

Flag Com: Energy Efficient Secure Routing Protocol**¹Alok Srivastava, ²Dr Rajeev Ratan**¹Department of Electronics & Communication Engineering, MVN
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Abstract

Mobile communication has become all pervasive in the present day scenario and has gained ubiquitous importance in everyday life. The radio spectrum, which form foundation of mobile communication is a physically limited resources, and is already reaching the threshold of saturation. Co-Operative communication is expected to be the next big change in mobile communication systems. The radio spectrum scarcity, which is prescribed to be reality sooner than we may realize, needs immediate addressing and cooperative communication provides hope of offering solution towards resolution. While looking at radio spectrum scarcity co-operative communication is a hope to resolve this problem. There are however, lot of issues like security, energy consumption, instability of nodes etc, which should be resolved before execution of co-operative communication. In this paper we suggest a protocol Flag-com, which may take care of all these issues. This protocol has been designed in such a way that the major portion of packet processing is done only on source and destination node. This will resolve not only security issue but will also reduce consumption of power at the relay nodes. It will also keep a tab on the movement of relay nodes so that proactive measures like searching and selection of new relay nodes can be done before the relay node moves out of the range.

Path selection is another major issue in co-operative communication. Since the transmitted power from any node is very low so effect any type of attenuation will affect the communication. Attenuation in a wireless or mobile network can be divided in two parts (i) attenuation due to nature (ii) attenuation due to interference. Attenuation due to nature cannot be reduced. In this paper we have dealt with both, Markov model has been used to predict the effect of nature on transmitted data packets and tabu search is used to find the path having lowest interference.

In this paper we have achieved almost 53% improvements in SNR and success probability of data packet delivery.

Keywords : Flag Com, Energy consumption, Markov model, Tabu search.

I. Introduction

Any communication protocol based on co-operative communication cannot be implemented without resolving the issues associated with it. The important issues which needed immediate addressing includes security, energy consumption, selection of path, low signal to noise ratio, high bit error rate, smooth change of nodes during communication and hardware impairment etc. In this paper a new protocol based on flag i.e flag com proposed to resolve all these problems except hardware impairment [XI].

The objectives of this paper are

- (1) To find the path with lowest attenuation in transmitted signals
- (2) To predict the probability of successful delivery of a data packet for efficiency considerations.

Attenuation can be attributed to two major sources including:

- (1) Natural – The attenuation caused by natural sources are major reason for attenuation. There are several types of attenuation which are caused by nature e.g scattering, refraction, reflection, absorption etc. These are dependent on atmospheric conditions. These are out of our control; only corrective measures can be taken if the effect is known in advance and power of the signal can be adjusted accordingly.
- (2) Interference – The attenuation caused by radiation of radio waves in same frequency spectrum from nearby sources. This type of noise can be controlled a little bit by putting restrictions on radiated power but cannot be controlled completely and moreover, it also affects the correction of natural attenuation by power adjustment.

The suggested protocol introduces two techniques

- i) Selection of path
- ii) Maintenance of path

Selection of path

In case of co-operative communication the main challenge is selection of a path. The path basically has four main requirements

- i) Security
- ii) Stability
- iii) Optimal energy
- iv) Low interference

Since the path is dependent on moving nodes and these nodes have limited energy source so they cannot afford to have special algorithms because running of these algorithms will stress their limited energy sources and this may drain out their batteries. At the same time the relay nodes are also unstable and they can move away at any time thereby increasing the risk of link disconnection between transmitter and receiver. As we have discussed in [I] which is a base study of this proposed protocol, every node in between transmitter and receiver may not support co-operative communication, it should be our primary phase of concern to search supportive relay nodes along with other concerns listed above.

II. Proposed protocol

The selection of relay node in cooperative communication is very complicated but necessary as they serve for routing of data. The relay nodes can be broadly categories [XV] into two categories based on:

- (i) Processing at nodes
- (ii) Processing only at source

Processing at node:

In this system [XIII] a source node transmit data to relay nodes. After receiving of data packet the relay nodes check the data packets for errors. If received data packets are found correct then data will be forwarded. If received packets are found with errors and cannot be retrieved, then it will be discarded. This system thus allowed transmission of checked data only. Thus it saves energy of relay nodes in transmission of data. But on the other hand it increases processes and delay at relay node. This will leads to security compromise.

Processing at source only:

In this technique [XIII] source send data to all possible directions. Every node will receive and forward to the next node until it reaches to either at base station or at destination node. The packet data will be checked only at destination. This is simplest method and will consume energy only at source and destination. Eg amplify and forward protocol [IX]

Both categories of protocols discussed above focus primarily on routing possibilities but do not consider the significant factor of losses due to interference.

The loss many be considered in terms of total packet loss/ energy loss or partial data loss which will induces delay, due to reconstruction or recovery of packet by error codes of regeneration.

All these protocols discussed about routing possibilities but one major thing that should be considered is the loss. These losses are very important because the signals are being transmitted by the mobile nodes and these nodes are low energy devices so the signal transmitted will also have low power. It has been established that

interference can degrade signals throughput by 53.09% [V]. Additional to the throughput reduction interference may increase delay by 20.63% [V]. So if effect of interference can be reduced then chances of survival of packets transmitted by a mobile node will increase.

The probability of success of a data can further be increase if effect of noise on data packets can be estimated. For this purpose a new method has been introduced in this paper named as flag bearer method which is the basis of Flag Com protocol.

III. Flag Bearer Method

Various methods have been suggested so far [VII]. Here we are suggesting a new protocol. As the name suggest a packet is broadcast in all directions before sending data. This packet is transmitted through all possible nodes and routes to base station. This packet will be checked at all the nodes. If the packet is ok then it will be transmitted to next node. Every node must inscribe its identification on the packet. Once it reaches to base station and found correct then its reverse journey starts through same path. Thus mo of paths can be made simultaneously. Every data packet will be send by these paths so that chance of success can be increased. In this protocol more than one path (if possible) has been suggested because any mobile node can move out of path and link can be broken. If this packet is correct then chance of correctness of next packet may be calculated using Markov model [VIII].

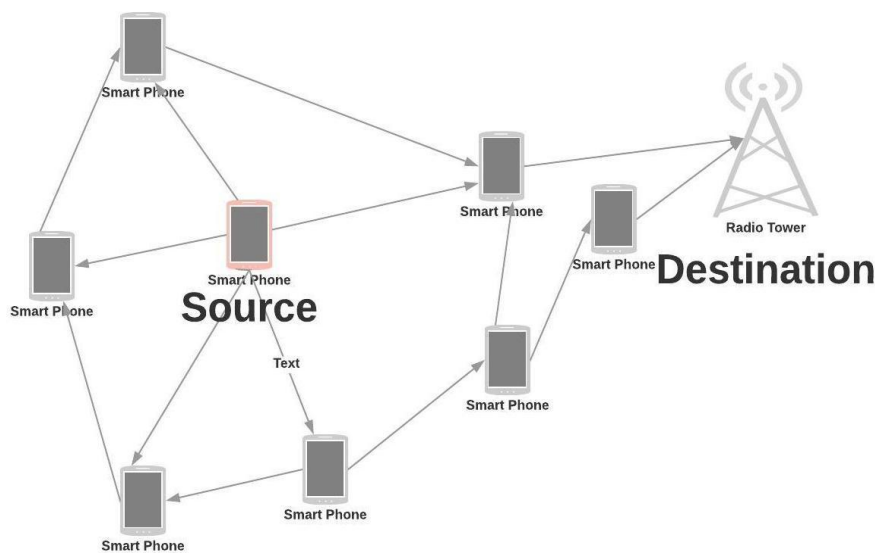


Fig 1 Flow of data packets for flag bearer

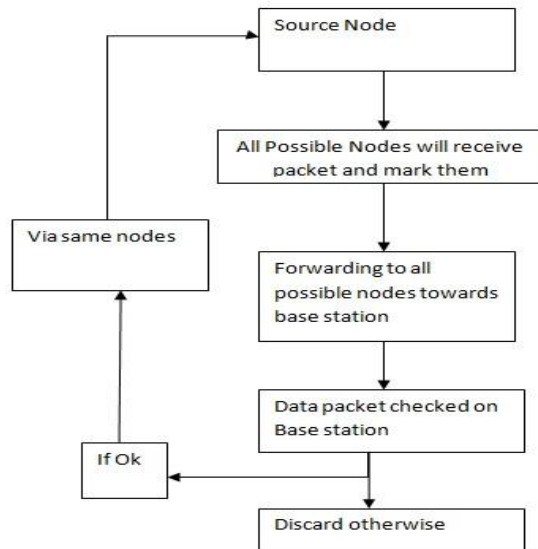


Fig 2 Algorithm for 1st packet transmission

Markov Model for node selection

Markov model can be used for channel modeling[XIV] [III]. Let us assume that at time 0, 1st data packet has been transferred and it is found correct on all the nodes. Assuming that probability of success of next packet is p , probability of unsuccessful delivery of packet to final destination is $1-p$. Let P is the power of transmission at any node. With the increasing distance from the transmitting node this power will be attenuated and for the next node there will be two possibilities, either the received packets have enough power so that they can be detected or remains undetected due to low power. After receiving packet again there are two possibilities either they can be decoded without errors or they cannot be decoded.

In all cases a successful delivery of packet will be considered only if it can be decoded without error.

We propose channel estimation at destination node. The node estimates the channel state for the next one based on the current status of received packet.

According to the Markov model, if the current state of data packet is good only then the next state can be estimated as good. Otherwise next state will be bad. If packet decoding is unsuccessful then again next state will be bad.

Since we have considered 1st packet is successful so our next state of packet will be considered as good.

So the whole system can be divided in two states

Successful

Unsuccessful

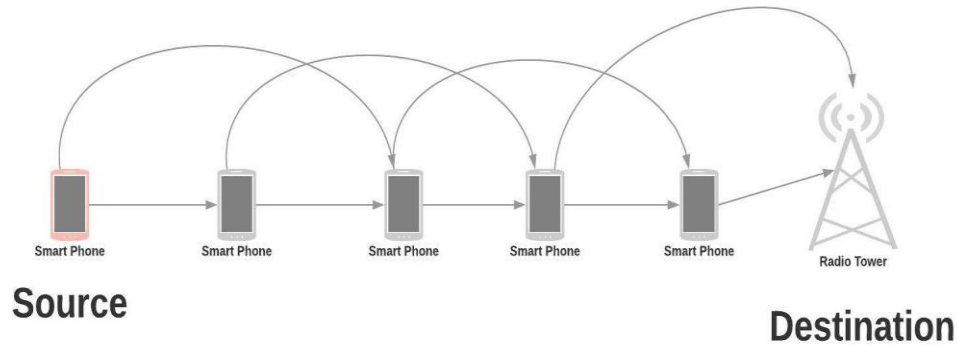


Fig3. Multi hop forwarding model for 4 relay nodes after route establishment.

Let us assume probability of success is X . Then probability of unsuccessful is $1-X$. For unsuccessful the probability

$X=0$. If P is the probability of success then same will be the successful retransmission of success i.e probability of retransmission of a packet is X .

So probability of forwarding a packet to next node = $X(1-X)$.

Probability of receiving an incorrect packet = $(1-X)^2$

Probability of forwarding packet while unsuccessful detection = $X(1-X^2)$

Let us assume that a node can transmit maximum up to 2 nodes then matrix for probability of success is

$$X_{\text{success}} = \begin{vmatrix} (1-X)^2 & X(1-X) & X & 0 & 0 \\ 0 & (1-X)^2 & X(1-X) & X & 0 \\ 0 & 0 & (1-X)^2 & X(1-X) & X \\ 0 & 0 & 0 & (1-X) & X \\ 0 & 0 & 0 & 0 & 1 \end{vmatrix}$$

By assuming equal probability for success and unsuccessful the value of X as 0.5

$$X_{\text{success}} = \begin{vmatrix} (1-0.5)^2 & 0.5(1-0.5) & 0.5 & 0 & 0 \\ 0 & (1-0.5)^2 & 0.5(1-0.5) & 0.5 & 0 \\ 0 & 0 & (1-0.5)^2 & 0.5(1-0.5) & 0.5 \\ 0 & 0 & 0 & (1-0.5) & 0.5 \\ 0 & 0 & 0 & 0 & 1 \end{vmatrix}$$

$$X_{\text{success}} = \begin{vmatrix} (0.5)^2 & 0.5(0.5) & 0.5 & 0 & 0 \\ 0 & (0.5)^2 & 0.5(0.5) & 0.5 & 0 \\ 0 & 0 & (0.5)^2 & 0.5(0.5) & 0.5 \\ 0 & 0 & 0 & (0.5) & 0.5 \\ 0 & 0 & 0 & 0 & 1 \end{vmatrix}$$

$$X_{\text{success}} = 0.0078$$

The above value of X_{success} is for single multihop system which is very low. To improve probability of successful delivery of data every node should process the data which ultimately removes effect of noise and attenuation. Before transmission every node should check the probability of successful delivery to next node and packets should be forwarded only if the probability of successful delivery is high. In this example if every node processes the data then probability of success is

$$X_{\text{success}} = X(1-X) = 0.5(1-0.5) = 0.25$$

If N paths to be considered then $X_{\text{success}} = 0.25 \times N$.

Thus the probability of success of data transmission can be increased using multipath system. By the use of Markov system a transmitting node can save its energy and that's too without decoding the packets. This will be a defiantly increase the level of security in the system. A node can take decision on the basis of probability of error in data packet.

MIMO system for data transmission

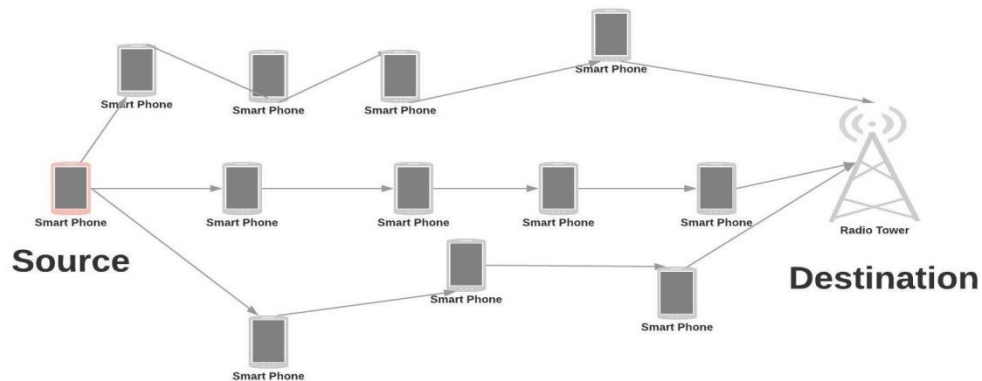


Fig4. Multipath forwarding model for MIMO.

MIMO or multiple input and multiple output system use multiple receiver and multiple transmitter antenna system. In this case receiver will be only one while transmitter can be more than one. If N transmitters are there then channel capacity can be defined as [II]

$$C = \sum_{i=1}^r \log_2 \left(1 + \frac{\text{Snr} P_i}{T_p} \right) \lambda_i$$

Where $r = \min(\text{Transmitters and receivers})$

Sp $r=1$

T_p = Total power available at transmitter side

$P_i = i^{\text{th}}$ path between transmitter and receiver.

If

T = Transmitted signal

R = Received signal and

C = Channel Characteristics

Then

$$R = C * T \quad (1)$$

If the channel has N Transmitters then transmitted signal T can be written as

$$T = [T_1, T_2, T_3 \dots \dots \dots T_N] \quad (2)$$

Thus channel matrix will have N rows of independent elements

$$\text{i.e } c = \begin{bmatrix} h_{1,1} \\ h_{2,1} \\ - \\ - \\ h_{N,1} \end{bmatrix}$$

Only one receiver antenna is assumed so the matrix will have single column only.

From equation (i)

$$R = c * T$$

$$R = [T_1, T_2, T_3 \dots \dots \dots T_N] * \begin{bmatrix} h_{1,1} \\ h_{2,1} \\ - \\ - \\ h_{N,1} \end{bmatrix} \quad (3)$$

$$R = h_{1,1}T_1 + h_{1,2}T_2 + h_{1,3}T_3 \pm \dots \dots \dots h_{1,N}T_N \quad (4)$$

If the transmitters are transmitting K packets at discrete time intervals for the training of the channel then

$$T = [T_1, T_2, T_3 \dots \dots \dots T_N] = \begin{bmatrix} T_{1,1} & \cdot & \cdot & \cdot & T_{1,N} \\ \cdot & & - & & \cdot \\ \cdot & & & & \cdot \\ T_{K,1} & \cdot & \cdot & \cdot & T_{K,N} \end{bmatrix} \quad (5)$$

The channel can be identified by a common state matrix (U).

$$C_T = U * T \quad (6)$$

$$C_R = U * Y \quad (7)$$

Then

$$\hat{C} = C_T^{-1} * C_R \quad (8)$$

According to Gram Schidmt Process

$$T = QM \quad (9)$$

Where

$$u_1 = T_1 \quad x_1 = \frac{u_1}{|u_1|} \quad \text{and } x_1 \in Q$$

$$u_2 = T_2 - (x_1^T \cdot T_2)x_1 \quad (10)$$

$$x_2 = \frac{u_2}{|u_2|} \quad \text{and } x_2 \in Q$$

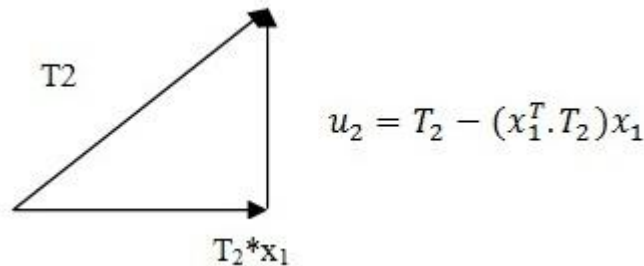


Fig 5 Vector sum of two dimensional signal

Similarly

$$U_N = T_M - (x_1^T \cdot T_M)x_1 - \dots - (x_{N-1}^T \cdot T_N)x_{n-1} \quad (11)$$

Where

$$x_N = \frac{u_N}{|u_N|} \quad \text{And } x_N \in Q \quad \text{and } Q \text{ will be matrix of same dimension as of } T.$$

Above calculation are made assuming no noise condition and line of sight communication.

Now including noise received signal can be represented as [IX]

$$R_X = \sum_{N=1}^N \sqrt{\beta_{Ti}} H_i^{1/2} X_i T_{pi}^{1/2} C_i T_i^{1/2} r_i + n \quad (12)$$

Where

β_{Ti} is attenuation between a transmitting node and receiving node for i th channel, H_i is a Hermitian matrix, X_i is matrix of independent elements, T_{pi} is transmission non negative matrix, T_i is the transmit vector of i^{th} node, and n is noise in channel

So it is clear that if signal to noise ratio increases then channel capacity and probability of success will also increase. For improvement in SNR Tabu search mechanism can be used as it can help in establishing low interference paths.

Tabu search for route selection

The data packets transmitted from a node to another have to face noise. A major portion of this noise is constituted by interference [VI] [XII]. If this interference can be removed from the path or path with low interference can be chosen then attenuation effect on signal can be reduced. For this purpose we propose Tabu search algorithm to be used.

The Tabu search[IV] is an algorithm which search neighbors for some selected parameters and accepts changes only if the next solution is better than previous. So employing tabu search will be a better idea for selection on low interference path. By the use of flag bearer method and Markov model the possible paths are already set. These paths will constitute tabu list. The next task is to find the path where neighboring nodes has minimal interference. The minimum interference can be calculated by the distance between nodes.

If transmission power of a non participating Node is P_T and P_I is the minimum power that can interfere

$$L_S = 36.56 + 20 \log_{10} f + 32 * 10^3 \log_{10} D \quad (13)$$

So

$$\frac{P_T}{\pi D^2} - P_I = 36.56 + 20 \log_{10} f + 32 * 10^3 \log_{10} D \quad (14)$$

Where D (in meters) is minimum distance of routing node from non participating nodes for low interference path.

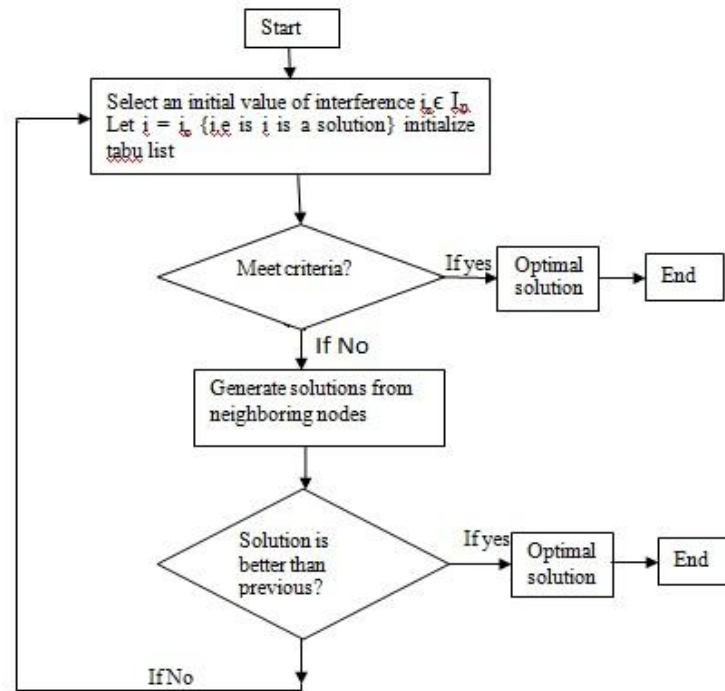


Fig 6 Tabu search algorithm

By using tabu search algorithm we have plotted a low interference path between source and destination having 48 relay nodes in between

IV. Results and Discussions

In this paper a network of 50 devices has been created in area of 1000 m^2 . Current range of adhoc network provided by a mobile node is approximately 20 m^2 . While designing routing nodes are considered within 20 m^2 areas. At the same time these mobile nodes can produce interference in same vicinity if they are not participating in relay of data. So routes has been designed in such a way that paths should come in the vicinity of non participating node. Considering the situation that where paths cannot be find so fuzzy logic system is used so that variations can be accommodated.

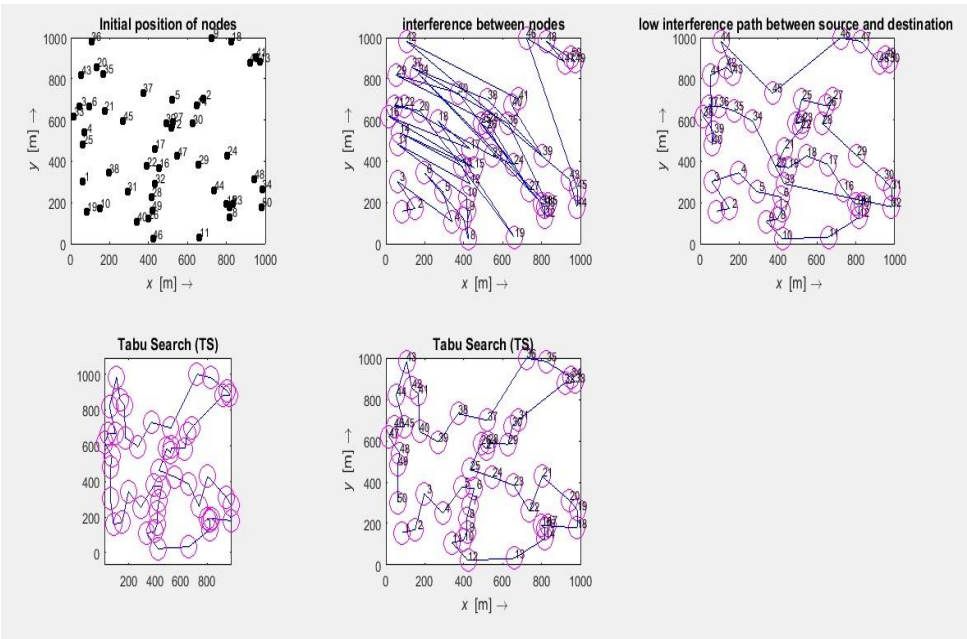


Fig 7 Low interference path using tabu

If low interference path is considered then effect of noise can be reduced up to 53%. This conclusion has been applied along with mimo (only 3 multi paths has been considered)

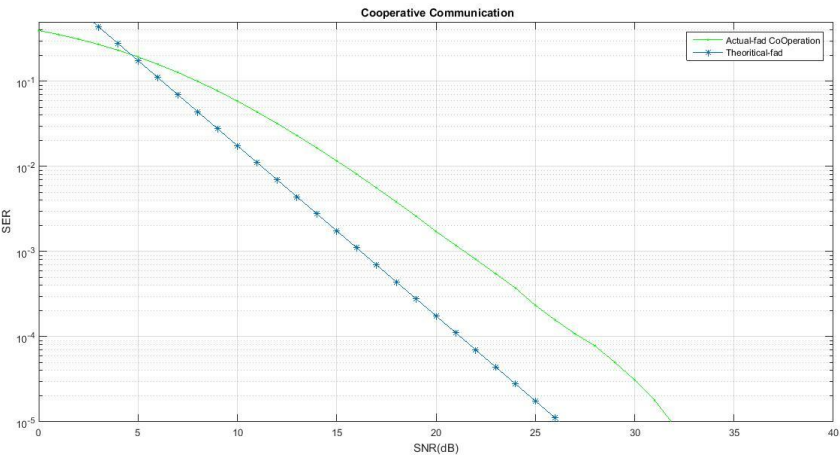


Fig 8 Graph between SER and SNR

If the same concept of low interference is applied with Markov model then the probability of success may increase upto 53%.

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