PERFORMANCE ANALYSIS ON RELAY ASSISTED CDMA-CA NETWORKS IN UNDERWATER COMMUNICATION

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ABSTRACT

Wireless transmission through the ocean is one of the enabling technologies for the development of future ocean-observation systems and sensor network applications. In this paper, the design aspects of different modulation schemes based on Code Division Multiple Access/ Collision Avoidance (CDMA/CA) for underwater acoustic (UWA) communications has been discussed, and its performance is analyzed using MATLAB software. The design criterion is to maximize the system throughput under a target average bit error rate (BER). The signals used to carry digital data via underwater channel are the acoustic waves because they can travel over a long distance unlike the radio signals like electromagnetic waves which cannot be used because they spread over short distances. It is very difficult to design an underwater communication system because of multipath, Doppler effects, noise, and attenuation. These factors lead to errors in the communication performance and limitation of maximum propagation distance. This analysis help us to calculate the distance that can be realized using the code division multiple access (CDMA) technique with direct-sequence spread spectrum in an underwater communication system considering only the attenuation and noise present in the acoustic channel.

Keyword: - *CDMA-CA, Relays, Underwater communication, BER.*

1. INTRODUCTION

Wireless communication technology is significant today because it has become part of our daily life; the idea of wireless undersea communications may still seem far-fetched. However, research has been active for over a decade on designing the methods for wireless information transmission underwater. Though, cabled submersibles remain indispensable if high-speed communication link is required wireless is considered to accomplish without burden of heavy cables. Together with sensor technology wireless communications will enable new applications. Since electromagnetic waves can only propagate extremely shorter distances, instead acoustic waves can be used. Undersea acoustic communications dates back to the development of manned submarines and the need to communicate with them. The main challenge for coherent detection of signals over underwater acoustic (UWA) channels is accurate channel estimation. Factors contributing to this challenge include the long delay spread, time variation of the UWA channel, and the wideband nature of the transmitted signals.

Underwater communication is a technique of sending and receiving messages below water. In underwater environments, acoustic wave is preferred over radio and optical waves as information carrier, because the latter two suffer from high attenuation and severe scattering correspondingly in the medium of water. According to the nature of acoustic wave propagation, in shallow water environment, there are sound reflection at the surface, bottom and any objects; in deep water environment, there are sound refraction caused by speed variation with depth. So, underwater acoustic communication channel is indeed fast varying, and hence often fast fading. The underwater acoustic communication channels, however, have limited bandwidth, and often cause signal dispersion in time and frequency. Despite these limitations, underwater acoustic communications are a rapidly growing field of research and engineering since acoustic waves are not the only means for wireless communication underwater, but they are the only ones that can travel over longer distances.

With advances and development in acoustic modem technology, sensor technology, relaying technology and vehicular technology, ocean engineering today is moving towards integration of these components into autonomous underwater networks. Depending on the application, future underwater networks are likely to evolve in two directions centralized and decentralized networks. In a centralized network, the communication between nodes occurs through a base station that covers one cell. Larger area is covered by more cells whose base stations are connected over a separate communications infrastructure. In recent times CDMA is preferred to OFDM because the drawbacks of an OFDM system are its high peak-to-average power ratio (PAPR) value and vulnerability to channel time variations. Regarding to underwater acoustic CDMA modem development, there are even fewer work are among the limited examples in this area. With all the developed theories and practical modems, their performance in real sea environments has to be tested. Finding out which are the relevant environmental factors and what are their impacts on underwater acoustic communication systems is critical for future system improvement.

The wide range of applications for this underwater communication and networks include future applications in enhancing myriad industries, ranging from the offshore oil industry to aquaculture to fishing industries. Additionally, pollution control, climate recording, ocean monitoring (for prediction of natural disturbances) and detection of objects on the ocean floor are other areas that could benefit from enhanced underwater communications. It is also used for environmental monitoring to gather oceanographic data. Other purposes include marine archaeology, search and rescue missions and in defense or military applications.

2. PROPOSEDSYSTEM

The performance of the underwater channel is analyzed in the acoustic medium implementing various modulation schemes. The sensor networks are clustered using clustering algorithm. In terms of physical layer, coherent MIMO-CDMA based communication is considered as feasible solution for the band limited/frequency selective underwater channel with more spectral efficiency, high data rates and reliable links. Hence it is implemented to attain simultaneous and asynchronous access to the channel by various users. Under Water Medium Access Control (UWMAC), a distributed Medium Access Control (MAC) protocol designed for Under Water-Autonomous Sensor Networks (UW-ASN) is introduced. This MAC protocol is a transmitter-based Code Division Multiple Access (CDMA) scheme that incorporates a novel closed-loop distributed algorithm to jointly set the optimal transmits power and code length.

UWMAC aims at achieving three objectives is to guarantee high network throughput, low channel access delay, and low energy consumption. It is demonstrated that UWMAC simultaneously achieves these three objectives in deep water communications (where the ocean depth is more than 100 m), which are usually not severely affected by multipath. UWMAC is the first protocol that leverages CDMA properties to achieve multiple accesses to the scarce underwater bandwidth, while other protocols tailored for this environment have considered CDMA merely from a physical layer perspective.

The channel characteristics are considered as the underwater channel rapidly changing. The underwater parameters are taken into account for the estimation of signal attenuation in the undersea environment. Two types of fading are fast fading and slow fading in which fast fading occurs when the coherence time of the channel is small relative to the delay requirement of the application. In this case, the amplitude and phase change imposed by the channel varies considerably over the period of use. Slow fading arises when the coherence time of the channel is large relative to the delay requirement of the application.

Addition to this various noises such as ambient noise, thermal noise due to water temperature and turbulent noise are included in the analysis. The factors that may affecting the underwater acoustics sensor networks communication is the noise. Ambient noise is that sound received by an Omni-directional sensor which is not from the sensor itself or the manner in which it is mounted. Noise from the sensor or its mounting is termed self-noise. Ambient noise is made up of contributions from many sources, both natural and anthropogenic.

Multi-hop propagation in the channel is accomplished using relays hence the channel is relay assisted. It helps in propagation over longer distances in the channel. Since fading occurs, multi-hop propagation helps in reducing loss of data. The relays used are balanced relay and Max-min relay and the characteristics are plotted. The modulation schemes employed are PSK, BPSK, QPSK and QAM. By modulating the signal in the transmission channel the error performance for each technique is calculated using BER analysis. The error rate is calculated from the demodulated signal and analyzed by plotting against average transmitted power.

2.1 Clustering Algorithm

The proposed solution, however, assumes a clustered network architecture and proximity among nodes within the same cluster, while we seek a more general and flexible solution suitable for different network sizes and architectures. Clustering has been accepted as one of the most efficient techniques for conserving energy of wireless sensor networks (WSNs). However, in a two-tiered cluster based WSN, cluster heads (CHs) consume more energy due to extra overload for receiving data from their member sensor nodes, aggregating them and transmitting that data to the base station (BS). Therefore, proper selection of CHs and optimal formation of clusters play a crucial role to conserve the energy of sensor nodes for prolonging the lifetime of WSNs. The Fig -1 depicts the clustering protocol.

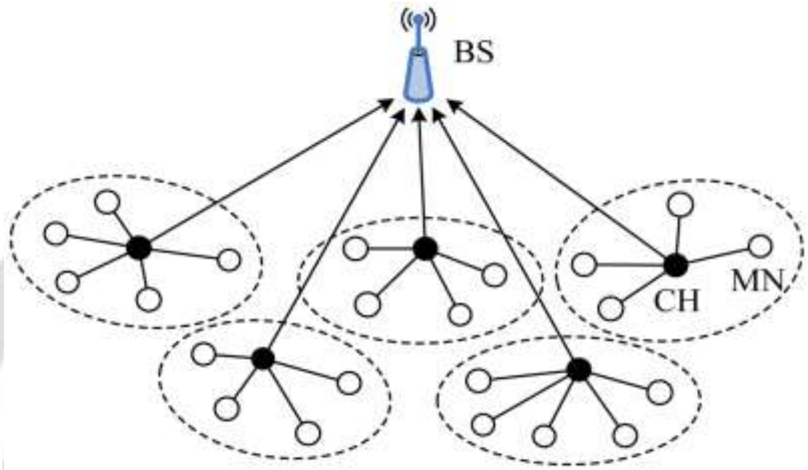

Fig -1: **Clustering Routing Protocols in Wireless Sensor Networks**

A. Setup Phase

Setup phase consists of cluster head selection, leader node selection and next hop selection steps as follows. It demonstrates the multilayer architecture of the network operation considering three types of nodes.

1) Cluster Head Selection

Nodes monotony distribution is one of the needs of clustered WSNs application. Suitable distribution makes possibility to create balanced cluster heads, which have different advantages, for example: maximum intra-cluster delay is proportional with biggest cluster, so balanced cluster avoids delay increase. Energy avoids in disposing of fertility balance of cluster heads. Also avoid long distance communications between cluster head and its' staffs. Protocol helps to have suitable distribution of cluster heads. Suitable cluster heads distribution makes possibility for creating balanced clusters which have several advantages and avoid intra-cluster long distance communications.

It also balances the loads on the cluster heads. The intended standards cause not to choose nodes, which are in unsuitable situations as cluster head because some of the nodes in some of net areas cannot be in a cluster center because of their situation in the network, anyway. So utilizes such nodes as cluster head cause the increase of intra-cluster energy. The receiver and the sender nodes consume much more energy than ordinary nodes. So giving two expensive spectrum synchronically to node especially in the network late age could finish all of the battery energy and non-operate the whole network. Therefore we attempt to choose parent nodes in each cluster in order to separate these two duties for productivity increase.

The two value functions in order to determine each sensory node competence for being cluster head or sender. We do this simply by nodes degree standard second power average of neighbor nodes on special ray and also distance to BS. Nodes with high degree are generally suitable for being cluster head. The advantage of this task is by less cluster head it could cover more nodes so as to avoid expensive communications. Both reduce consumption and equipoising could increase lifetime.

2) Next Hop Selection

In this step, the next hop is determined for each node in order to send data. If a cluster has no leader node based on lines, then each ordinary node will consider its cluster as next hop. An ordinary node selects the nearest node among cluster head nodes and leader node or nodes. Each leader node considers its cluster head as the next hop. Then cluster head node selects the nearest cluster head as its next hop in a circle with a smaller radius and closer to BS in order to send its data. After this, each cluster head node sends a message in order to inform other leader nodes.

B. Steady State Phase

At this phase, each cluster head node or leader node aggregates received data from ordinary nodes or other leader nodes with its own data. Then, cluster head nodes send data to BS with a multi-hop view.

2.2 Block diagram

The typical communication link contains the source block from which the message is modulated using modulator and the medium is accessed by CDMA-CA protocol, since it is an underwater link the channel is depicted as fading channel with relay assistance. The receiver section is inverse of transmitter section with error detection block included. The error detection implemented is maximum likelihood detection which is suited for detecting errors in multiple access technique such as CDMA. Both the source and destination depicted are transceivers and are sensor networks deployed in the ocean bed. Mostly the data collected by the sensors are in digital format hence suitable modulation schemes are used. The Fig -2 shows the overall block diagram of the underwater communication link.

As in any communication system, the underwater wireless link has transmitter and receiver section. In the transmitter section, the digital data from the source (usually sensors deployed in ocean bed) is modulated using acoustic modem. The modem can be programmed to any type of modulation technique as in our proposed system. The modulated data is sampled and the packets are transmitted into the channel by a UWMAC technique that is CDMA-CA. The characteristics of the channel are discussed above such as fading contributed by various noises in ocean environment leading to attenuation of the signal.

Existing MAC solutions are mainly focused on Carrier Sense Multiple Access (CSMA) or Code Division Multiple Access (CDMA). This is because Frequency Division Multiple Access (FDMA) is not suitable for UW-ASNs due to the narrow bandwidth in Under Water Acoustic (UW-A) channels and the vulnerability of limited band systems to fading and multipath. Moreover, Time Division Multiple Access (TDMA) shows limited bandwidth efficiency because of the long-time guards required in UW-A channels.

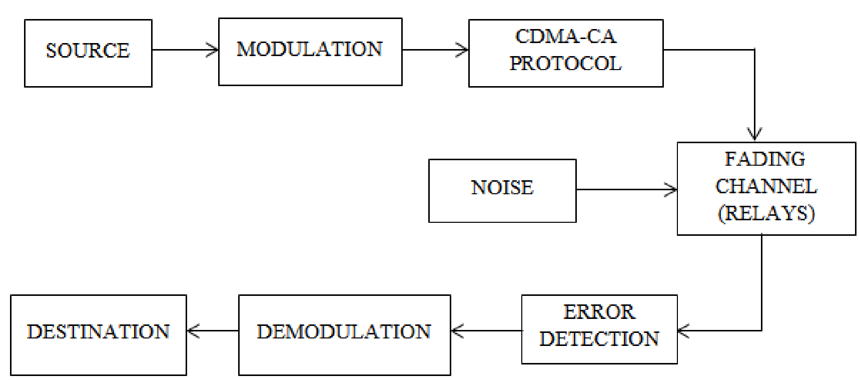

Fig -2: Block Diagram of Communication Link

Underwater acoustic channel usually has low data rate, long propagation delay, severe multipath effect, and time varying fading. Cooperative transmission is a new wireless communication technique in which diversity gain is achieved by utilizing relay nodes as virtual antennas. In cooperative transmission scheme, the relay nodes amplify the signal received from the source node, and then forward the signal immediately to the destination. The goal is to influence the multipath effect at the receiver. The receiver is equipped with maximum likelihood error detection protocol and the BER is calculated to simulate the performance of the underwater communication channel.

A Bit Error Rate (BER) is defined as the rate at which errors occur in a transmission system. It is a key parameter that is used in the accessing systems that transmit digital data from one location to another. If the medium between the transmitter and receiver is good and the signal to noise ratio is high, then the bit error rate will be very small. The knowledge of the BER also enables other features of the link such as power and bandwidth etc. to be tailored to enable the required performance to be obtained. BER can be expressed as follows,

BER= (Bits in Error) / (Total bits received)

For detecting the error at the receiver maximum likelihood error detection technique is used which is explained as follows. The method of maximum likelihood provides estimators that have both a reasonable intuitive basis and many desirable statistical properties. The method is very broadly applicable and is simple to apply. Once a maximum-likelihood estimator is derived, the general theory of maximum-likelihood estimation provides standard errors, statistical tests, and other results useful for statistical inference.

Under very broad conditions, maximum-likelihood estimators have the following general properties: Maximum-likelihood estimators are consistent. They are asymptotically unbiased, although they may be biased in finite samples. They are asymptotically efficient — no asymptotically unbiased estimator has a smaller asymptotic variance. They are asymptotically normally distributed. If there is a sufficient statistic for a parameter, then the maximum likelihood estimator of the parameter is a function of a sufficient statistic. A sufficient statistic is a statistic that exhausts all of the information in the sample about the parameter of interest.

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. Noise strength, in general, can include the noise in the environment and other unwanted signals (interference). BER is inversely related to SNR, that is high BER causes low SNR. High BER causes increases packet loss, increase in delay and decreases throughput. The exact relation between the SNR and the BER is not easy to determine in the multi-channel environment.

3. RESULTS AND DISCUSSIONS

The process that is performed in the system is shown through the below snapshots. In underwater communication, the process is done through the MATLAB software. In each modulation techniques, the carrier signal is taken from the acoustic waves. The carrier can change its phase, amplitude and its frequency depends upon the particular modulation technique used.

3.1 Modulation Schemes

Phase-shift keying (PSK) is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave). Any digital modulation scheme uses a finite number of distinct signals to represent digital data. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase, as shown in Fig -3.

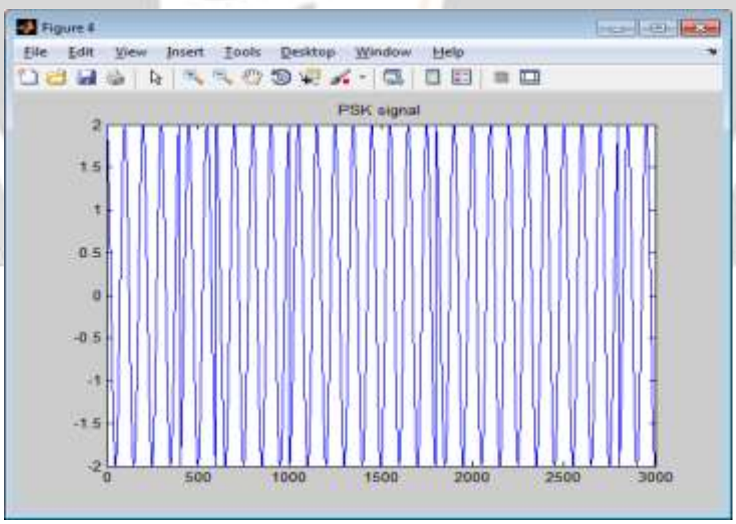

Fig -3: PSK Modulated Signal

The below Fig -4 shows the BPSK modulated signal, this modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol and so is unsuitable for high data-rate applications. In the presence of an arbitrary phase-shift introduced by the communications channel, the demodulator is unable to tell which constellation point is which. As a result, the data is often differentially encoded prior to modulation. BPSK is functionally equivalent to 2-QAM modulation.

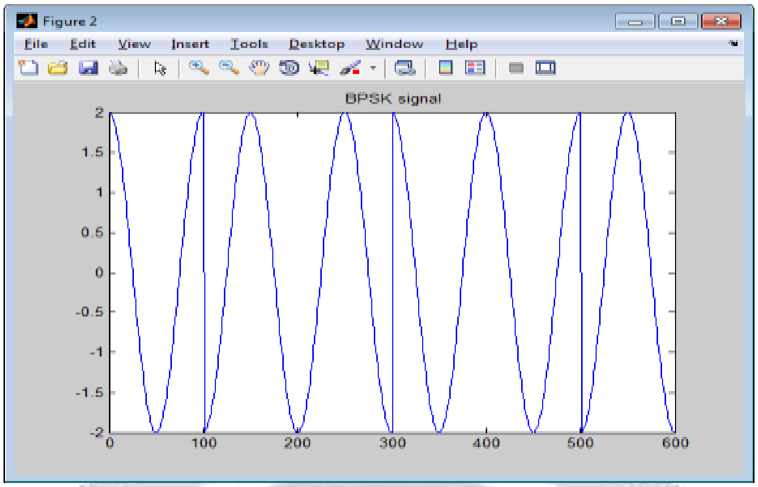

Fig -4: BPSK Modulated Signal

The mathematical analysis shows that QPSK can be used either to double the data rate compared with a BPSK system while maintaining the same bandwidth of the signal but halving the bandwidth needed. In this latter case, the BER of QPSK is exactly as same as the BER of BPSK - and deciding differently is a common confusion when considering or describing QPSK. The transmitted carrier can undergo numbers of phase changes, as shown in Fig -5.

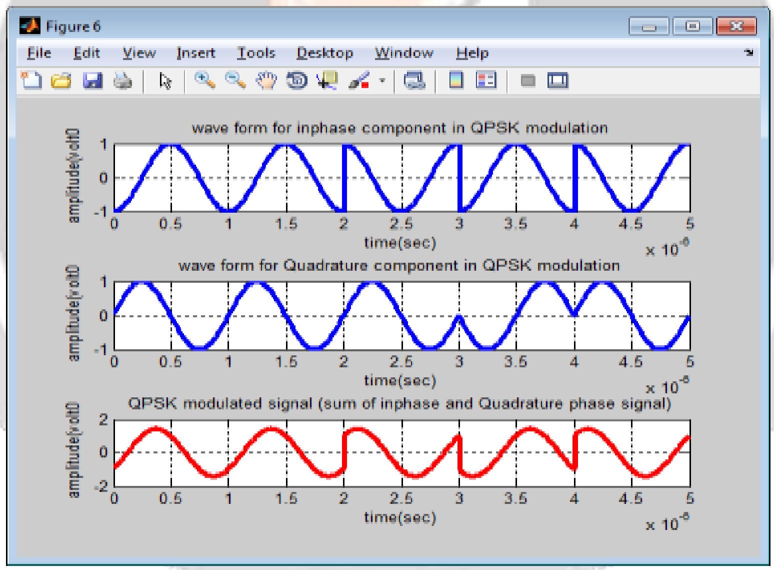

Fig -5: QPSK Modulated Signal

Quadrature Amplitude Modulation or QAM is a form of modulation which is widely used for modulating data signals onto a carrier used for radio communications. It is widely used because it offers advantages over other forms of data modulation such as PSK, although many forms of data modulation operate alongside each other. A scatter plot of a signal shows in the Fig -6 describes the signal's value at a given decision point. In the best case, the decision point should be at the time when the eye of the signal's eye diagram is the most widely open. Scatter plots are often used to visualize the signal constellation associated with digital modulation. A scatter plot can be useful when comparing system performance to a published standard. It is widely used because it offers advantages over other forms of data modulation such as PSK, although many forms of data modulation operate alongside each other.

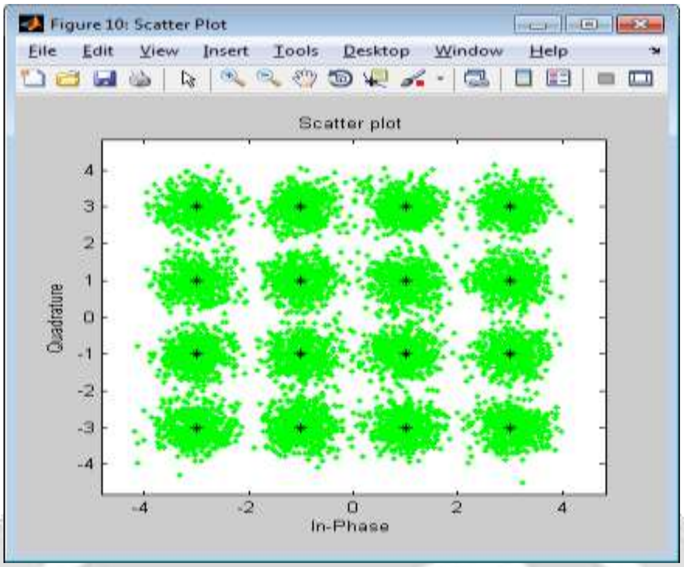

Fig -6: Scatter plot of 16-QAM

3.2 Relay Performance

Relay nodes are also battery-operated devices capable of wireless communication. But the type of relay nodes proposed in different publications is not unique. Some have suggested that the relay nodes should be of equal capabilities as sensor nodes, even sensor nodes can be assigned the role of relay node. On the other hand, some others have suggested that relay nodes should be of higher capabilities than the sensor nodes in terms of initial energy provisioning, the transmission range and the data processing (data gathering, data aggregation) capability. Higher capability relay nodes are mainly suggested in cluster-based sensor networks; where higher energy provisioned relay nodes take the role of cluster heads. The Fig -7 describes about the performance of relay such that as the distance increases the throughput get varies.

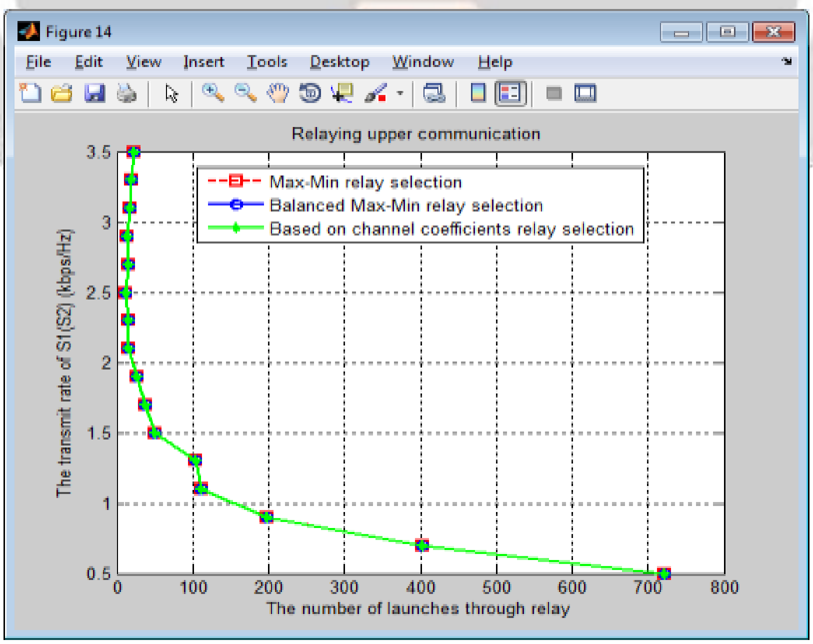

Fig -7: Relaying in communication

3.3 BER vs SNR Performance Analysis

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. Noise strength, in general, can include the noise in the environment and other unwanted signals (interference). BER is inversely related to SNR, that is high BER causes low SNR. High BER causes increases packet loss, increase in delay and decreases throughput. The exact relation between the SNR and the BER is not easy to determine in the multi-channel environment. Signal to noise ratio (SNR) is an indicator commonly used to evaluate the quality of a communication link and measured in decibels.

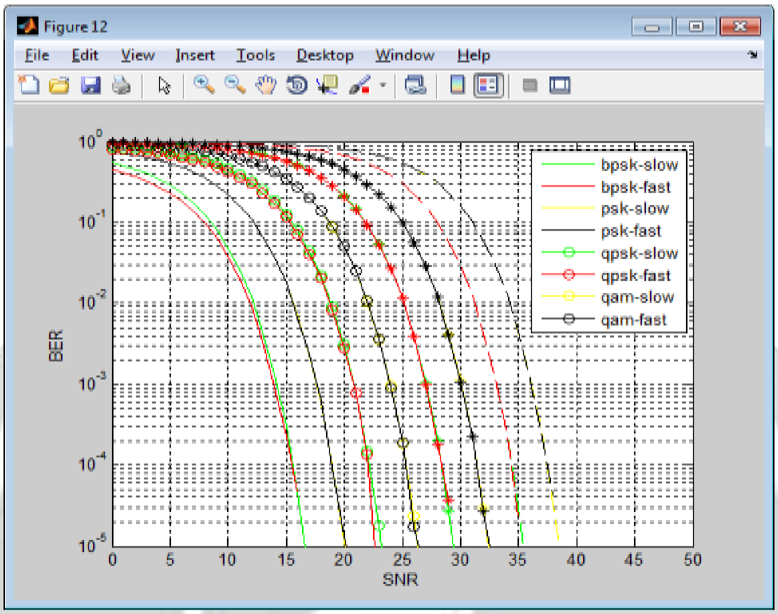

Fig -8: BER vs SNR for overall modulation schemes

From the Fig -8, it is found that the BER has been reduced and the SNR has been increased. Here the SNR has been increased up to 40 db. It can achieve maximum at the rate of 45 db.

4. REFERENCES

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