Performance Analysis Of Decode and Forward Two Way Relaying Network With Co-Channel Interference and Channel Estimation Error

DISSERTATION-II REPORT

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by

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Under the Guidance of

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TOPIC APPROVAL PERFORMA

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Declaration

I, Shilpa, student of M-Tech Electronics and communication under Department of Electronics and communication of Lovely Professional University, Punjab, hereby declare that all the information furnished in this Dissertation-II report is based on my own intensive research and is genuine.

This thesis does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

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Abstract

Cooperative relaying is a promising diversity achieving technique to provide reliable transmission, high throughput and extensive coverage for wireless networks in a variety of applications. Two-way relaying is a spectrally efficient protocol, providing one solution to overcome the half-duplex loss in one-way relay channels. Moreover, incorporating the Multiple Input Multiple Output (MIMO) technology can further improve the spectral efficiency and diversity gain. A lot of related work has been performed on the Two-Way Relaying Network (TWRN), but most of them assume perfect Channel State Information (CSI). In a realistic scenario, however, the channel is estimated and the estimation error exists. So in this thesis, we explicitly take into account the Channel Estimation Error (CEE) and also Co-Channel Interference (CCI) and investigate its impact on the performance of Decode and Forward (DF) TWRN. The performance metric which is used for analysis is Signal to Noise Gap Ratio (SNGR) which measures the reduction in the SNR value in presence of CCI and CEE. On the basis of this metric, effect of different parameters on the DF TWRN with CCI and CEE is evaluated. In a realistic scenario, however, the channel is estimated and the estimation error exists. So in this thesis, we explicitly take into account the Channel Estimation Error (CEE) and also Co-Channel Interference (CCI), and investigate its impact on the performance of Decode and Forward (DF) TWRN.

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List of Abbreviations

NC-Network Coding

AF- Amplify-and Forward

DF-Decode-and-Forward

CF-Compress-and-Forward

LAN -Local Area Network

OP-Outage Probability

HDAF- Hybrid Decode-Amplify-Forward

CRC- Cyclic Redundancy Check

OWRN- One Way Relaying Network

PNLC- Physical Network Layer Coding

TWRN-Two Way Relaying Network

BER-Bit Error Rate

SNR-Signal to Noise Ratio

SINR-Signal to Interference Noise Ratio

SNGR-Signal to Noise Gap Ratio

OF-Orthogonalize and Forward

CCI-Co-Channel Interference

CSI-Channel State Information

CEE-Channel Estimation Error

DSTBC-Distributed Space-Time Block Code

OJISR-Opportunistic Joint Incremental Selection Relaying

IAF- Incremental Amplify-and-Forward

BEP- Bit Error Probability

Chapter 1

Introduction

1.1 Network Coding

There has been a meteoric expansion in development of narrative overlay network architectures in the past decade. Many of these are peer-to-peer or cellular mesh networks offering origin and path diversity to data delivery applications. Network diversity allows us to enhance service quality of multimedia streaming applications with added throughput and better resilience to failures [1].

Overlay networks provide flexibility of utilizing basic processing functions at intermediate network nodes, in addition to providing increased source or avenue variety. These important properties can add to improve delivery performance [2]. For instance, the nodes are capable of doing simple coding functions on packets before transmitting to be able to raise the goodput. This concept is recognized as network coding and it has truly gone quite a distance from a strictly analytical strategy to an approach suitable to data dissemination in the web at the moment. Network Coding (NC) systems still face important issues in sensible systems because of the decoding delays enforced by successive network coding functions.

Network Coding holds lot of promise as a technique for communication systems in future. The fundamental thought behind NC may be the linear blend and compression of varied traffic flows using algebraic functions at intermediate nodes for example routers or relay stations. This approach will provide a maximum capacity and high data rates for various wireless applications [3].

Most of the network secret writing analysis to this point has been centered either on theoretical aspects of network secret writing like realizable capability and secret writing gain, or on its sensible aspects like lustiness and raised output once the quantity of innovative packets is spare for excellent decryption [4].

Over the last decade, there have been numerous investigations on the application of NC. The main designing aim is to make a network of such kind which can help us to gain maximum capacity and provide high data rate with minimum number of losses. To make this effort a reality, various new algorithms and protocols were proposed. Basically NC depends on the global network topology. As compared to wired networks, wireless networks are able to apply NC flexibly for getting maximum gain and maximum throughput for unicast communication. Nowadays, two way relaying networks have gained a lot of interest as it helps to overcome the losses that we face in one way relaying networks.

An extensive study has been carried out throughout the last decade in the field of Wireless Network Coding. Wireless Network Coding can mainly be categorized into two scenarios, namely TWR with 3 time slots (where the 2 Source Nodes transmit in 2 different time slots hence avoiding mutual interference) and the 2 time slot Two Way Relaying (where both the sources transmit at the same time resulting in the superimposition of the both signals in air).

NC is a promising networking technique which is used to enhance the throughput, scalability and robustness of a network. Theoretically, NC can certainly improve the robustness and the goodput of a wireless network. However, before NC technique is really accepted and applied in practical scenarios, security challenges must be carefully addressed [7]. Inability to address these security challenges may lead to lack of confidence among people in accepting and actuating this NC technique [8]. Although nowadays researchers are focusing their research on network coding security challenges in seclusion and pollution attacks. To prevent from various attacks or to make our security more powerful, researchers are using various cryptographic techniques like Diffie Hellman Key exchange, Rivest Shamir Adleman, Pretty Good Privacy, etc. But still with the increasing technology, various new challenges are also coming day by day related to the security. Therefore, the researches related to make NC security more secure and powerful is still going on and researchers are trying to find new algorithms which will deal with the new updated applications and provide us more reliability and security.

Data transmission over relay nodes relies on the assumption that each relay node performs a predetermined function on its received signal and sends the result over the network. However, the capacity of a wireless relay network can be reduced due to existence of malfunctioning or malicious nodes (inserting errors).

Nowadays, Two Way Relaying has come forth as a prominent and a more powerful technique for increasing a network’s throughput and spectral efficiency. There are various numbers of relaying protocols proposed namely Amplify-and Forward (AF), Decode-and-Forward (DF) and Compress-and-Forward (CF). On the other hand, reliability and secrecy of data transmission is an important issue in communication over a wireless network in presence of malicious nodes. Such a node may wish to limit the communication by sending jamming signal to the network, or pretend to be the legitimate transmitter. The NC offers a wireless network performance improvement for two–way communication or multiway communication flows [10]. There are so many previous researches which have already been done on the one way relaying protocol and bidirectional relaying protocol. The researches include various new algorithms and techniques which were analyzed over various propagating channels. From the different researches, it is concluded that two way relaying networks have the capability to overcome the losses which are faced by one way relaying networks.

Recent Two Way Relaying protocols have gained attention by overcoming the losses that has occurred in OWR network. It completes its work of information exchange within 2 or 3 time slots whereas the OWR network completes its communication within 4 time slots [11].

1.2 Relays

The throughput extend coverage of cellular networks can be increased by using relays. The relays are used for transmission and reception of signals between mobile stations and base stations. Infrastructure relays do not require wired connection to the network thereby reducing operators' backhaul expenditures. LAN (Local Area Network) between the Mobile users which are under the wide area of cellular networks can be built by using mobile relays.

Amplify-and-Forward (AF) relays amplify the signal coming from the source and forward that amplified signal to the destination whereas Decode–and-Forward (DF) relays decode the signal coming from the source and then after perfect decoding re-encodes the decoded signal and then forwards that decoded signal to the destination. The working mode of Relays is either half-duplex mode or full-duplex mode. In half duplex mode, transmission and reception is not done simultaneously. And in full-duplex mode, the transmission and reception is done simultaneously. Spatial separation between the transmit and receive antenna is required for the latter operation. Spatial separation is required for reducing loop back interference from the transmit antenna.

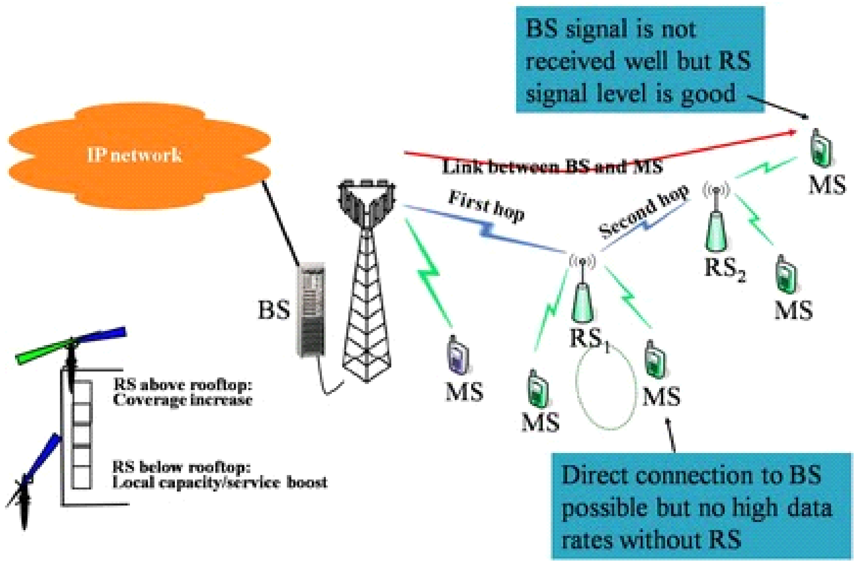


Fig 1.1: Relay Assisted Communication

1.2.1 Relays in Information Theory

Basic information theory on relay results date back to 1970s. The capacity of the setup shown in figure 1.2: setup consists of one source node, one destination node and one relay node. One signal to destination is coming from the direct source and second signal is coming from the source to relay and then from relay to destination. This is the general case that is represented in this setup. Various researches have been done for this general case. Several upper and lower bounds have been presented for this general case scenario for increasing capacity of the degraded channel.

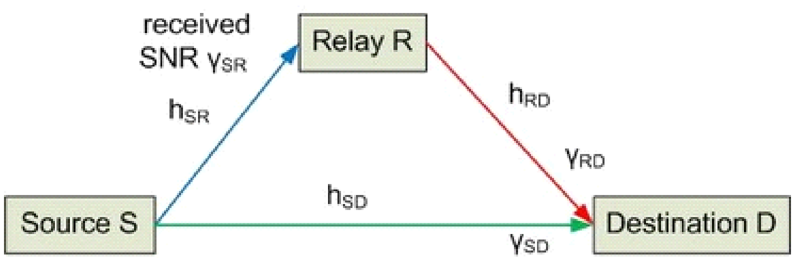


Fig 1.2: General Relay Channel

Techniques involving the use of Cooperative relay have earned a lot of interest in the last few years. Given below is a typical link-level setup, where multiple relays are used for establishing a communication between Mobile Station and Base Station. Operation of relays is based on space-time coding or relay selection criteria. In relay selection criteria, it can choose the most reliable relay among the ‘N’ relays. When one relay is chosen, other relays terminate their operation of transmission.

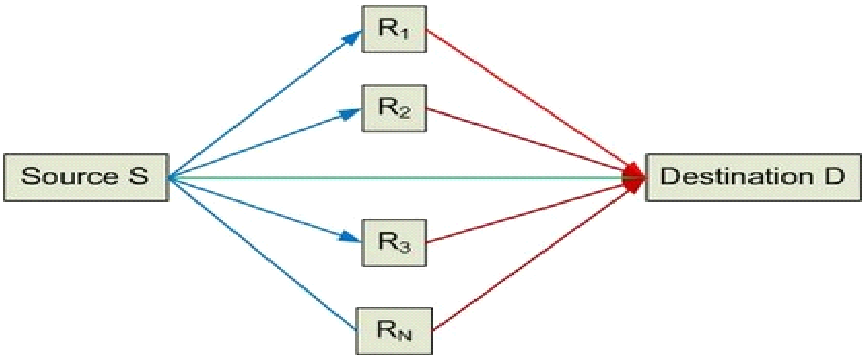


Fig 1.3: Link Level Setup

1.2.2 Relay Assisted Cooperative Communication

The demand for power efficiency and higher spectrum is facilitated from the next generation mobile communication system. The introduction of relay assisted cooperative communication into the pre-existing cellular infrastructure is seen as the most practical progression under high rate and coverage. Relay helps to increase coverage, throughput and provides high data rate. But this relay assisted communication also increases the cost of the infrastructure as compared to conventional cellular systems. Transmission in relay-aided cooperative networks can be classified into three types: the 3-terminal transmission model, 3-hop multi-relay parallel transmission model and multi-hop multi-relay transmission model. Multiple relays form a virtual array in the relay-assisted communications system and cooperate with one another to work. Diversified access modes are enabled using the relay-assisted broadband wireless communications, which mainly differentiate it from legacy wireless access systems. Wireless networks can be accessed by mobile terminals either directly through relay stations or by means of cooperative relaying. Basically, Relay-assisted communication system has the following advantages:

- Same frequency and time slots can be used simultaneously by multiple relays resulting in saving of radio resources;
- Transmission capacity of the system can be improved through space diversity and space multiplexing between relays;

- Enables a smooth evolution of live communication networks without necessitating a great change in the existing backbone architecture of the system.

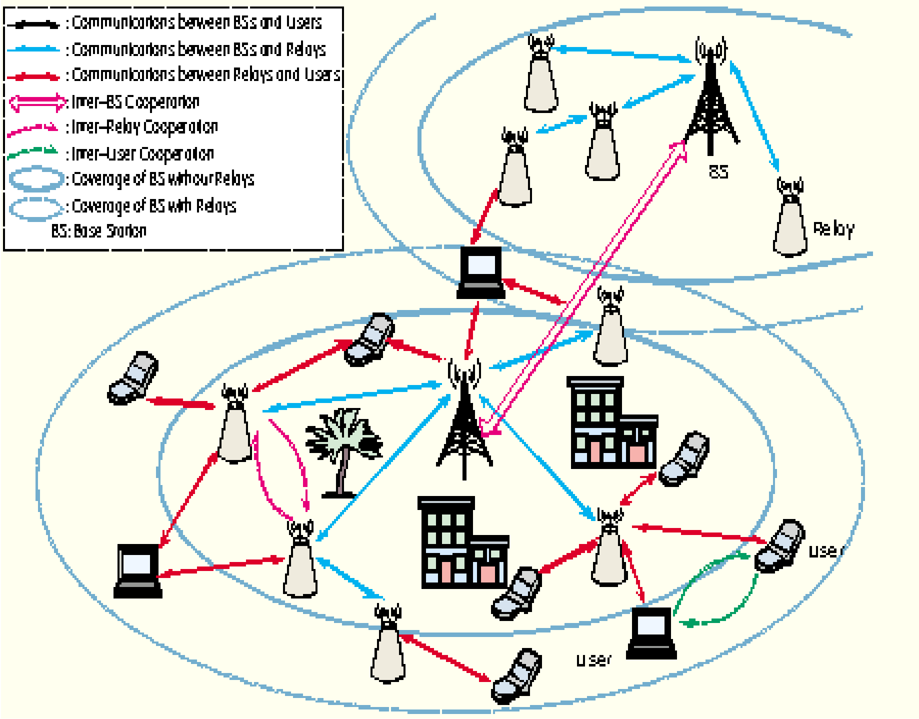


Fig 1.4: Relay Assisted Communication Network

1.2.3 Relaying Protocols:

The main key point that cooperative communication tells us is that how the operation between relays and sources' signals is done. This feature is called relaying protocol. Relaying protocols are basically categorized in two categories: Decode and Forward (DF) and Amplify-and-Forward (AF). A hybrid scheme is also there which combines the advantages of both DF and AF, which we commonly named as Hybrid Decode-Amplify-Forward (HDAF).

1.2.3.1 Decode-and-Forward: Regenerative Relay

This Decode and Forward (DF) relaying protocol is the earliest approach of traditional cooperative communications. This is also called regenerative relay as it decodes the source signal and then encode it before sending to the destination. As wireless system suffers from various problems (like fading, interference, etc.), if signal is not decoded perfectly it may cause errors. So we prefer only one way direct communication if the source signal is decoded perfectly at the relay. Decoding can be done by the various techniques like Cyclic Redundancy Check (CRC), etc.

1.2.3.2 Amplify-and-Forward: Non regenerative Relay

The Amplify and Forward (AF) is also called non-regenerative relaying protocol. It is the easiest protocol as it involves simply the amplification of the signal without any encoding or decoding process. Here, the source sends the signals to the relaying node, then relaying node amplifies that signal and forwards it to the destination. Along with the signal, noise is also amplified. So the signal that we are getting at the destination node may not be the exact one. Here, relay sends the signals to the destination without any encoding or decoding process so its complexity is reduced as compared to Decode and Forward technique whose complexity is very high because of encoding decoding circuitry.

1.3 Two Way Relaying

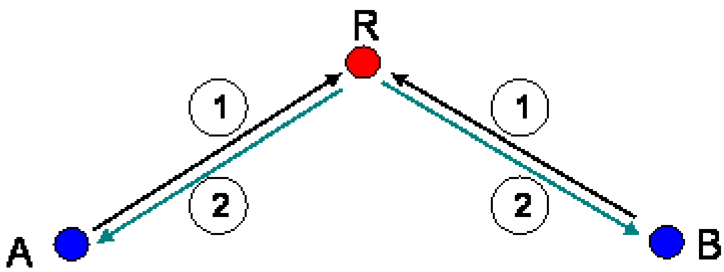


Fig 1.5: Two Way Relaying

Nowadays relaying networks play an important role in the wireless network communication. A relay provides us significant performance gains in the wireless communication networks. A relay increases the coverage and provides high data rates. Two-way relaying, which is also called Bidirectional relaying allows two source nodes to communicate in two time slots with the help of a relaying node. For reducing the cost of relays, the hardware of relays is made from lower quality components. This makes the relay more prone to impairments [12].

The two sources A & B send their information to the relay in the first time slot and relay does processing according to the technique applied either Amplify and Forward or Decode and Forward. Then in the second time slot, relays broadcast this information to both the sources. Since it is assumed that both sources know their own signal, so they remove their own signal and in this way whole communication is taking place in Two Way Relaying Network (TWRN). Two way relaying increases the spectral efficiency, increases the coverage area and provides high data rates than the One Way Relaying Network (OWRN).

The coding schemes used for the Two Way Relaying Network are Analogy Network Coding (ANC) and Physical Network Layer Coding (PNLC). ANC is used for AF TWRN and PNLC is used for DF TWRN. In ANC technique, simple amplification process is done and PLNC involves both decoding and encoding process.

CHAPTER-2

TERMINOLOGY

- **Network coding-** Network coding is used to secure the transmitted data with the help of various security techniques.
- **Cooperative communication**- Communication which depends on the cooperation among nodes for achieving significant gains and high throughput.
- **Half duplex communication-** no simultaneous transmission and reception of signals.
- **Full duplex communication-** simultaneous transmission and reception of signals.
- **Relay**- Relays are used to receive signal between source and destination.
- **Amplify and Forward Relay**- Relay performs amplification of source signals and then forwards that signal to the destination.
- **Decode and Forward Relay**- Relay first decodes the source signals and then re-encodes the signals before sending it to the destination.
- **One Way Relay Network**: Source which wants to communicate, sends a signal to the intended relay. Then relay forwards the signal to destination, then destination replies back to relay and relay further transmits this signal to source. In this way, whole communication takes place in 4 time slots.
- **Two Way Relay Network**: Two Sources who want to communicate, send their data to the relay and then relay after performing operations, broadcasts that information to both the sources. In this way, whole communication is taking place in 2 time slots.
- **Signal to Noise ratio-** It is the ratio of signal power to the noise power.
- **Bit error rate-** It is the ratio of bits in error to the total number of transmitted bits.
- **Signal to Noise Gap Ratio-** It is metric which shows the reduction of SNR from its original value.
- **Channel Estimation Error-** The error which exists during the measurement of channels is known as Chanel Estimation Error.
- **Co-Channel Interference-** Interference which exists within the same cell is called Co-Channel Interference.

Chapter 3

Literature Review

Petar Popovski and Hiroyuki Yomo, "Physical Network Coding in Two–Way Wireless Relay Channels", in *Proc. of IEEE Int. Conf. on Commun. (ICC)*, pp. 707-712, 3 July 2007.

In this paper, the existing techniques are divided into two generic techniques named as three–step and two–step techniques respectively. The criteria for the maximization of the 2- way rate for each individual techniques: the Decode and Forward (DF) three step technique, 3 different techniques with 2 steps: Amplify and Forward (AF), JDF (Joint Decode and Forward) and Denoise and Forward (DNF). It is also observed that for the maximization of two way rate we see the relationship between the duration of step 2 and step 1 and it depends on the transmission rates at the step1 which is used for the maximization of the 2- way rate in the two-step techniques. Some operational restrictions are applied on the techniques but two–way relay channel's absolute capacities are not provided. From the results we have concluded that upper bound of DNF has higher 2- way rate and it is also proved that no other schemes are there which has higher 2- way rate. It is also observed from the Signal to Noise Ratio configurations that JDF technique is almost similar with the upper bound of DNF technique. The technique which has a potential for offering higher and best 2- way rate is DNF technique. The most important result of this research is JDF technique which provides same maximal 2 -way rate as the upper bound on the rate for DNF technique [1].

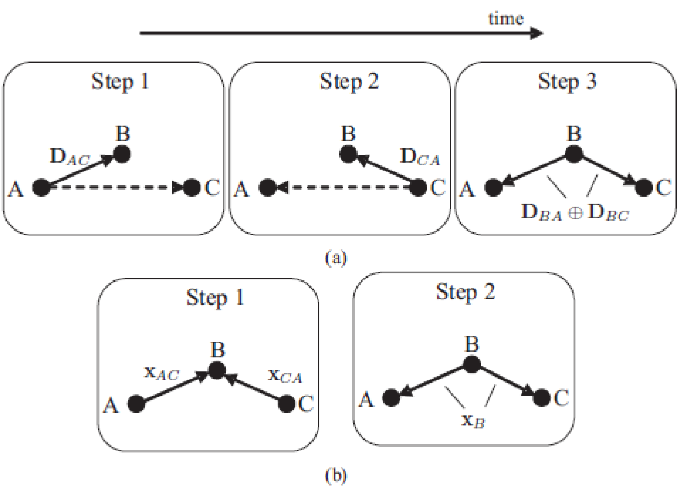


Fig 2.1: Physical Network Coding Generic Schemes Over the Bidirectional Relay Channel. (a) 3–Step Scheme (b) 2–Step Scheme

Youyun Xu, Xiaochen Xia, Kui Xu, and Yande Chen, "Symbol Error Rate of Two-way Decode-and-Forward Relaying with Co-channel Interference", IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), pp. 138 - 143, September 2013.

This paper discussed about two way relaying networks with co-channel interference. Analysis is performed on Rayleigh fading channel with Binary Phase Shift Keying (BPSK) technique. The performance metric which is used for their analysis is Symbol Error Rate (SER). The closed form approximate expressions of the average SER were also derived. On the basis of these expressions simulation is done. It is also discussed that we can use these simulations results into any straightforward NC protocol. Accuracy, correction and validity of the analytical results were proved through the Monte Carlo simulations [2].

Wei Chen, Zhigang Cao, Lajos Hanzo, "Maximum Euclidean distance network coded modulation for asymmetric decode-and-forward two-way relaying", IET Communications,vol.7, issue 10, pp. 988 - 998 , July 2013.

This paper discussed about Network Coded Modulation (NCM) for the joint performance of Network Coding and modulation. Like in classic coded modulation, maximization of the Euclidean distance between the symbols is done. Therefore the error probability of symbols is minimized. Set-partitioning based Network Coded Modulation is a universally accepted concept which can be combined with arbitrary no of constellations. Then practical Phase-Shift Keying/Quadrature Amplitude Modulation (PSK/QAM) NCM schemes is achieved, which is referred as network coded Phase-Shift Keying / Quadrature Amplitude Modulation. It is done on the basis of modulo addition of the normalized phase/amplitude. A NC oriented maximum ratio combining scheme is proposed for achieving a spatial diversity gain at a very low complex rate. Network Coding is used for the combination of the signal which is network coded and source signal. An adaptive Network Coded Modulation is also discussed for maximizing the overall throughput as well as guaranteeing a target BEP. Numerical result and analysis as well as conceptual performance analysis shows that the proposed Network Coded Modulation is able to achieve at least 3dB SNR gain and diversity gain is 2 times greater [3].

O. Simeone, O. Somekh, Y. Bar-Ness, H. V. Poor, and S. Shamai (Shitz), "Capacity of Linear Two-hop Mesh Networks with Rate Splitting Decode-and-forward Relaying and Cooperation", IEEE Journal on Selected Areas in Communications, vol 8, no.1–2, pp. 117-712, October 2007.

This research uses cooperative communication concept at the relaying nodes i.e. from relaying node to the base station for improving the performance rate at the 2^{nd} hop .The cooperative communication technique provides the common information that is obtained from the relaying node as a by-product of the use of dividing of the rate in the 1^{st} hop. Numerical results of relaying cooperation tell us the network topology and power constraints conditions under which splitting of the rate is proved to be beneficial. Joint decoding process at the base station or we can say that Multi-cell processing concept is also discussed for reference [4].

Thinh Phu Do, Jin Soo Wang, Iickho Song and and Yun Hee Kim, "Joint Relay Selection and Power Allocation for Two-Way Relaying with Physical Layer Network Coding", IEEE Communications Letters , vol. 17, no. 2, pp. 301-304, February 2013.

Here, performance is analyzed for DF Two-Way Relaying (TWR) network. PNLC (Physical Network Layer Coding) is used for their analysis. The performance metric which is used for their research is Symbol Error Probability (SEP). The scheme which is proposed for improving SEP is Joint Relay Selection and Power Allocation (JRS-PA). The channel and the technique which is used for the analysis is Rayleigh fading channel and BPSK technique. The expressions are derived for the the proposed and the benchmark scheme. On the basis of expressions, simulation is performed and verified with the analytical results. It is also proved that the proposed scheme provides an asymptotic Signal to Noise Ratio gain which is about 1.76 dB as compared to the benchmark scheme at the same diversity order [5].

Boris Rankov and Armin Wittneben, "Spectral Efficient Protocols for Half-Duplex Fading Relay Channels", IEEE Trans. Inf. Theory vol. 25, no. 2, pp. 241 - 244, February 2007.

Here, Two-hop communication protocols are proposed for single and multiple relay communication. These protocols are proposed for half duplex communication. Two hop means two channels are needed for the transmission of one symbol from source to the destination. This will create a spectral efficiency loss because of the pre-log term one-half is used in expressions of capacity. Bidirectional connection is considered between the two sources. The relaying process which is used for the simulation is AF. The protocol is extended to a multi user scenario where technique used for the communication is Orthogonalize-and-Forward (OF). In OF, the relays orthogonalize the different 2-way transmissions. The algorithm which is used for this communication is Zero-Forcing (ZF) algorithm [6].

M.Xiao and T.Aulin, "On the Bit Error Probability of Noisy Channel Networks With Intermediate Node Encoding", IEEE Transactions on Information Theory, Vol 54, Issue 11, pp. 5188 –5198 , November 2008.

In this paper, sink Bit Error Probability (BEP) approach is studied for a network with intermediate node encoding. Statistically independent noisy channels are employed for the network. An error marking algorithm for binary network codes is used for finding error weight .Thus, the exact sink BEP from the channel BEPs is calculated. Then the approach to non-binary codes is generalized. Galois field $2n$ is used for coding scheme where n is a positive integer. A sub graph decomposition approach is discussed which is used to reduce complexity. Computational complexity is reduced to a great extent and numerical and simulation results are also exact. Error events consisted in single channel are studied by this approach for which we have calculated approximate results. The results are well approximated with the exact results in low Bit Error Probability regions and having lower complexity. It is mentioned that this approach will help the future work in the optimization of NC scheme with the minimum Bit Error Rate. Main issues are coding variables that we have used are still integer values .Therefore it is difficult to find the solution with polynomial complexity [7].

R. Ahlswede, N. Cai, S.-Y. R. Li, and R. W. Yeung, "Network information flow" , IEEE Trans. Inf. Theory, vol. 46, no. 4, pp. 1204-1216, July 2000.

This paper has discussed the novel power allocation techniques that use the mean strength of channel in AF Two Way Relaying network .The Rayleigh fading channel is used for the simulation. These techniques provide maximum upper bound of sum rate average and the trade-off of outage probability among the two source terminals. Numerical and simulation results showing the improvement in the performance as compare to previous power allocation techniques [8].

C. Hausl and J. Hagenauer, "Iterative network and channel decoding for the two-way relay channel," in Proc. IEEE ICC, pp. 1568–1573, June 2006.

Here relay channel, extended to multiple relay that we named as bidirectional relay channel is discussed .The bidirectional relay channel consists of 2 sources who want to communicate with each other with the help of one relay. Here, two-way relaying channel with time division is taken but with no power control and the broadcast channels are orthogonalized in time. Channel model is presented for the used Joint channel coding. Here channel codes are used at the sources and a network coding is used at the relaying node. The channel coding and the networking coding forms a distributed turbo code which is called turbo network code and which is decoded reiteratively at the other side of the user. Closed form expressions of the lower bounds for the capacities of the channel with time division relaying and bidirectional relay channel with no power control provides simulation results of the proposed turbo network coding [9].

T. Ho, M. Médard, R. Koetter, D. Karger, M. Effros, J. Shi, and B. Leong, "A random linear network coding approach to multicast," IEEE Trans. Inf. Theory, vol. 52, pp. 4413–4430, Oct. 2006.

Here, new approach of distributed random linear network coding is discussed. This approach is used for transmission and the compression of data. It is assumed that no node depend on other node for their operation. Nodes randomly choose linear mappings from inputs link to output link in some field. It is also shown that capacity is achieved with probability exponentially approaches to 1 with the code length. Simulation results proved that this approach will provide good results with compression also. This approach will provides so many advantages like decentralized network operation and robustness to the changes in the network. Also it is shown that this approach provides another advantage for improving success probability and providing robustness in the network. The derivation of this analysis also provides a new bound which is required in field size for centralized wireless NC which is on general multicast networks [10].

Y. Jing and H. Jafarkhani, "Distributed differential space-time coding for wireless relay networks," IEEE Trans. Commun., vol. 56, no. 7, pp. 1092-1100, July 2008.

In this paper, differential transmission scheme is discussed, which requires information of the channel neither at relays nor at the receiver for the relaying networks. Circular matrices are used for distributed differential space-time codes that work with networks which consist of any number of relays. This technique will help the distributive relaying nodes antennas to work as transmitting antennas of the sender. The generation of a space-time coding is done at the receiver. This technique will help to achieve maximum diversity. This scheme does not require channel estimation information at the relaying node but it requires complete channel state information (CSI) at the destination node [11].

R. Ahlswede, N. Cai, S.-Y. R. Li, and R. W. Yeung, "Network information flow," IEEE Trans. Inf. Theory, vol. 46, no. 4, pp. 1204-1216, July 2000.

Here, new type of issue is discussed which is known as flow of network information. This issue is taken from applications of computer networks. Here, point to point communication of nodes is considered. It is assumed that all Source nodes are independent from each other. The main issue is characterizing the coding rate region. Admissible coding rate region is discussed with 1 source which has information and simple characterization of the coding rate region. Max-Flow and Min-Cut theorem is used for the information flow in the network. This work revealed that it is in general form but not ideal to regard the information to be multicast which can modestly be replicated by using coding technique at the nodes which is known as NC. This thing has momentous concussion on future designing of network switching systems [12].

L. Ding, M. Tao, F. Yang, and W. Zhang, "Joint scheduling and relay selection in one- and two-way relay networks with buffering," in Proc. IEEE International Conf. Commun. (ICC'09), pp. 1-5, June 2009

Here, one way relay and two way relay networks with buffering capabilities of relaying nodes are discussed with a framework for relay selection and joint scheduling. The main objective of joint scheduling and relay selection is to increase throughput with the use of multiuser diversity. The new algorithm called Joint Scheduling and Relay Selection (JSRS) is developed for unidirectional and bidirectional traffic. The performance metrics used for the relay selection depends on both instantaneous condition of channel and the queuing status of the network. Simulation is done to evaluate the performance of the Joint Scheduling Relay Selection with buffering as compare to with traditional Fixed Time Division (FTD) without buffering. The increase in the throughput is 101 percent and 110 percent as observed in one-way and two-way relay networks respectively, at low SNR ratio (0 dB) [13].

K.-S. Hwang, Y.-C. Ko, and M.-S. Alouini, "Performance bounds for two-way amplify-and-forward relaying based on relay path selection," in Proc. IEEE Veh. Technol. Conf. (VTC'09), pp. 1-5, April 2009

Here, performance bounds for the AF bidirectional relaying are discussed. Relay selection criteria is used for choosing the best nodes among 'n' nodes. Discussed scheme chooses duplex communication which gives the best end-to-end performance. The proposed technique does not require any external communications between the relays. On the basis of proposed RS criteria, this analysis offers the performance bounds on the average sum-rate, average SER and outage probability over the same independent identically distributed Rayleigh fading channels. Simulation and numerical results analysis proved that discussed scheme provides considerable sum-rate gains and also increases the diversity orders rate as the no. of relays increases [14].

Q. F. Zhou, F. C. M. Lau, and S. F. Hau, "Asymptotic analysis of opportunistic relaying protocols," IEEE vol.8, pp. 3915-3920, August 2009

Cooperative networks with multiple relays are tested. Opportunistic relaying technique is used for the selection of the "best" relay among the N relays. The asymptotic outage performance of Incremental Amplify-and-Forward (IAF) is evaluated. Moreover, two new protocols, namely opportunistic incremental selection Amplify and Forward (OISAF) and Opportunistic Joint Incremental Selection Relaying (OJISR) are proposed. The expressions for the outage probabilities are also discussed. Atlast, comparison is done between the simulated one and analytical asymptotic outage probabilities. Simulation results proved that the OJISR protocol performance is better than the other protocol [15].

G. Li , F. Gong ; N. Zhang ; Y. Wang, "A Fuse-and-Forward Protocol for Two-Way Relaying Networks With Relay Having Its Own Broadcasting Information", IEEE Communications Letters ,vol. 19, issue. 8, pp. 1450 – 1453, August 2015.

Here, performance is evaluated for two way relaying networks. It is assumed that relaying node consists of number of antennas and source consists of only one antenna. Distributed Space-Time Block Code (DSTBC) is used for obtaining full diversity and for ensuring that destination node is concurrently decoding the information that is coming from source and relay nodes. The Alamouti scheme is also discussed which is based on Fuse-and-Forward (FF) relaying protocol. In this protocol, the relaying node adds its own information with the received signal and then performs broadcasting of the signal to all source nodes [16]

B. Rankov and A. Wittneben, "Spectral efficient protocols for half-duplex fading relay channels", *IEEE J. Sel. Areas Commun.*, vol. 25, no. 2, pp. 379-389, February 2007.

In this paper, two new protocols are discussed. These protocols works on half duplex communication. These protocols ignore the pre-log factor one-half. In first protocol 2 way connections is established between two source terminals. Relay can use either AF technique or DF technique for its communication. Then this first protocol is used to evaluate the performance for multi user systems and the technique which is used at the relaying node is Orthogonalize and Forward (OF). In second protocol, relay can use either AF technique or DF technique but alternatively for its communication [17].

Y. Jing and B. Hassibi, "Distributed space-time coding in wireless relay networks", *IEEE Trans. Wireless Commun.*, vol. 5, no. 12, pp. 3524-3536, December 2006.

Space coding technique is used by the relaying node for the communication in the wireless network. The Rayleigh fading channel is used for the communication. Here, 2-stage protocol is discussed. In first stage the source sends the signal to the relaying node and then relay node performs encoding of the received signal into a distributed Linear Dispersion Code (LDC) and then forwards the coded signal to the destination node. Fixed transmission power is used for multiple numbers of relays. The power is distributed in an optical manner among the source nodes and relay nodes. Half power is allocated to source nodes and half power is allocated to the relaying nodes. From the analysis it is concluded that for high and low value of Signal to Noise Ratio the coding gain remains same as we get from the system which comprises multiple antennas [18].

Q. F. Zhou, Y. Li, F. C. Lau and B. Vucetic, "Decode-and-forward two-way relaying with network coding and opportunistic relay selection", IEEE Trans. Commun., vol. 58, no. 11, pp. 3070-3076, November 2010.

Here, performance analysis of DF bidirectional relaying network is studied. An Opportunistic Two-Way Relaying (O-TWR) scheme is proposed. This scheme depends on joint network coding and opportunistic relaying. Max Min criterion is used for the relay selection. A Monte Carlo simulation is used to verify the proposed scheme. Simulation results proved that the above discussed scheme will provide the best and a more accurate results than the previous techniques which are considered to be best one for decode and forward [19].

J. Laneman, D. Tse, and G. Wornell, "Cooperative diversity in wireless networks: Efficient protocols and outage behavior," IEEE Trans. Inform. Theory, vol. 50, no. 12, pp. 3062–3080, Dec. 2004.

In this paper, diversity protocols which are having lower complexity are discussed. These protocols help to remove fading that is caused by multiple propagation in wireless communication. Various techniques used for the cooperative networking are discussed. It also includes AF and DF selection relaying techniques. These schemes change according to channel measurement between the cooperative nodes. Performance metric which is used for the analysis is outage probability. Cooperation in half duplexing communication needs double bandwidth as compared to line of sight communication. This causes larger reduction in Signal to Noise Ratio values. Also additional hardware is required for sources to relay and for one another so it will increase cost. Thus without the need of the physical arrays, the powerful benefits of space diversity are provided which are applicable to any wireless cellular or Adhoc networks. The performance characteristic reveals that more power or energy can be saved by using these protocols. Therefore reliability is increased for the same transmit power [20].

D. B. da Costa and S. Aissa, "End-to-end performance of dual-hop semi-blind relaying systems with partial relay selection," IEEE Trans. Wireless Commun., vol. 8, no. 8, pp. 4306–4315, August 2009.

Here, end to end performance of the network with fixed gain relays is discussed. The selection scheme considers here that source monitors the connectivity between the relays of the 1^{st} hop only. It is also shown that fixed gain relays provide reduced implementation capacity in the system design as compare to CSI based relays. Here the relays are distributed close together and they are selected by a long term process of routing. The relay selection effect on the overall system's performance is analyzed. Analysis proved that maximum performance is yielded for more than two relay nodes. Dynamic behavior of the end to end envelope is also discussed [21].

H. A. Suraweera, H. K. Garg, and A. Nallanathan, "Performance analysis of two hop amplify-and-forward systems with interference at the relay," IEEE Commun. Lett., vol. 14, no. 8, pp. 692–694, August 2010.

Here, performance analysis of AF bidirectional network is studied. The channel which is used for their research is Rayleigh fading channel and the technique used is BPSK. They have taken relay interference into account and perfect CSI conditions .The performance metrics which are used for their research are BER and Outage Probability (OP). Numerical expressions for BER and OP are analyzed and calculated. From the simulations we are able to observe the effect of interferers on the OP and BER. [22].

H. A. Suraweera, D. S. Michalopoulos, and C. Yuen, "Performance analysis of fixed gain relay systems with a single interferer in Nakagami fading channels," IEEE Trans. Veh. Technol., vol. 61, no. 3, pp.1457–1463, March 2012.

Here performance analysis is done for fixed gain relays systems. The channel used for their analysis is Nakagami fading channel. The technique which they have used for their research is BPSK. The performance metrics which are used for their research are OP and average BER. Expressions for the average BER and OP are discussed and calculated. On the basis of these expressions simulation is performed for both metrics. Asymptotic outage probability expressions are also discussed. Simulations results show the effect of interference and how the interference at the relay or the destination node affects the overall consummation of the wireless system [23].

R. H. Y. Louie, Y. Li, and B. Vucetic, "Practical physical layer network coding for two-way relay channels: performance analysis and comparison," IEEE Trans. Wireless Commun., vol. 9, no. 2, pp. 764–777, February 2010.

Here, performance of bidirectional network is studied. The scheme which they have used for their research is Physical Layer Coding (PNC) scheme. Analysis involved 2 sources and 1 relay. Here Transmission is performed over 2, 3 and 4 timeslots. Analysis proved that PNC scheme with 2 time slots provides maximum sum rate performance and lower sum BER than the PNC scheme with 4 timeslots. Second observation from simulations is that 3 time slot PNC scheme will provide the performance better than 2 time slot PNC but lesser performance than 4 time slot PNC. An Opportunistic Relaying (OR) scheme is used for this communication where a single relay is taken for the maximization of sum-rate performance or minimization of the sum-BER. The observations also reveal that opportunistic relaying scheme can eminently improve the performance of the system as compared to a single relaying network [24].

L. Yang, K. Qaraqe E. Serpedin, and Mohammad Slim Alouini, "performance analysis of Amplify and Forward Two Way Relaying with Co-Channel Interference and Channel Estimation Error," IEEE Trans. Communications, vol 61, no-6 June 2013

Here, performance analysis of AF TWRN with CCI and CEE effect is done. The channel which they have used for their research is Rayleigh fading channel and the technique used are QPSK and BPSK. Analysis is done for all relay participating case and for relay selection case. The performance metrics which they have used for their research are Outage Probability and BER. SINR expressions are derived and with the help of these expressions, expressions for the BER, OP and sum rate are derived. On the basis of these expressions simulation is done and numerical results are calculated .The important result of this analysis is that simulation results proved that it is not compulsory that relay selection scheme always performs better but sometimes all relay participating case also provides better performance [25].

CHAPTER-4

Rationale and Scope Of The Study

Cooperative Two Way Relaying networks have gained a lot of interest nowadays [26]. With the increasing technologies, demand for the data rates is also increasing. Cooperative TWR relaying provides high data rate, high reliability, high coverage and high throughput [27]. As compared to one way half duplexing relay technique, bidirectional relaying allows simultaneous communication between two users and also helps to improve spectral efficiency [28]. Most of the researchers have done their work on TWRN or we can say bidirectional networks. The previous researches have implemented one way and two relaying in a very efficient way [29]. Various new algorithms and techniques were proposed for improving the accuracy, reliability and throughput of the bidirectional network. Bidirectional relaying is already studied by many researchers with different scenarios like for single user as well as for multiusers system. But the main issues or problems with previous researches is that they have not included the two main effects called CCI and CEE in their researches. Some have taken CCI effect but excluded CEE from their research. Previous researches have assumed perfect ideal case and ignored these parameters from their research. But these parameters actually exist in wireless scenario. So it must be included in our research to make the analysis more accurate. CEE degrades the performance by increasing Bit Error Rate (BER) and CCI decreases the Signal to Interference Noise Ratio (SINR) which further degrades the system. So, it is important to study the influence of CEE and CCI on the performance of wireless system.

SCOPE OF THE STUDY:

Most of the previous researches have excluded the two main parameters CCI and CEE from their research, which affects the wireless communication system in a very drastic way. In our research, we have included these two parameters to make the previous researches more accurate and correct one. Our study will help to know how much reduction in Signal to Noise Ratio occurs when these two parameters are taken into consideration. This will further help to increase SNR values and reduce BER which will make future researches more accurate.

CHAPTER-5

Objectives Of The Study

- Two-way relaying is a spectrally efficient protocol, providing a way to prevent the half-duplex loss in one-way relay channels.
- Moreover, incorporating Multiple-Input-Multiple-Output (MIMO) technology can further improve the spectral efficiency and diversity gain.
- Main issues from which wireless system suffers are Channel Estimation Error (CEE) and Co-Channel Interference (CCI). In practice, Channel State Information (CSI) must be estimated and therefore estimation error exists. So, it is important to study the influence of channel estimation error on the performance of system in DF TWRN.
- CEE degrades the performance by increasing BER and CCI decreases the Signal to Interference Noise Ratio which further degrades the system. So, it is important to study the influence of both CEE and CCI on the performance of system in DF TWRN.
- Furthermore, the strategies to enhance the performance and combat the channel uncertainty resulting from the estimation error are also of practical interest.
- To minimize BER (Bit Error Rate)
- To minimize SNGR (Signal To Noise Gap Ratio)
- To avoid the interference and to reduce the power constraints.
- To increase average throughput. Analyze the system and average SNGR of the DF distributed TWRN in the presence of CSI estimation errors as well as Co-Channel Interference.
- Thereafter, the related work in the literature for DF/AF TWRN has been investigated and demonstrates the lack of research in the area of performance analysis and enhancement with imperfect CSI and motivates work of this thesis.

CHAPTER-6

Materials and Research Methodology

The research methodology comprises of various stages:

- Firstly, deep study of Decode and Forward / Amplify and Forward Two Way Relaying network.
- Obtained the demerits or problems which were associated with previous researches.
- Various performance metrics which are necessary for the research have been searched.
- Mathematical equations for those performance metrics have been collected from various research papers.
- Mathematical equations have been calculated.
- On the basis of performance metric, various parameters are analysed to study Decode and Forward Two Way Relaying Network with Co-Channel Interference and Channel Estimation Error.

6.1 Research Concept and Techniques:

In practice, Channel State Information (CSI) must be estimated and therefore estimation error exists. So, it is important to study the influence of channel estimation error on the system performance in DF TWRN. Furthermore, the strategies to enhance the performance and combat the channel uncertainty resulting from the estimation error are also of practical interest. The related work in the literature for DF/AF ANC based TWRN has been investigated, which demonstrates the lack of research in the area of performance analysis and enhancement with imperfect CSI and motivates the work of this thesis. For the DF/AF TWRN, most of the known results in relaying have taken assumption that in the second time slot both the sources removed their own signal part. But such type of interference removal in reality is not possible. In reality, it becomes very difficult to get accurate channel estimation because of so many reasons like channel estimation error and delay in the feedback. Because of these reasons, perfect Channel State Information is difficult to estimate which degrades the performance of the system. Some papers have discussed about channel estimation error but not in detail and they have also mentioned some other issues like Co-Channel interference which are creating issues in wireless communication. So, these are the main considerations of this thesis. The scenario which is taken for the base paper is Two Way Relaying Network with Amplify and Forward technique and assumed that relaying node is affected by interferers and two source nodes are affected by noise. The assumptions that are taken for base paper are:

1) First assumption is that the relaying node is interference-limited and source nodes are affected by Additive White Gaussian Noise (AWGN). This assumption is clarified by this example: assume two users want to communicate with each other in a particular wireless cellular network with the help of relaying node which is near to the edge of the cell. Therefore, adjacent cell interference is more dominating and effect of noise is also ignored. If two source nodes are far from the edge of the cell then they are free from interference and they are only affected by noise.

2) For the implementation of self- interference cancellation, we assumed that two sources have access to their own estimated channel.

3) Amplify and Forward technique is applied at the relaying node and the relay is able to get the complete Channel State Information of the interference links. As relaying node is located at the edge of the cell, so relay is able to get the Channel State Information of the links.

SINR expressions are derived for a single relay node network. On the basis of SINR value, expressions for the OP are derived. CDF method is used to derive the BER. Then single relay network is extended to multiple relay networks and analysis is performed for equal power case [25].

As there are some limitations in Amplify and Forward technique, so we performed this research with another better technique called Decode and Forward (DF) technique. DF technique is better than Amplify and Forward technique as it first decodes the signal and checks if any redundancy is present or not and then forwards the signal to the destination. So, the signal received at the destination is correct one which is sent by the source to the destination. Whereas in AF technique, the signal which is arrived at the relay is just amplified and then forwarded to the destination. As there is no decoding or encoding process, the signal received at the destination might not be the correct one.

The assumptions that we have taken for DF TWRN are:

1) Both sources and relays are affected by the interferers and noise is assumed to be Additive White Gaussian Noise.
2) There is no direct link present between two sources.
3) It is assumed that perfect decoding is taking place (i.e. no errors) and relays forward only the correctly decoded signal and discard the rest.

Here, a performance metric which is used for studying DF TWRN is called Signal to Noise Gap Ratio which measures the deviation of Signal to Noise Ratio from its exact value in presence of Co-Channel interference and Channel Estimation Error.

6.2 Performance Analysis Parameters

6.2.1 Cumulative Density Function (CDF)

In probability theory and statistics, the CDF is used to find the probability of random variable X whose value is less than equal to x. It is the "area so far" function of the PDF (Probability Distribution Function).

6.2.2 Outage Probability

Wireless communication system suffers from various problems like fading, interference, etc. which will cause loss in the signal power. Thus, in fading, γ_s is a random variable with distribution $p_{\gamma s}(\gamma)$, and therefore $P_s(\gamma_s)$ is also random. The rate of change of fading depends upon performance metric when γ_s is random. There are 3 different performance criteria which are used for the characterization of the random variable P_s. The outage probability Pout, defined as the probability that γ_s falls below a given value corresponding to the maximum allowable P_s. Many symbols will be affected by deep fade if signal power is changing slowly (Ts << Tc). Thus, large error bursts are caused due to fading. Therefore, end-to-end performances are degraded due to these large error bursts. In such cases it is not possible to guarantee acceptable performance without transmission power increment. Under such cases, an outage probability is used to specify the non-usability of channel for some period of time. The outage probability relative to γ_o is defined as:

$$P_{out} = p(\gamma_s < \gamma_o) = p_{\gamma s}(\gamma)\, d\gamma$$

The limit of above integral is from 0 to γ_o, where γ_o typically specifies the minimum signal to noise ratio needed for acceptable performance.

6.2.3 Bit Error Rate (BER)

The BER is defined as the total bits which are in error per unit time. The bit error ratio is the ratio of bits which are in error to the total number of transmitted bits. Bit Error Rate is a unitless quantity.

6.2.4 Signal to Noise Gap Ratio (SNRG)

The Signal to Noise Gap Ratio measures the how much Signal to Noise Ratio is deviated from its actual value which is the measurement of reduction in the SNR value. .

The SNRG is given by this expression:

$$R1_C = \frac{\gamma|\,\alpha=0 - \gamma|\,\alpha\neq 0}{E1(\gamma|\alpha=0)} \quad , \gamma \text{ is instantaneous SNR value}$$

6.3 Base paper Implementation

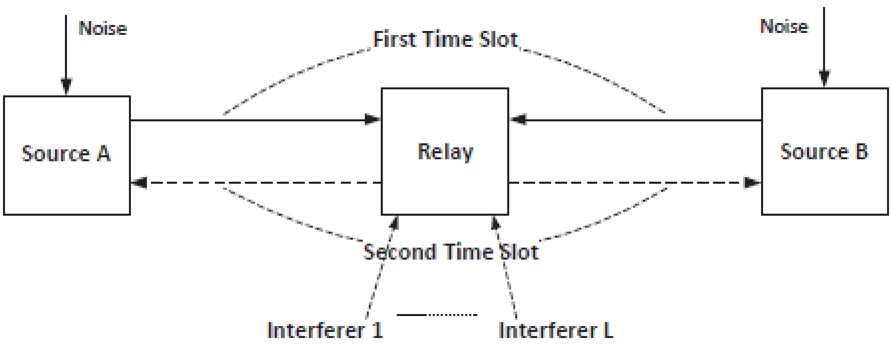


Fig 6.1: Two Way Relaying Network

Consider a bidirectional-hop relaying wireless network consisting of 2 source nodes A and B and 1 relay as shown in Fig 4.1. We have considered that relay is using Amplify and Forward technique. We have also assumed that both the sources are transmitting with a same power P_S, the relay power is denoted by P_R, and the noise at the two sources have unit variance and zero mean. We have assumed [30], [31] that the relaying nodes are only suffering from co-channel interferers and two sources are suffering by AWGN. So, the whole communication will be completed in 2 time slots. In the first time slot, two sources transmit the signals to the relay node. We have assumed that the relay is only deteriorated by a finite no. of interferers. So, the signal which is received at the relaying node is:

$$y_{R=} \sqrt{Ps}\, h_A\, x_A + \sqrt{Ps}\;\; h_B x_B + \sum_{I=1}^{L} \sqrt{P(I,l)}\;\; h_{I,l} S_I \qquad \textbf{(1)}$$

In the second time slot, the received signal is processed by relay by using AF scheme for the normalization of y_R and then broadcast the signal to both the sources. For the implementation of self-interference cancellation, all the previous existed works have taken assumption that both the sources have obtained perfect channel state information h_A and h_B. But such type of assumption is not correct in practical applications. Therefore, the actual channels and the estimated channels can be modeled as

$$h_A = h_A + e_A \qquad \textbf{(2)}$$

$$h_B = h_B + e_B \qquad \textbf{(3)}$$

where e_A and e_B are the channel estimation errors. For reducing complexity, we assumed $E[|e_A|^2] = E[|e_B|^2] = \sigma^2_E$, is the parameter that is showing the accuracy of channel estimation, the amplifying factor β is given by this equation:

$$\beta = \sqrt{\frac{P_R}{P_S\left(|\hat{h}_A|^2 + |\hat{h}_B|^2\right) + 2P_S\sigma_E^2 + \sum_{l=1}^{L} P_{I,l}\ |h_{I,l}|^2}} \qquad \textbf{(4)}$$

Most of the papers have ignored the interference term, the relay requires to obtain all the CSI $h_{I,l}$ to find β, which increases complexity and requires a lot of overhead. But relay is not able to differentiate between interferers and signals. Relay performs normalization without doing any processing. The signal which we get at the two sources are:

$$y_A = \sqrt{Ps}\ \beta h^2_A\ x_A + \sqrt{Ps}\ \beta\ h_A\ h_B\ x_B + \beta h_A \sum_{I=1}^{L} \sqrt{P(I,l)}\ \ h_{I,l} S_I\ + n_A \qquad \textbf{(5)}$$

$$y_B = \sqrt{Ps}\,\beta h^2_B x_B + \sqrt{Ps}\,\beta h_A h_B x_A + \beta h_B \sum_{I=1}^{L} \sqrt{P(I,l)}\ \ h_{I,l} S_I\ + n_B \qquad \textbf{(6)}$$

where n_A and n_B are the noises at the two sources. After self-interference cancellation, the signals at the 2 sources can be represented as:

$$r_A = \sqrt{Ps}\beta \hat{h}_A \hat{h}_B x_B + \sqrt{Ps}\beta(\hat{h}_A e_B + \hat{h}_B e_A e_B) x_B + \sqrt{Ps}\beta(2\hat{h}_A e_A + e^2_A) x_A + \beta(\hat{h}_{A+} e_A) \sum_{I=1}^{L} \sqrt{P(I,l)}\ h_{I,l} S_I + n_A \qquad \textbf{(7)}$$

$r_B=\sqrt{Ps}\beta\hat{h}_A\hat{h}_B x_B + \sqrt{Ps}\ \beta(\hat{h}_A e_B+ \hat{h}_B e_A e_B)x_B +\sqrt{Ps}\beta(2\hat{h}_A\, e_A + e^2_A)x_B+ \beta(\hat{h}_{B+}\, e_B) \sum_{I=1}^{L} \sqrt{P(I,l)}$ $h_{I,l}S_I +n_B$ **(8)**

Performance Analysis

In this part, we have found outage probability, Bit Error Rate and Sum Rate performance. For the analysis, we are concentrating our analysis for the higher P_S and P_R case.

Analysis of outage probability

We can define the outage event as the probability when either R_{BA} or R_{AB} value becomes less than the threshold rate of the R_{th}. Therefore, the overall system Outage Probability can be written as:

$$P_{out}=P_r\{\min(R_{AB},R_{BA})<R_{th}\}$$

$$=1-P_r(\gamma_{BA}>\gamma_{th},\ \gamma_{AB}>\gamma_{th}) \quad \textbf{(9)}$$

where $\gamma_{th} = 2^{2R}{}_{th} - 1$. However, since γ_{BA} and γ_{AB} are not independent. So, according to this criteria the equivalent SINR of the total system as $\gamma_S = \min(\gamma_{BA}, \gamma_{AB})$.

Approximations of Closed-form expression for the metric Outage Probability are given by the following equation:

$$\text{Pout} \approx 1\text{-e}^{\frac{-2\gamma_{th}(1+5P_R\sigma_E^2)}{(1-\sigma_E^2)}} \sum_{i=1}^{\alpha(U)} \sum_{j=1}^{\tau_i\,(U)} \frac{X_{i,j}\ \ (U)}{\left(\frac{-2\gamma_{th}(1+5P_R\sigma_E^2)}{(1-\sigma_E^2)P_S}+1\right)^{j}} \quad \textbf{(10)}$$

The overall system OP is given by this expression:

$$\text{Pout} \approx 1\text{-e}^{\frac{-3\gamma_{th}(1+5P_R\sigma_E^2)}{(1-\sigma_E^2)P_R}} - \text{e}^{\frac{-4\gamma_{th}+12\gamma_{th}P_R\sigma_E^2)}{(1-\sigma_E^2)P_R}} \times \sum_{i=1}^{\alpha(U)} \sum_{j=1}^{\tau_i\,(U)} \frac{X_{i,j}\ \ (U)}{\left(\frac{-2\gamma_{th}(1+5P_R\sigma_E^2)}{(1-\sigma_E^2)P_S}+1\right)^{-j}} \quad \textbf{(11)}$$

The closed form of analysis is elaborated. So it can be determined easily. It does not provide any perceptions into the effects of the parameters and on the powers. Therefore, another case is considered, where $P_{I,l} = P_I$ for all interferers.

Hence,

$$Z=P_I \sum_{l=1}^{L} |h_{I,l}|^2 \qquad \textbf{(12)}$$

Now, closed form expression of outage is:

$$\text{Pout} \approx 1\text{-e}^{\frac{-3_{\gamma th}(1+5P_R\sigma_E^2)}{(1-\sigma_E^2)P_R}} \left(\frac{(1-\sigma_E^2)P_S}{2_{\gamma th}P_{i+(1-\sigma_E^2)P_R}}^{L}\right) \qquad \textbf{(13)}$$

Multiple-Relay Systems Extension

The previous analysis is only applicable for single relay TWRN. Now, we are extending the analysis to multi relay i.e. k relay network .We have assumed that relay have same power and suffers from same type of interferers. We can take unequal power case also. The system still remains same and the whole transmission will still take 2 stages:

At the 1st stage, the 2 sources send their signals to all the relays. At the 2nd stage, the relay performs broadcasting and hence $K + 1$ time slots are needed for the working. Then the self-interference cancellation process takes place, after that the source node i ($i = A,B$) applies diversity combining techniques to combine the signal r^k_i from all relays. Here we have applied Maximum Ratio Combing (MRC) diversity combining technique for $k = 1...,K$. The selection of weighting coefficients is done by this method:

$$w_i^k = \sqrt{P_s}\, \beta_k\, \hat{h}_A^k\, \hat{h}_B^k \,/\, N_{i,k}^{tot} \qquad \textbf{(14)}$$

where $\hat{h}_A^k\ and\ \hat{h}_B^k$ are the channels estimated between the k^{th} relay and 2 source nodes and β_k is the amplifying factor of the k^{th} relaying node. For source node A, $N_{i,k}^{tot}$ is the power of the total noise plus interference and can be expressed as

$$N_{i,k}^{tot}=P_s\beta_k^2(|\hat{h}_A^k|^2+|\hat{h}_A^k|^2)\,\sigma_E^2+4P_s\beta_k^2\,|\hat{h}_A^k|^2\sigma_E^2+2P_s\beta_k^2\sigma_E^4+\beta_k^2(|\hat{h}_A^k|^2+\sigma_E^2)\sum_{l=1}^{L}|h_{I,l}|^2\,P_{I,l}+1 \qquad \textbf{(15)}$$

Analysis of Relay Selection Scheme

Asymptotic BER Analysis

In relay selection, the relay which is having best quality of channel is chosen .The relay selection scheme in Two Way Relaying Network with Amplify and Forward technique has been studied in the past. However, the work on the performance analysis in Two Way

Relaying Network with AF technique with CCI is still not studied in the past researches of the literature section.

In this segment, we have analyzed the expressions for a metrics OP and BER performance. The selection policy is given by this equation:

$$\kappa^{*} = \arg\max\ (\min(\gamma_{BA}^{\kappa}, \gamma_{AB}^{\kappa})) \qquad \textbf{(16)}$$

Asymptotic BER is given by this equation:

$$P_e^{MA} \approx \frac{\Gamma(K+0.5)}{2\sqrt{\pi\,\Gamma}\,(K+1)}(\zeta + L\varepsilon)^K \qquad \textbf{(17)}$$

max-min criteria is used for the relay selection which helps to provides full diversity order. When the relay is selected, we can find the OP by this method:

$$P_{out}^{S} = \Pr[\min(\gamma_{BA}^{k*}, \gamma_{AB}^{k*}) < \gamma_{th}] = (P_{out})^k \qquad \textbf{(18)}$$

The asymptotic performance for the relay selection scheme can be represented by this equation:

$$P_e^S \approx \frac{\Pi_{i=1}^{K}(2i-1)}{2^{K+1}} \left(\frac{2+10P_{R\sigma_E^2}}{2+10P_{R\sigma_E^2}} + \frac{2LP_1}{P_{S\rho^2}}\right)^k \qquad \textbf{(19)}$$

For a reasonable contrast, it is requisite to confine the total power at the relays to P_{RT}. Thus, we have $P_R = P_{RT}/K$ for the all-relay participating system and $P_R = P_{RT}$ for the RS scheme. With this, we obtain the following ratio:

$$\frac{P_e^S}{P_e^{MA}} = K!\left(\frac{1+5P_{RT}\,\sigma_E^2 + L\frac{P_1}{P_S}P_{RT}}{K+5P_{RT}\sigma_E^2 + L\frac{P_1}{P_S}P_{RT}}\right)^k \qquad \textbf{(20)}$$

From the above equation, we have concluded that under this total power at the relays, we observed that RS criteria performs better when there is no CEE i.e. $\sigma^2_E = 0$ and also interference i.e. $P_I = 0$. But, if CCI and CEE is there, then this ratio becomes lesser than 1 for all *relays (k)* ≥ 2 case. If K value and power of source (P_S) is less, then in that case, relay selection criteria will have indigent performance. But, if value of K *and* P_S is large, then by applying relay selection scheme, the performance of the system can be enhanced. Such type of observation is verified in our numerical analysis.

6.4 Limitations of Amplify and Forward (AF) technique over Decode and Forward (DF) technique:

- In Amplify and Forward technique, relay simply amplifies the signal and forwards that signal to the destination. If noise is present in the signal, then that noise is also amplified along with the signal. So, the signal received at the destination may be noisy. Whereas in Decode and Forward technique, relay first decodes the signal and then re-encodes the signal and then forward that signal to the destination. Here, no amplification of signal is there and the signal received at the destination has less noise than the signal which is received through AF technique.
- In DF technique, the signal received at the destination is the exact signal that the source has transmitted but in AF the signal received at the destination may not be same as that transmitted by the source.
- In DF technique, the signal received at the destination is error free as various techniques are employed at the relay for checking the signal errors like CRC (Cyclic Redundancy Check) but in AF technique the signal received at the destination may not be error free or accurate because this technique does not check the signal errors. It just amplifies and forwards that signal to the destination.

6.5 Decode and Forward Implementation

The system model for Two Way Relaying Network is shown in figure 6.2. It comprises N relay nodes and two sources. The full duplex mode of communication is used by all of them. There is no line of sight communication link among the two sources. The channel used between the sources to relay and from relay to sources is Rayleigh fading channel. The notations used for channel coefficients are h_{AN} for source A and h_{BN} for source B. The noise to be considered is AWGN (Additive White Gaussian Noise) whose mean is zero and variance is one.

System Model:

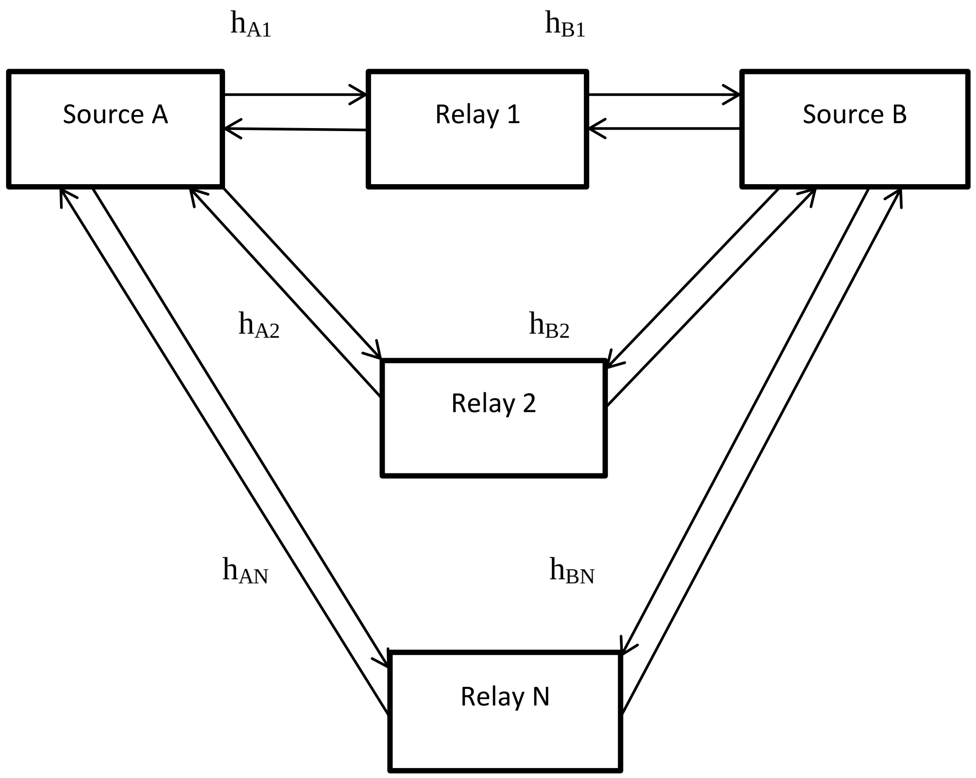


Fig 6.2: DF TWRN with Multiple Relays

Performance of Decode and Forward Two Way Relaying Network (TWRN) in the presence of channel estimation error.

Here, it is assumed that node A wants to communicate information to node B. Firstly, calculation for one relay is done and then it is extended to multiple 'N' relays.

The parameter to be used is Signal to Noise Gap Ratio (SNGR). The SNGR is defined as:

$$R1_C = \frac{\gamma|\ \alpha=0 - \gamma|\ \alpha\neq 0}{E1(\gamma|\alpha=0)} \quad \textbf{(1)}$$

In the 1st time slot, two source nodes transmit their data signal to the relay. The information signal received at the relay node is given by this expression:

$$\mathrm{Y1_r} = \sqrt{P1_o}\,(h_A + e_A)x_A + \sqrt{P1_o}\,(h_B + e_B)x_B + \sqrt{N_o}\; n1_r \qquad \textbf{(2)}$$

where '$P1_o$' is the source power, $n1_r$ is the relay noise, it is modeled as unit complex random unit variance and zero mean.

x_A is the signal transmitted from source A.

x_B is the signal transmitted from source B.

h_A and h_B is the channel coefficients whose variance is δ_B^2 and δ_A^2 and channel estimation error are denoted by e_A and e_B which are modeled as Gaussian random variable whose variance is α.

$\sqrt{P_o}\ \ e_A x_A$ and $\sqrt{P_o}\ \ e_B x_B$ are additional noise terms which are sculpted as complex Gaussian random variables whose mean is zero and variance is $\alpha\, P_o$.

So, we can rewrite equation (2) as:

$$\mathrm{Y_r} = \sqrt{P_O}(h_A x_A + h_B x_B) + \sqrt{\alpha\, P_o + N_o}\, n1_r \qquad \textbf{(3)}$$

In 2nd slot, it is assumed that relay decodes the signal correctly, so the signal broadcasted from the relay to the 2 source nodes A and B is given by this equation:

$$\mathrm{Y_A} = \sqrt{P_1}\, h_A \hat{x} + n_A \qquad \textbf{(4)}$$

$$\mathrm{Y_B} = \sqrt{P_1}\, h_B \hat{x} + n_B \qquad \textbf{(5)}$$

where $\hat{x} = x_A + x_B$ is the signal which is jointly decoded by the relay and P_1 is the transmitted power of relay. Self- interference term is subtracted by the source B who knows its own signal. The assumption is that perfect decoding is taking place. Now, after the subtraction and the cancellation of self -interference term and $\sqrt{P_o}\ \ e_B x_A$ is the zero mean Gaussian random variable whose variance is P_1 . Therefore the signal received at the source B is given by this equation:

$$\mathrm{Y_r} = \sqrt{P_1}\, h_B\ x_A + \sqrt{\alpha\, P_o + N_o}\ n_b \qquad \textbf{(6)}$$

$\sqrt{P_1}\, h_B\ x_A$ is the required term in equation (6) and $\sqrt{\alpha\, P_o + N_o}$ is the undesired signal or we can say noise signal. The instantaneous Signal to Noise Ratio at the source node B is given by the following equation:

$$\gamma = \frac{P_1\,|h_B|^2}{\alpha\,P_o + N_o} \quad \textbf{(7)}$$

'γ' for the case when α =0 i.e. no channel estimation error is given by the following equation:

$$\gamma|\,\alpha = 0 = \frac{P_1\,|h_B|^2}{N_o} \quad \textbf{(8)}$$

And mean value is represented by this equation:

$$E(\gamma|\alpha = 0) = \frac{P_1\ \delta_B^2}{N_o} \quad \textbf{(9)}$$

Signal to Noise Gap Ratio equation becomes [by substituting equation (7), (8), (9) in equation (1)] :

$$\mathrm{R_c} = \frac{\alpha P_1\,|h_B|^2}{\delta_B^2(\alpha\,P_o + N_o\ \ )} \quad \textbf{(10)}$$

Source B applies Maximal Ratio Combining (MRC) technique for adding the signals from N relays. Therefore the instantaneous SNR equation at the MRC output is given by this following equation:

$$\gamma = \sum_{i=1}^{N} \frac{\alpha P_i\,|h_{Bi}|^2}{(\alpha\,P_i + N_o\ \ )}$$

Therefore the Signal to Noise Gap Ratio for the N relay is given by this equation:

$$\mathrm{Rc}^{M} = \frac{\sum_{i=1}^{N}\alpha {p_i}^2|h_{Bi}|^2/\alpha P_1 + N_o}{\sum_{i=1}^{N} P_i\,\delta_{Bi}^2} \quad \textbf{(11)}$$

And its average is given by this equation:

$$\mathrm{E(Rc}^{M}) = \frac{\sum_{i=1}^{N}\alpha {p_i}^2\delta_{B\,i}^2\ \ \ /\alpha P_1 + N_o}{\sum_{i=1}^{N} P_i\,\delta_{Bi}^2} \quad \textbf{(12)}$$

Performance analysis in the presence of Co-Channel interference

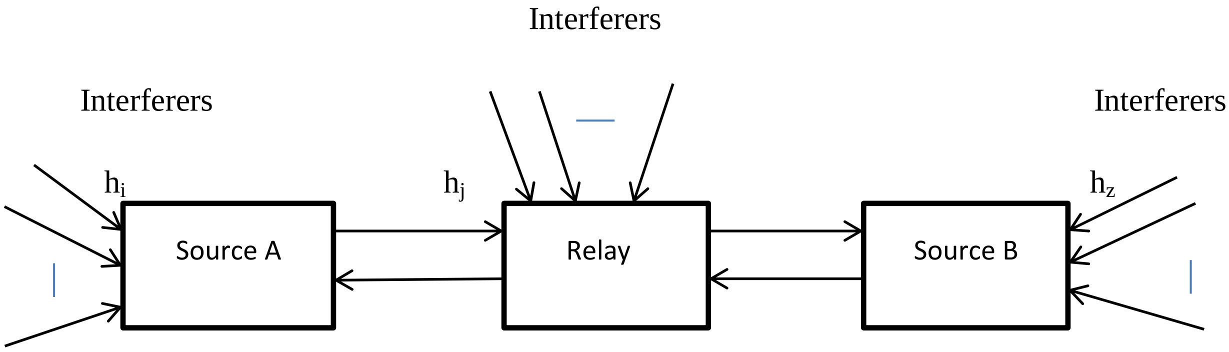


Fig 6.3: DF Co-Channel Interference

Here, the effect of CCI is studied in [25], for this case the Signal to Noise Gap Ratio is given by the following equation:

$$R_C = \frac{\gamma|\, M=0 - \gamma|\, M\neq 0}{E(\gamma|M=0)} \qquad \textbf{(13)}$$

It is assumed that there is M interferers, h_j is the channel coefficients between source A and interferers, h_z is the channel coefficients between relay and interferers, h_k is the channel coefficients between source B and interferers. The channels are modeled as complex random Gaussian variables whose mean is 0 and variance is δ_p^2 where p is =i,z,k . The signal received at the relay is given by the following equation:

$$Y_{r}=\sqrt{P_o}\,(h_A\, x_A + h_B x_B\,) + \sum_{z=1}^{M} \sqrt{P_z}\;\, h_z\, x_z\; + \sqrt{N_o} n_r \qquad \textbf{(14)}$$

Where this term $\sum_{z=1}^{M} \sqrt{P_z}\;\, h_z\, x_z$ represents the co-channel interference from 'M' no of interferers which can be sculpted as complex Gaussian random variable whose mean is zero and variance is $\sum_{z=1}^{M}\; \delta_z^2 P_z$ .So equation (14) can be rewritten as:

$$Y_{r}=\sqrt{P_o}\,(h_A\, x_A + h_B x_B\,) + \sqrt{\sum_{z=1}^{M}\; \delta_z^2 P_z + N_o n_r} \qquad \textbf{(15)}$$

The received signal at the relay after its joint decoding it verifies the signal and broadcast that signal to both sources A and B which is given by these equation:

$$Y_{A}=\sqrt{P_1}\, h_B \hat{x} + \sqrt{\sum_{j=1}^{M}\; \delta_j^2 P_j + N_o n_A} \qquad \textbf{(16)}$$

$$Y_B = \sqrt{P_1}\, h_B \hat{x} + \sqrt{\sum_{k=1}^{M} \delta_k^2 P_k + N_o n_B} \quad \textbf{(17)}$$

Now source B subtracts its self- interference term i.e. $\sqrt{P_1} \ \ e_B x_B$ to get the information which is provided by source A . Therefore, the resulting signal at the source B is given by this equation:

$$Y_B = \sqrt{P_1}\, h_B \hat{x} + \sqrt{\sum_{k=1}^{M} \delta_k^2 P_k + N_o}\ n_B \quad \textbf{(18)}$$

In the equation (18) , the term $\sqrt{P_1}\, h_B \hat{x}$ is the required term after subtraction and this term $\sqrt{\sum_{k=1}^{M} \delta_k^2 P_k + N_o}\ n_B$ is the noise term, therefore instantaneous Signal to Noise Ratio is given by this equation :

$$Y = \frac{P_1 \, |h_B|^2}{\sum_{k=1}^{M} \delta_k^2 P_k + N_o} \quad \textbf{(19)}$$

$\gamma|\alpha = 0 \ and \ \ E(\gamma|\alpha = 0)$ are same as used in equation 8 and 9 . Now, put value of equation (8), (9) and (19) in equation (13) we get Signal to Noise Gap Ratio by the following equation:

$$R_i = \frac{|h_B|^2 \sum_{k=1}^{M} \delta_k^2 P_k}{\delta_B^2 (\sum_{k=1}^{M} \delta_k^2 P_k + N_o)} \quad \textbf{(20)}$$

Therefore the Signal to Noise Gap Ratio for the N relay is given by this equation:

$$R_i^M = \frac{\sum_{i=1}^{N} |h_{Bi}|^2 P_i \sum_{k=1}^{M} \delta_k^2 P_k}{\sum_{k=1}^{M} \delta_k^2 P_k + N_o} \quad \textbf{(21)}$$

And its average is given by this equation:

$$E(R_i^M) = \frac{\sum_{k=1}^{M} \delta_k^2 P_k}{\sum_{k=1}^{M} \delta_k^2 P_k + N_o} \quad \textbf{(22)}$$

Performance analysis in the presence of Co-Channel interference and Channel estimation error

For this case Signal to Noise Gap Ratio is given by the following equation:

$$R_C = \frac{\gamma|\ M=0,\alpha=0 - \gamma|\ M\neq 0,\alpha\neq 0}{E(\gamma|M=0,\alpha=0)} \quad \textbf{(23)}$$

The signal received at the first time slot at the relay is given by the following equation:

$$\mathrm{Y}_{\mathrm{r}}=\sqrt{P_o}\,(h_A\, x_A + h_B x_B\,) + \sqrt{\sum_{k=1}^{M}\ \delta_z^2 P_z + \alpha\, P_o + N_o n_r} \tag{24}$$

The broadcasted signal from the relay to the 2 sources is given by these equations:

$$\mathrm{Y}_{\mathrm{A}}=\sqrt{P_1}\, h_B \hat{x} + \sqrt{\alpha\, P_o + \sum_{j=1}^{M}\ \delta_j^2 P_j + N_o}\, n_A$$

$$\mathrm{Y}_{\mathrm{B}}=\sqrt{P_1}\, h_B \hat{x} + \sqrt{\alpha\, P_o + \sum_{k=1}^{M}\ \delta_k^2 P_k + N_o}\, n_B \tag{25}$$

The instantaneous value of SNR is given by this equation:

$$\mathrm{Y} = \frac{P_1\, |h_B|^2}{\alpha\, P_1 + \sum_{z=1}^{M}\ \delta_z^2 P_z + N_o} \tag{26}$$

$\gamma|\alpha = 0\ and\ \ E(\gamma|\alpha = 0)$ are same as used in equation 8 and 9 . Now, put value of equation (8), (9) and (26) in equation (23) we get Signal to Noise Gap Ratio by the following equation:

$$\mathrm{R} = \frac{|h_B|^2(\alpha\, P_1 + \sum_{z=1}^{M}\ \delta_z^2 P_z)}{\delta_B^2(\alpha\, P_1 + \sum_{z=1}^{M}\ \delta_z^2 P_z + N_o)} \tag{27}$$

Therefore the Signal to Noise Gap Ratio for the N relay is given by this equation:

$$R_i^M = \frac{\sum_{i=1}^{N} |h_{Bi}|^2 P_i(\alpha\, P_i + \sum_{z=1}^{M} \delta_z^2 P_z)\backslash(\alpha\, P_i + \sum_{z=1}^{M} \delta_z^2 P_z + N_o)}{\sum_{i=1}^{N}\ \delta_{Bi}^2 P_i} \tag{28}$$

And its average is given by this equation:

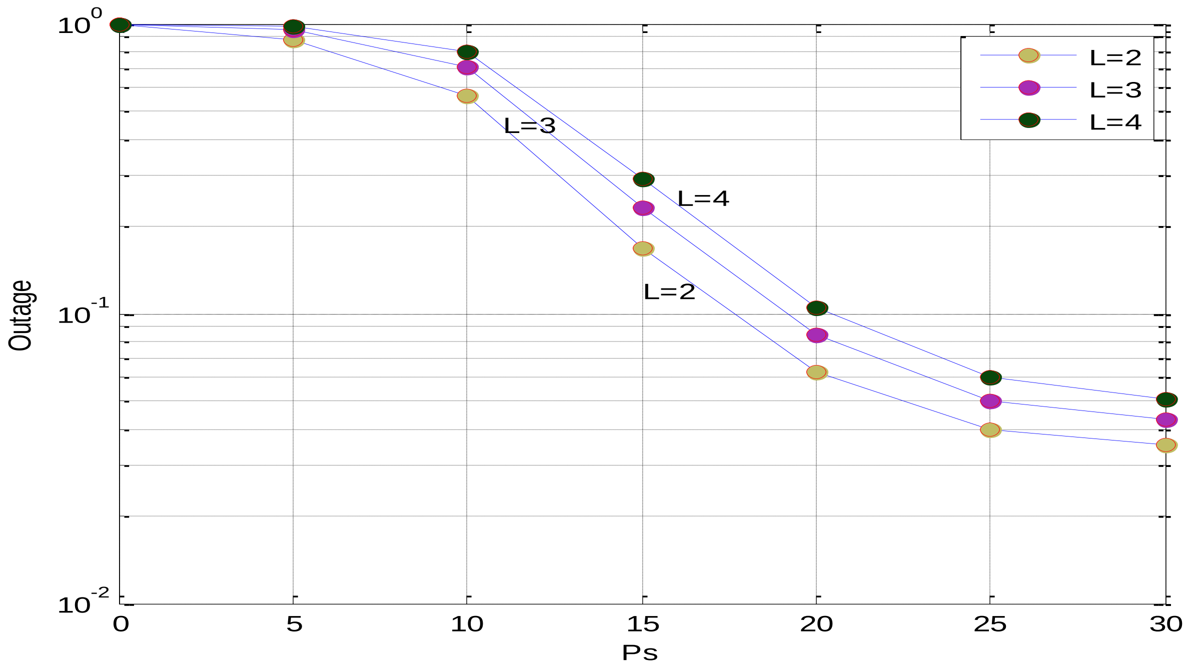
$$\mathrm{E}(R_i^M) = \frac{\sum_{i=1}^{N} \delta_{Bi}^2 P_i(\alpha\, P_i + \sum_{z=1}^{M} \delta_z^2 P_z)\backslash(\alpha\, P_i + \sum_{z=1}^{M} \delta_z^2 P_z + N_o)}{\sum_{i=1}^{N}\ \delta_{Bi}^2 P_i} \tag{29}$$

CHAPTER-7

RESULTS AND DISCUSSIONS

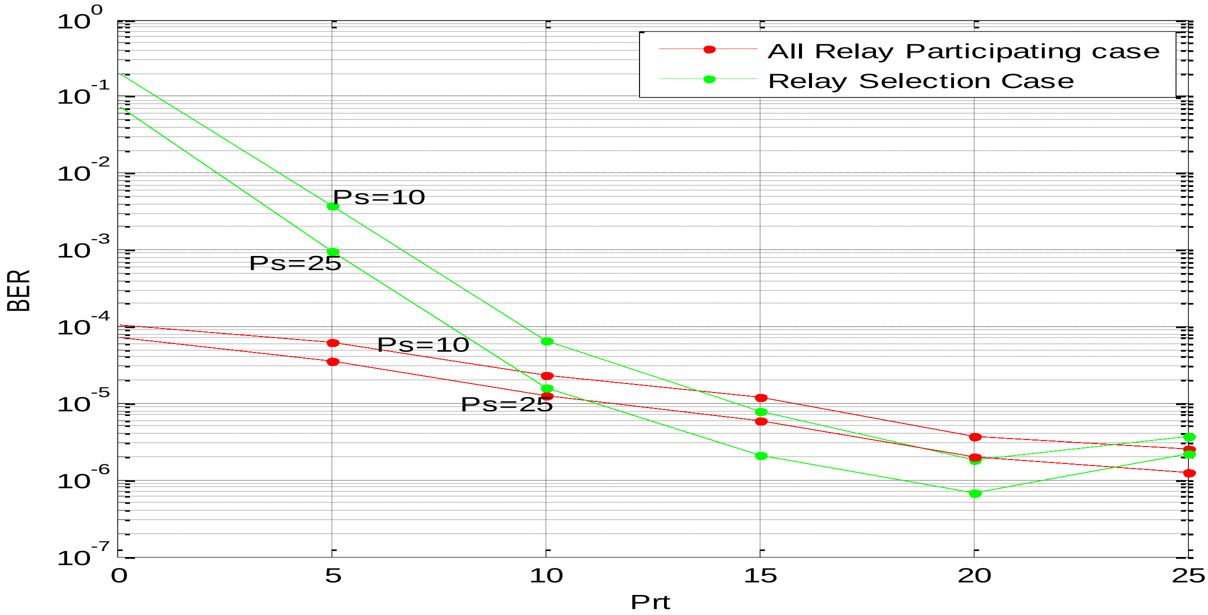
Basepaper Implementation

1) Outage probability vs Source power for different interferers



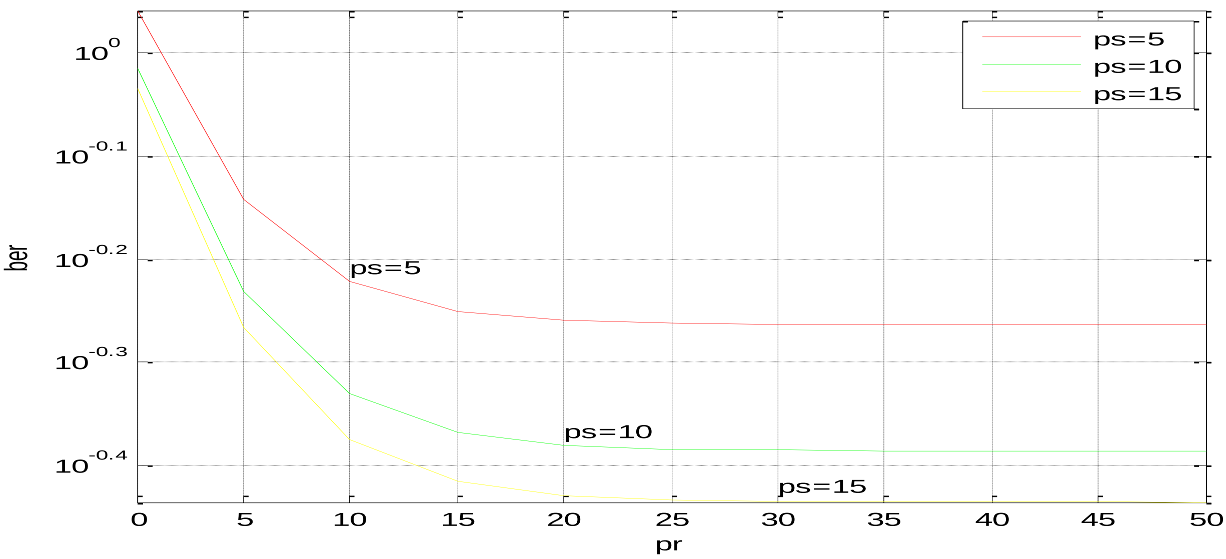
➢ From the graph it can be concluded that for more number of interferers outage probability is more and for less number of interferers outage probability is less. It means there is direct relationship between outage probability and number of interferers.

2) BER vs total power at the relays (P_{RT}) for all relay participating case and all relay selection case



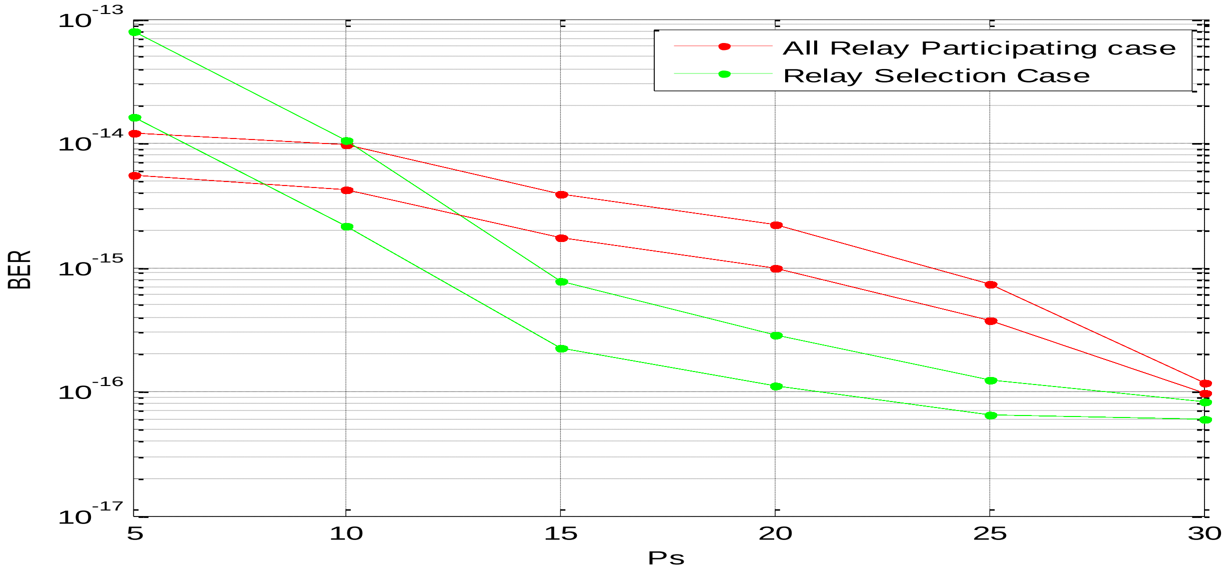
➢ From the graph, it is concluded that all relay participating case performance is better than the relay selection case. So, from this analysis we have concluded that relay selection scheme is not always good.

3) BER vs power at the relays for different source powers (ps)



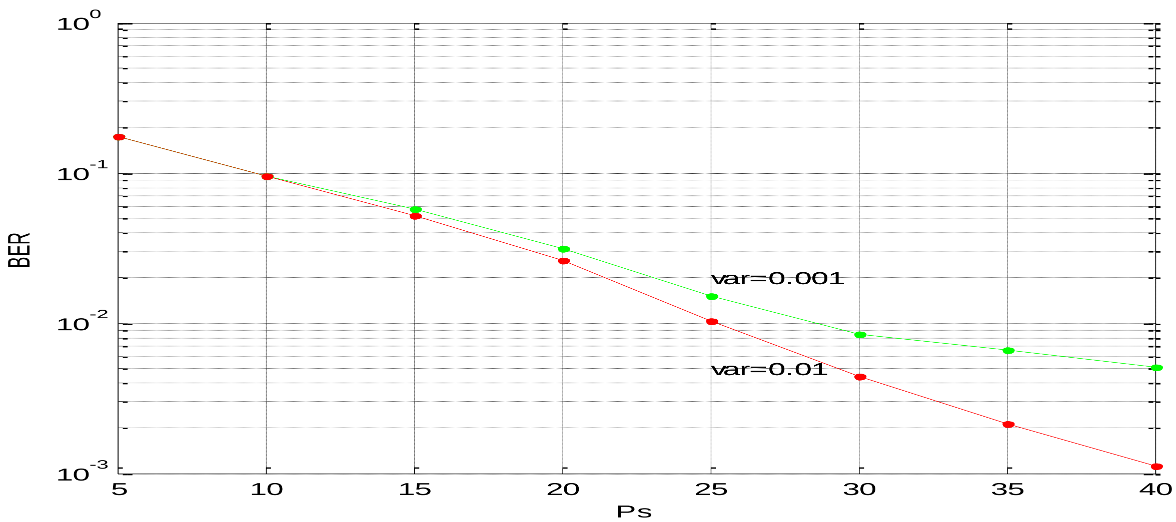
➢ From the graph we can observe that with the increases of source power, Bit Error Rate (BER) reduces. It means there is inverse relationship between source power and BER.

4) BER vs Source Power (P_s) for all relay participating case and relay selection



➢ From the graph, we can observe that the relay selection gives better rate performance as compare to the all-relay participating case.

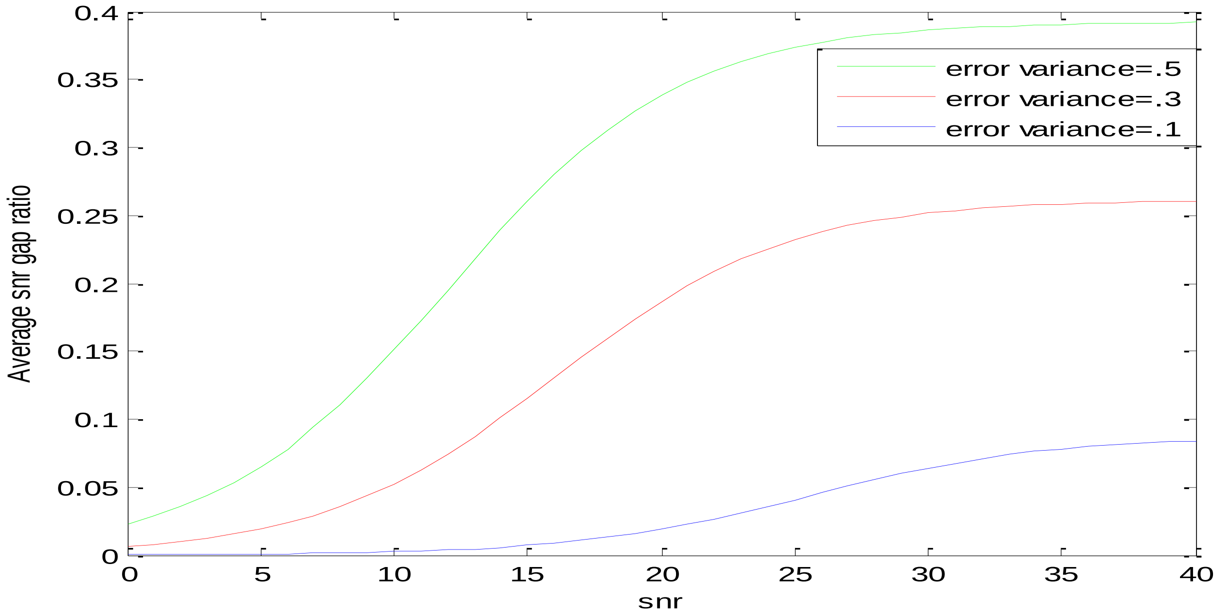
5) BER vs Source Power(P_s) with different variances



- Graph is showing that BER increases with increase of variance and becomes less when variance is less. It means there is direct relationship between BER and variance.

Decode and Forward Implementation

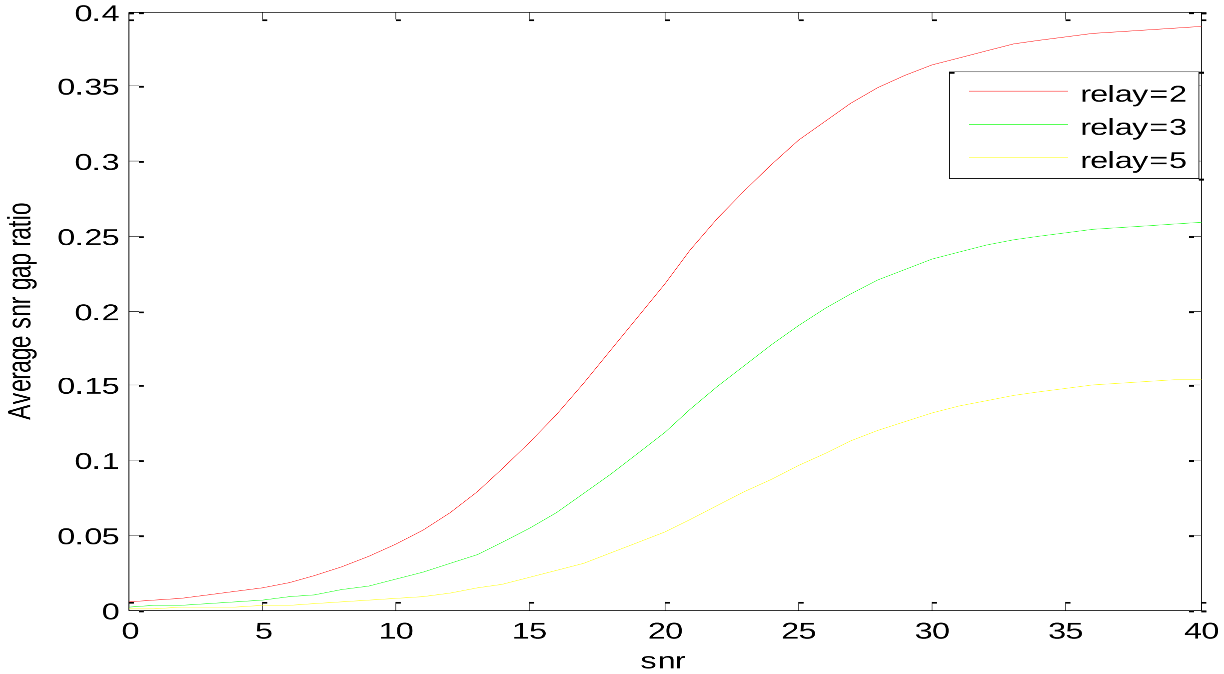
1) Average SNGR vs SNR in presence of Channel Estimation Error for different error variances



From the graph it is concluded that:

- When error variance is more, Signal to Noise Gap Ratio increases and when error variance is less, Signal to Noise Gap Ratio decreases. Hence, there is a direct relationship between error variance and average Signal to Noise Gap Ratio.
- Signal to Noise Gap Ratio basically signifies how much SNR is deviated from its original value.
- Signal to Noise Gap Ratio must be less for better communication.
- Graph is showing that when Signal to Noise Gap Ratio is more, then channel estimation error is more and vice versa.

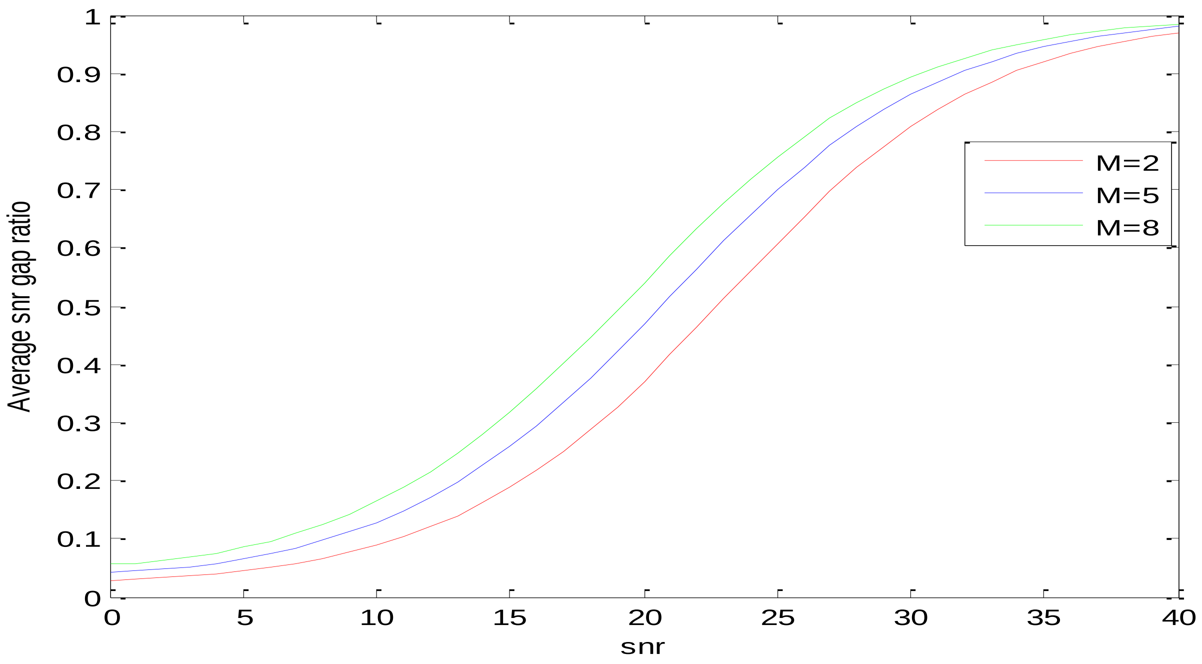
2) Average SNGR vs SNR in presence of Channel Estimation Error for different relays



From the graph it is concluded that:

- When there is more number of relays, then the Signal to Noise Gap Ratio is less and when there is less number of relays, the Signal to Noise Gap Ratio is more. It means there is inverse relationship between number of relays used and average Signal to Noise Gap Ratio.
- It is preferred that Signal to Noise Gap Ratio must be less, means less deviation of SNR from its exact value .
- Signal to Noise Gap Ratio must be less for better communication.
- Graph is showing that Signal to Noise Gap Ratio is less for the more number of relays. So, SNR reduction is also less.

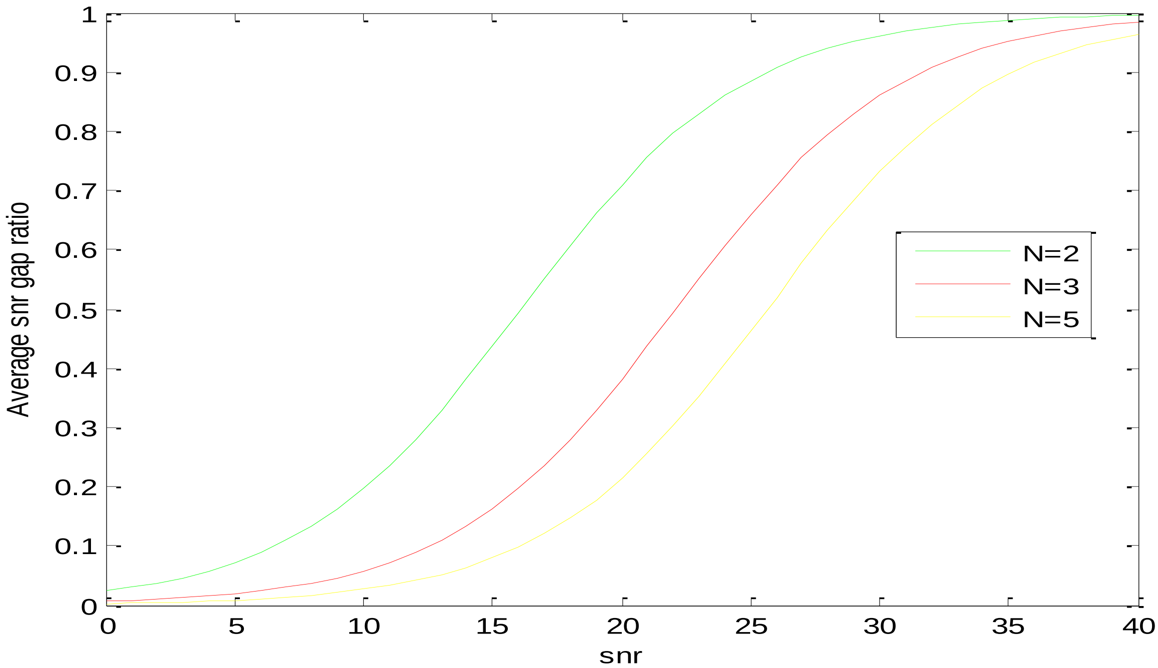
(3) Average SNGR vs SNR in presence of Co-Channel Interference for different interferers



From the graph it is concluded that:

- When there is more number of interferers then the Signal to Noise Gap Ratio is more and when there is less number of interferers, the Signal to Noise Gap Ratio is less. It means there is direct relationship between number of interferers and average Signal to Noise Gap Ratio.
- It is preferred that Signal to Noise Gap Ratio must be less, means less deviation of SNR from its exact value.
- Signal to Noise Gap Ratio must be less for better communication.
- Graph is showing that Signal to Noise Gap Ratio is less when there is less number of interferers. The Co-Channel Interference is less for less number of interferers. Hence the lower Signal to Noise Gap Ratio signifies less reduction in SNR which is preferable for the better system.

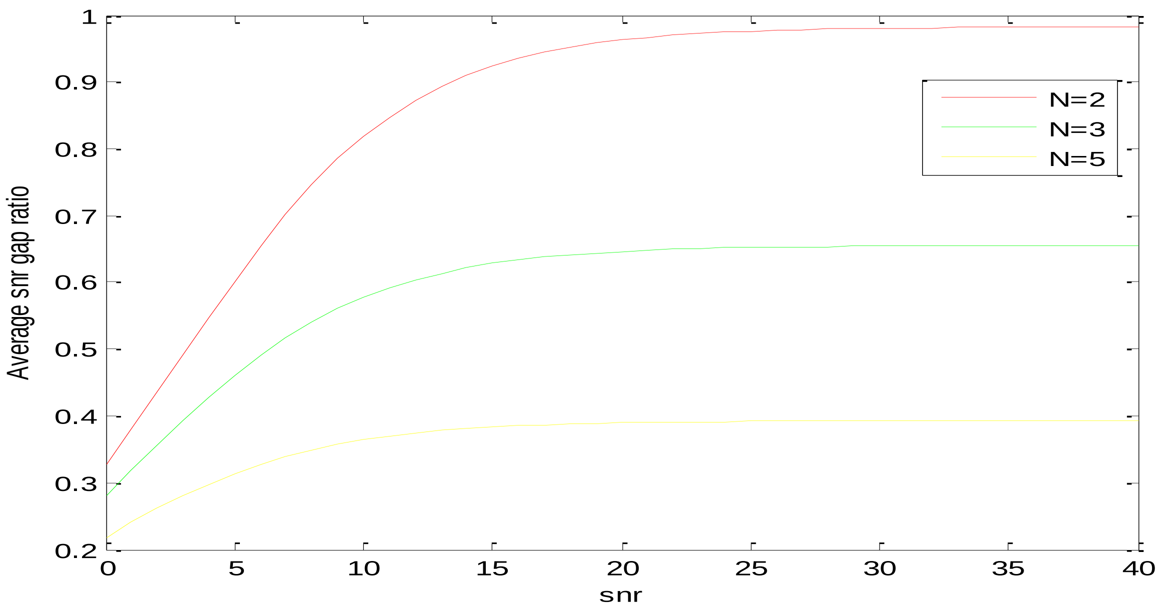
4) Average SNGR vs SNR in presence of Co-Channel-Interference for different relays



From the graph it is concluded that:

- When there is more number of relays then the Signal to Noise Gap Ratio is less and when there is less no of relays, the Signal to Noise Gap Ratio is more. It means there is inverse relationship between number of relays and average Signal to Noise Gap Ratio.
- It is preferred that Signal to Noise Gap Ratio must be less, means less deviation of SNR from its exact value.
- Signal to Noise Gap Ratio must be less for better communication.
- Graph is showing that Signal to Noise Gap Ratio is less when more number of relays are used in the wireless system. Therefore, the Co-Channel Interference is also less for more number of relays. Hence the lower Signal to Noise Gap Ratio signifies less reduction in SNR which is preferable for the better system.

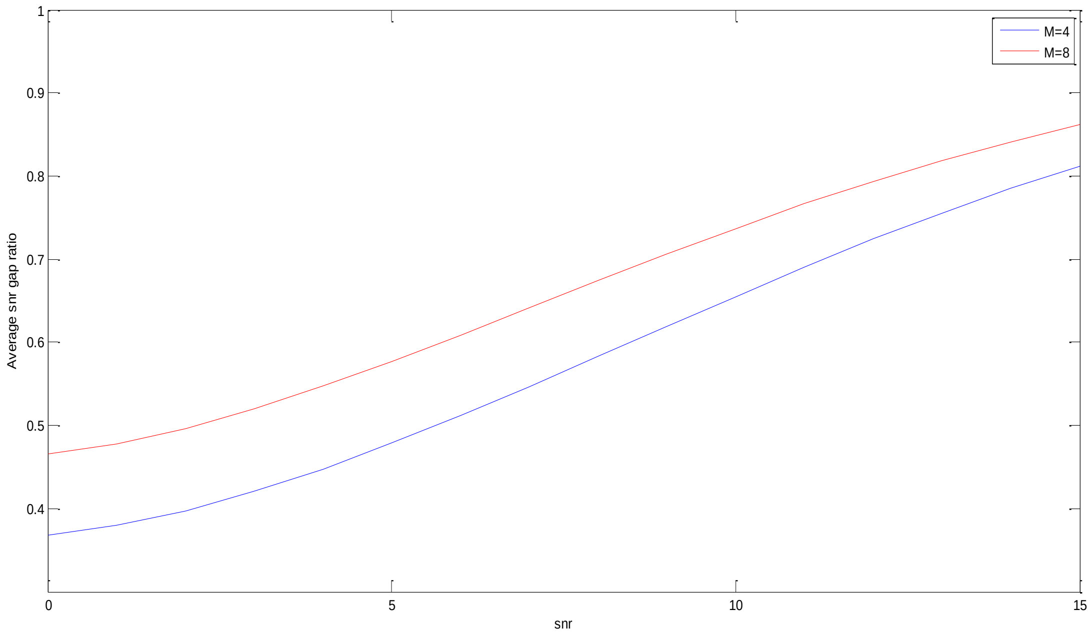
5) Average SNGR vs SNR in presence of Channel Estimation Error and Co-Channel Interference for different relays



From the graph it is concluded that:

- When there is more number of relays then the Signal to Noise Gap Ratio is less and when there is less no of relays, the Signal to Noise Gap Ratio is more. It means there is inverse relationship between number of relays and average Signal to Noise Gap Ratio.
- It is preferred that Signal to Noise Gap Ratio must be less, means less deviation of SNR from its exact value.
- Signal to Noise Gap Ratio must be less for better communication.
- Graph is showing that Signal to Noise Gap Ratio is less when more number of relays are used in the wireless system. Therefore the Co-Channel Interference and Channel Estimation Error is also less for more number of relays .Hence, the lower Signal to Noise Gap Ratio signifies less reduction in SNR which is preferable for the better system.

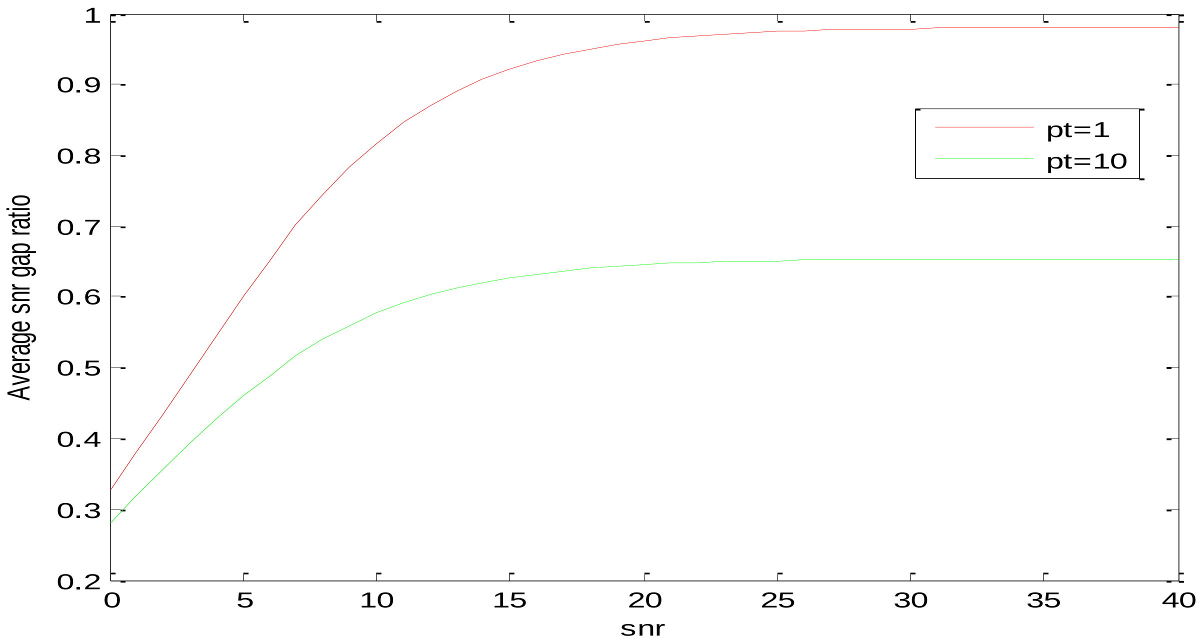
6) Average SNGR vs SNR in presence of Channel Estimation Error and Co-Channel Interference for different interferers



From the graph it is concluded that:

- When there is more number of interferers then the Signal to Noise Gap Ratio is more and when there is less number of interferers, the Signal to Noise Gap Ratio is less. It means there is direct relationship between number of interferers and average Signal to Noise Gap Ratio.
- It is preferred that Signal to Noise Gap Ratio must be less ,means less deviation of Signal to Noise Ratio from its exact value .
- Signal to Noise Gap Ratio must be less for better communication.
- Graph is showing that Signal to Noise Gap Ratio is less when there is less number of interferers. For less number of interferers, the Co-Channel Interference and CEE is less and the Signal to Noise Gap Ratio is also less which is preferable.

7) Average SNGR vs SNR in presence of Channel Estimation Error and Co-Channel Interference for different transmission power



From the graph it is concluded that:

- When less power is used for transmission then the Signal to Noise Gap Ratio is more and when more power is used, the Signal to Noise Gap Ratio is less. It means there is inverse relationship between transmitted power and average Signal to Noise Gap Ratio.
- It is preferred that Signal to Noise Gap Ratio must be less, means less deviation of SNR from its exact value.
- Signal to Noise Gap Ratio must be less for better communication.
- Graph is showing that Signal to Noise Gap Ratio is less when transmitted power is less. For more transmitted power, the Co-Channel Interference and CEE is also less. Hence, the lower Signal to Noise Gap Ratio signifies less reduction in SNR which is preferable for the better system.

CHAPTER-8

Conclusion and Future Work

Relay networks have become hugely popular in recent times for the benefit of spectral efficiency. Comparing to one-way half-duplex relaying, bidirectional relaying is a spectrally efficient protocol which provides simultaneous communication between two users. In practice, CSI must be estimated, and therefore estimation error exists. So it is important to study the influence of CEE on the system performance in DF/AF TWRN. Furthermore, the strategies to enhance the performance and combat the channel uncertainty resulting from the estimation error are also of practical interest. In our work, the performance analysis of Decode and Forward Two Way Relaying Network in presence of Co-Channel Interference and Channel Estimation Error is studied. It has been investigated that these two effects increase the Signal to Noise Gap Ratio which measures that how much Signal to Noise Ratio is deviated or reduced from its exact value. In future, we can enhance this TWRN research in presence of Co-Channel Interference and Channel Estimation Error effect, with some more effective technique like by the combination of both Decode and Forward (DF) and Amplify and Forward (AF) technique. Combination of both techniques will definitely provide us more accurate and effective results as both have their own advantages and disadvantages. So, by the combination of these two techniques, we will definitely get better and accurate results.

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