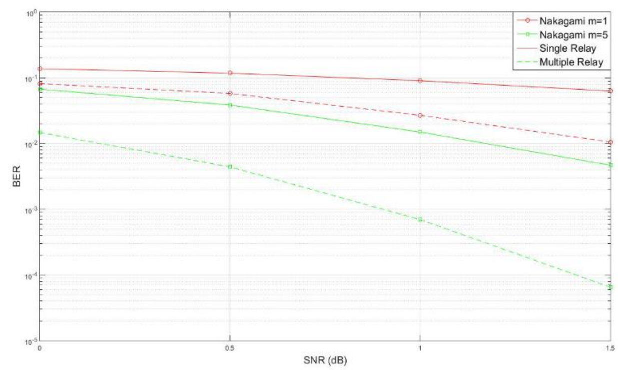

Figure 6. Nakagami M fading Channel BER Analysis

B. Fading Channel's Performance

The performance on diverse fading channel is examined in the form of bit error rate vs signal to noise for cooperative networks using WiMAX Low-density parity-check code. Initially, the performance of fading communication channels for parameters having both individual and multi-relay cooperative networks code with dissimilar fading communication channel is examined in BER vs SNR. Here, factor m is varied in Nakagami-m channel whereas factor k is altered in Rician-K channel to evaluate the BER performance. In the second step of simulation, the performance analysis having dissimilar fading channels for individual and several relay cooperative networks with iterative and non-Iterative Bit-Interleaved Coded Modulation. In this simulation, Q-PSK modulation having code rate 1/2 is supposed because the simulation results illustrate low value of SNR with lower BER. Fig. 6 shows the simulation sequence as listed below:

1. Fading Channel.

2. One Relay communication networks:
   - Nakagami M
   - Rayleigh
   - Rician K
3. Multi Relay communication Networks:
   - Nakagami M
   - Rayleigh
   - Rician K

C. Nakagami M Fading Channel–BER analysis

Nakagami-m distribution fading channel is used for performance analysis as shown in fig. 6 here at lower SNR value, the system shows lower BER value for m 1 to 5. The performance increases at m=5 instead of m=1. In the same manner, the multiple relay performance shows that with small SNR, the BER is low than one relay for both m=1 and m=5. Results show that the best performance result is achieved using Nakagami distribution with m=5 using multiple relays. Here, at 1.4 dB SNR, the BER value is 10-4, which is better for reliable communication.

D. Rician-K Fading Channel-BER Analysis

Fig. 7 relates to performance analysis for Rician-K fading channel. Using individual and several relays, three diverse values of K are captured to visualize the performance. For both one and multiple relays, the factor K is changed from 1 to 10. At lower SNR value, the system comes up with a lower Bit error rate value. For both the individual and several relays, the Rician with K=10 shows the best performance than K=1 and K=5. As per results, the performance of several relays are better than an individual relay for any K value. With multiple relays, simulation result with K=10 shows best performance. This means, bit error rate of 10-4 is viewed at SNR of 1.4 dB which is very effective for trustworthy communication.

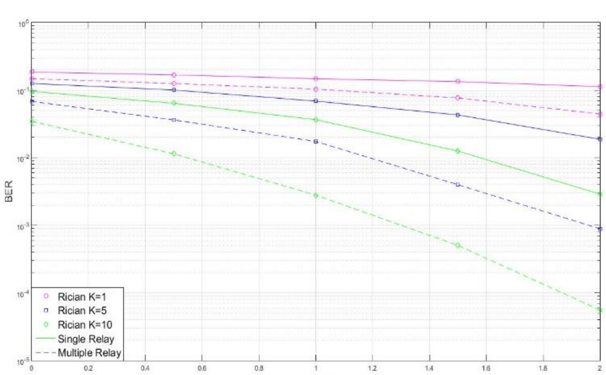

Figure 7. Rician K fading Channel BER Analysis

E. LDPC-BICM for BER Analysis

In Fig. 8 the performance is analyzed using LDPC BICM with multiple fading channels having one and multiple relays. In the aforementioned simulations on basis of their better performance, Nakagami m=5 and Rician K=10 are here considered. For both the individual and several relays, the Nakagami performance is greater than Rician and Rician performance is greater than Rayleigh fading communication. At lower signal to noise value, the bit error rate value is very low. Using Nakagami m=5, the BER value 10-3 is observed with very low SNR vale with multiple relays.

F. LDPC-BICM-ID for BER Analysis

In Fig. 9, using both individual relay and several relays, the performance of LDPC-BICM-ID with multiple fading channels is observed. Using Nakagami and Rician fading channel, the simulation is observed with K=10 and M=5. The BER 10-4 is attained with low i.e 1.4 dB SNR. The Rician performance is greater than Rayleigh fading communication channel using one and multiple relay networks.

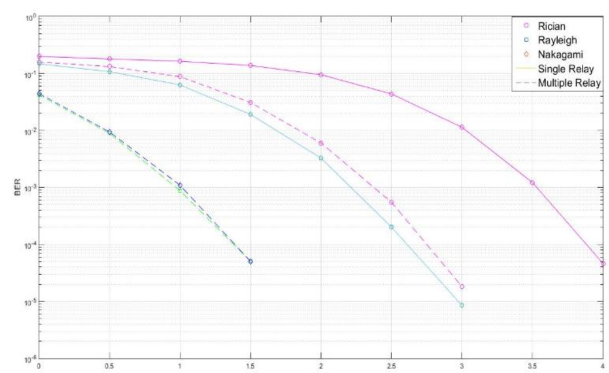

Figure 8. LPD-BICM-BER Analysis

G. BI-LDPCM and BI-LDPC-ID-BER Comparison

Fig. 10 shows BI-LDPC-ID with different fading channels is examined using multiple relays. To achieve better results. As the graph shows, BI-LDPC-ID indicates low BER value 10-3 at 0.9 dB SNR as compared to BI-LDPCM having BER of 4.5 dB with same SNR. The BI-LDPC-ID performance enhances to 3.6 dB greater than BI-LDPCMH.

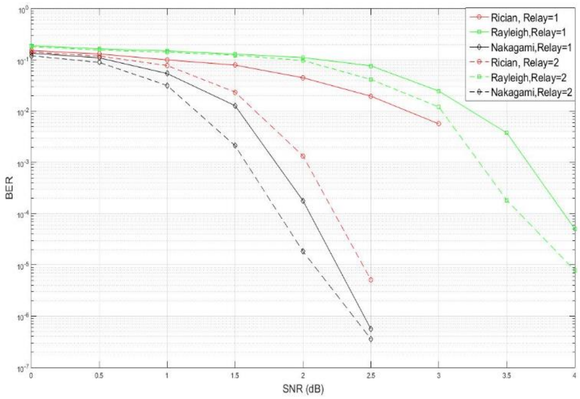

Figure 9. LPD-BICM-ID-BER Analysis

H. Performance Measurement of Fading Channel with and without path loss effect

Considering free space path loss in analysis, the performance analysis is examined for diverse fading. For better results, the positions of relays from source/destination are changed. The performance of Nakagami channel is greater than Rician and Rayleigh. At low SNR value, it has a lower BER. It has more improved gain of 2 dB than Raleigh and 0.5 dB gain than Rician. The BER is 10-3 with 4.4 dB SNR for Nakagami channel. It can be concluded from figure 10 that without path loss, BER is small.

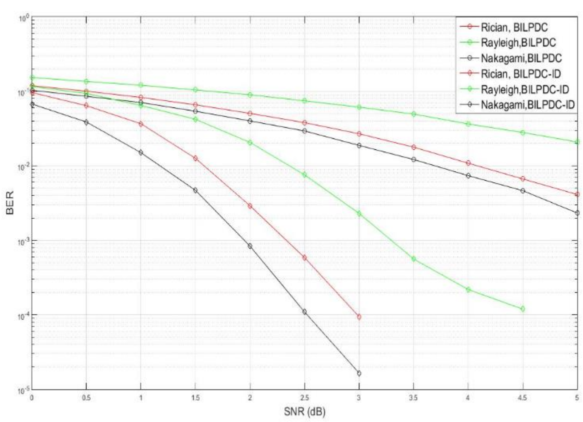

Figure 10. BI-LDPCM and BI-LDPC-ID-BER Comparison

I. Variation of Relay position- BER Analysis

The position of relays are varied from source to destination at different positions as shown in figure 11 with following sequence:

- At 0.25 distance from source to destination
- At 0.50 distance from source to destination
- At 0.75 distance from source to destination.

As shown in fig. 12, at the midpoint the results are better than other two positions. The BER at mid-point is low for low SNR. Relay placement at mid-level from both source and destination results a trustworthy communication.

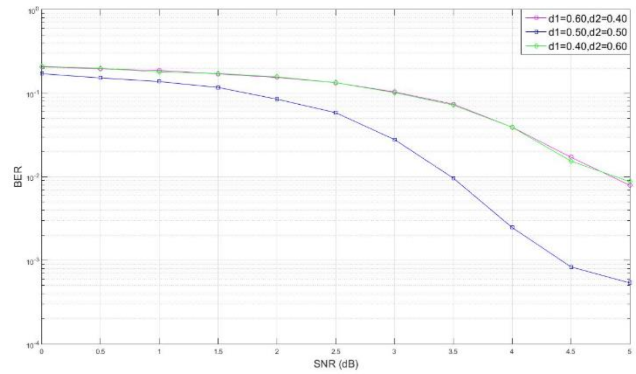

Figure 12. Variation of relay position BER Analysis

CONCLUSION

The objective of this research is the improvement in 4G system, in the design of system model and its testing using AWGN fading channel environment and in Multipath fading using MATLAB. MIMO technologies have composite hardware with cell size restriction. The solution to the problem is OFDMA Cooperative networks. Multiple modulation techniques are checked and concluded that QAM and QPSK deliver low BER and higher data rates than conventional methods. In WiMAX-LDPC Cooperative networks, the QPSK modulation is used. Initially, on single and multiple relays the performance analysis of multiple coding was done. Better BER performance is achieved using multiple arrays. Using multiple relays, Nakagami-m fading performance is superior to Rician-K and Rayleigh fading. With a low power transmitter, the Range, Reliability and Rate (RRR) are improved. The cost effectiveness is observed in this method due to no use of multiple antennas and previous MIMO based systems

REFERENCES

1. Cisco Visual Networking Index: Forecast and Methodology, 2016-2021, Aug, 2017. [Online]. Available:https://www.cisco.com

2. Tausif Zahid, Xiaojun Hei, Wenqing Cheng, Adeel Ahmad, Pasha Maruf, On the Tradeoff between Performance and Programmability for Software Defined WiFi Networks, Wireless Communication and Mobile Computing, 2018
3. Chung, M-A, Chang, W-H. Low-cost, low-profile and miniaturized singleplane antenna design for an Internet of Thing device applications operating in 5G, 4G, V2X, DSRC, WiFi 6 band, WLAN, and WiMAX communication systems. Microwave Optical Technology Letter. 2020.
4. R. Laroi, S. Uppala and J. Li, "Designing a Mobile Broadband Wireless Access Network", IEEE Signal Processing Magazine, Vol. 25, Sep. 2004.
5. Tausif Zahid, Xiaojun Hei, Wenqing Cheng, Understanding Performance Bottlenecks of a Multi- BSS Software Defined WiFi Network Testbed, The First IEEE International Conference on Computer Communication and the Internet (ICCCI 2016), Wuhan China, Oct 13-15, 2016.
6. Dattatreya, G, Naik, KK. A low volume flexible CPW-fed elliptical-ring with split-triangular patch dual-band antenna. International Journal of RF and Microwave Computer Aided Engineering, 2019.
7. T. Zahid, X. Hei, W. Cheng, Understanding the Design Space of a Software Defined WiFi Network Testbed, 14th International Conference on Frontiers of information Technology (FIT2016), Islamabad Pakistan, Dec. 19-21, 2016.
8. Hui Liu and Guoqing Li, "OFDM-Based Broadband Wireless Networks", John Wiley and Sons, Inc., 2015.
9. Sah, BK, Singla, G, Sharma, S. Design and development of enhanced bandwidth multi-frequency slotted antenna for 4G-LTE/WiMAX/WLAN and S/C/X-band applications. International Journal of RF Microwave and Computer Aided Engineering, 2020.
10. Li X., and Ritcey J. A., Bit-interleaved coded modulation with iterative decoding,"IEEE Commun. Lett. vol. 1, pp. 169171, Nov. 2015.
11. Sedighi Maragheh, S, Dousti, M, Dolatshahi, M, Ghalamkari, B. A dual-mode tunable bandpass filter for GSM, UMTS, WiFi, and WiMAX standards applications. Int J Circ Theor Appl pp 561- 571, 2019.
12. Mohammad Saadh, AW, Poonkuzhali, R, Ali, T. A miniaturized single-layered branched multiple-input multiple-output antenna for WLAN/WiMAX/INSAT applications. Microwave and Optical Technology Letter pp 1058- 1064, 2019.
13. Sharma, M, Awasthi, YK, Singh, H. Compact multiband planar monopole antenna for Bluetooth, LTE, and reconfigurable UWB applications including X-band and Ku-band wireless communications. Int J RF Microwave Computer Aided Engineering, 2019.
14. Frank H. P. Fitzek and Marcos D. Katz,"Cooperation in Wireless Networks: Principles and Applications" Springer, 2006.
15. E. C. van der Meulen, "Three-terminal communication channels", Advances in Applied Probability, vol. 3, 1971
16. Rahul Kulkarni. "WiMAX Mesh Based Back-Haul For Tactical Military And Disaster Area Networks", Fourth International Conference on Communication Systems and Networks, COMSNETS ,2012
17. Nabar Rohit U., Blcskei Helmut, and Kneubhler Felix W, "Fading Relay Channels: Performance Limits and Spacetime Signal Design," IEEE Journal on selected areas in Communications, VOL. 22, NO. 6, August 2004.
18. IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed Broadband Wireless Access Systems. [Online]. Available: www.standards.ieee.org › standard › 802_16-2001
19. Li X., and Ritcey J. A., Bit-interleaved coded modulation with iterative decoding,"IEEE Commun. Lett. vol. 1, pp. 169171, Nov. 2015.
20. B. K. Khoo, S. Y. Le Goff, B. S. Sharif, and C. C. Tsimenidis, "Bit- interleaved coded modulation with iterative decoding using constellation shaping," IEEE Transactions on Communications, vol. 54, no. 9, pp. 1517-1520, Sep.2016.
21. G. Ungerboeck, "Channel Coding with Multilevel/Phase Signals," IEEE Transactions on Information Theory, Vol. IT-28, No. 1, pp. 55-67, January 1982. vol.52, no. 1, pp. 262271, January 2015.
22. A. Meier, "Cooperative Diversity in Wireless Networks", MSc Thesis, University of Edinburgh, 2014.
23. J. N. Laneman, G. W. Wornell and D. N. C. Tse, "An Efficient Protocol for Realizing Cooperative Diversity in Wireless Networks", Proc. IEEE ISIT, Washington DC, June 2015.
24. Sah, BK, Singla, G, Sharma, S. Design and development of enhanced bandwidth multi- frequency slotted antenna for 4G-LTE/WiMAX/WLAN and S/C/X-band applications. International Journal of RF Microwave and Computer aided Engineering, 2020