Performance Analysis of AF & DF Cooperative Communication Protocols with various Signal Combining Techniques in TSR

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Abstract--The wireless communications are playing a vital role in sending the information. However, many wireless devices are limited by size or hardware complexity to one antenna. Over the past few decades lot of research lead us for new techniques. The Cooperative communication is to process the overhead information at the surrounding information exchange points and retransmission towards the destination to improve the quality and reliability of a wireless link. To achieve the quality and reliability the researchers are developed many cooperative communication protocols. Among all those cooperative communication protocols the Amplify and Forward, Decode and Forward are the protocols which provide the good quality and reliability. The Performance parameter Bit Error Rate, outage probability is used to estimate the quality and reliability. Here the proposed work is to provide the performance analysis of Cooperative communication protocols Amplify and Forward, Decode and Forward. At the destination for combining the signal combining techniques are used. To evaluate the performance the signal to noise ratio, Probability of error and Bit Error Rate Parameters are need to be calculated and tabulate.

Keywords: Communication protocols, Cooperative MIMO.

I.Introduction

The major challenges in future wireless communications system design are increased spectral efficiency and improved link reliability. The wireless channel constitutes a hostile propagation medium, which suffers from fading (caused by destructive addition of multipath components) and interference from other users. Diversity provides the receiver with several (ideally independent) replicas of the transmitted signal and is therefore a powerful means to combat fading and interference and thereby improve link reliability. Common forms of diversity are time diversity (due to Doppler spread) and frequency diversity (due to delay spread). In recent years the use of spatial (or antenna) diversity has become very popular, which is mostly due to the fact
that it can be provided without loss in spectral efficiency. Receive diversity, that is, the use of multiple antennas on the receive side of a wireless link, is a well-studied subject [1]. The use of multiple antennas at both ends of a wireless link (multiple-input multiple-output (MIMO) technology) has recently been demonstrated to have the potential of achieving extraordinary data rates [5–9].MIMO produces link reliability, or in other word, diversity which reduces fading. To achieve diversity using MIMO, the transmitter should use more than one antenna. But due to size, cost or hardware limitations many wireless devices may not be able to support more than one antenna. In conventional point-to-point wireless communications, channel links can be highly uncertain due to multipath fading and therefore continuous communications between each pair of transmitter and receiver is not guaranteed. Recently a new class technique called cooperative communications has been proposed that allow single antenna to reap some of the benefits of the MIMO system a new communication paradigm, was proposed for wireless networks such as cellular networks and wireless ad hoc networks.

II.Multi Hop Cooperative Communication

The source broadcasts its information to both the destination and the relay in broadcast phase. The received signals $y_{s,d}$ and $y_{s,r}$ at the destination and relay [1] respectively can be given as

$$y_{s,d} = (\sqrt{P})h_{s,d}x + \eta_{s,d} \quad (2.1)$$

$$y_{s,r} = (\sqrt{P})h_{s,r}x + \eta_{s,r} \quad (2.2)$$

Where P is the transmitted power at the source, x is the transmitted information symbol, and $\eta_{s,d}$ and $\eta_{r,d}$ are the additive noise. In the above two

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equations $h_{s,d}$ and $h_{r,d}$ are the channel coefficients from the source to the destination and the relay respectively. Channel coefficients are modeled as zero-mean, complex, Gaussian random variables with variances as $\delta^2_{s,d}$ and $\delta^2_{s,r}$ respectively. The noise terms $\eta_{s,d}$ and $\eta_{r,d}$ are modeled as zero-mean, complex Gaussian random variables with variance N_0.

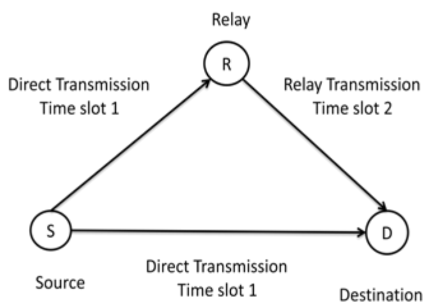

Fig.1 Simple Cooperative model

Consider a simple cooperative model as depicted in Figure 2.1, where the source transmits with power P1 and the relay transmits with power P2. In broadcast phase, a source sends its message to its destination, and the message is also received by the relay at the same time. In cooperation phase, the relay help the source by forwarding or retransmitting the message received during broadcast phase to the destination.

$$y_{r,d} = \frac{\sqrt{P_2}}{\sqrt{P_1 |h_{s,r}|^2 + \chi_0}} h_{r,d} y_{s,r} + \eta_{r,d} \quad (2.3)$$

2.2 Cooperative Transmission Protocol

The cooperative transmission protocols used at the relay are amplify and forward (AF), decode and forward (DF), compress and forward and coded cooperation. The most commonly used strategies are AF and DF.

2.2.1 Amplify and Forward Protocol

The received signal at the relay is given by [2.1]

$$y_{s,r} = \sqrt{P} h_{s,r} x + \eta_{s,r} \quad (2.4)$$

Similarly signal received at the receiver through direct communication ($y_{s,d}$) is given by

$$y_{s,d} = \sqrt{P} h_{s,d} x + \eta_{s,d} \quad (2.5)$$

The relay has to send the signal at the same power level at which it received the signal; hence the relay has to use a gain of

$$\beta_r = \frac{\sqrt{P}}{\sqrt{P |h_{s,r}|^2 + N_0}} \quad (2.6)$$

Thus signal received at the destination is

$$y_{r,d} = \frac{\sqrt{P}}{\sqrt{P |h_{s,r}|^2 + N_0}} h_{r,d} y_{s,r} + \eta_{r,d} \quad (2.7)$$

$$y_{r,d} = \frac{\sqrt{P}}{\sqrt{P |h_{s,r}|^2 + N_0}} h_{r,d} \sqrt{P} h_{s,r} x + \eta'_{r,d} \quad (2.8)$$

Where equivalent noise is given as:

$$\eta'_{r,d} = \frac{\sqrt{P}}{\sqrt{P |h_{s,r}|^2 + N_0}} h_{r,d} \eta_{s,r} + \eta_{r,d} \quad (2.9)$$

2.2.2 Decode and Forward Protocol

The received information at the receiver via relay can be expressed as:

$$y_{r,d} = x h_{r,d} + \eta_{r,d} \quad (2.10)$$

The Decode and Forward method can be implemented in two ways. One is when the relay can completely decode the message, but this requires a lot of time. If there is an error correcting code in the source message, then the received bit errors can be corrected at the relay station.

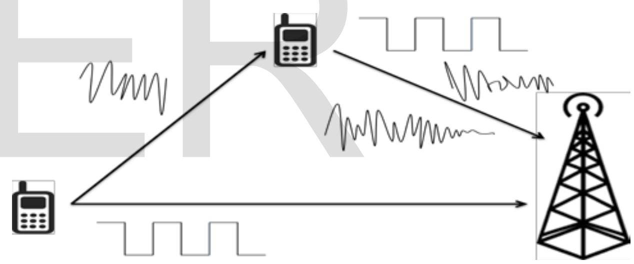

Fig.2 Decode and Forward

2.3 Signal Combining Techniques

Since there are more than one incoming transmissions, hence all the incoming information has to be combined at the receiver side before they can be compared.

2.3.1 Equal Ratio Combining (ERC)

In ERC, the weighting coefficient $k_1 = k_2 = k_3 = \cdots k_N$, the signal received at destination given by:

$$y_d[n] = \sum_{i=1}^{k} y_{i,d}[n] \quad (2.11)$$

And in case of single relay the equation (2.11) is modified to :

$$y_d[n] = y_{s,,d}[n] + y_{r,d}[n] \quad (2.12)$$

Where, $y_{s,,d}[n]$ is the signal from the source node to the destination node. $y_{r,d}[n]$ is the signal from the relay to the destination node.

2.3.2. Fixed Ratio Combining (FRC)

The weighting coefficients need to be determined by the channel fading and other factors. The signal received at destination in FRC can b expressed as

$$y_d[n] = \sum d_{i,d} \cdot y_{i,d}[n] \quad (2.13)$$

Here, $d_{i,d}$ is the received signal, $y_{i,d}$ is the weighting factor, if only one relay, then the equation (2.13) can be written as:

$$y_d[n] = d_{s,d} \cdot y_{s,,d}[n] + d_{s,r,d} y_{r,d}[n] \quad (2.14)$$

Where, $d_{s,d}$ is the weighting coefficient of a direct link and $d_{s,r,d}$ is the weighting coefficient of the relay link.

2.3.3. Signal to Noise Ratio Combining (SNRC)

In SNRC, the weighting factor is based on the SNR of the received signal. The combined signal can be obtained as

$$y_d[n] = \sum_{i=1}^{k} SNR_i \cdot y_{r,d}[n] \quad (2.15)$$

and in case of single relay, the equation (2.15) is modified to:

$$y_d[n] = SNR_{s,d} \cdot y_{s,d}[n] + SNR_{s,r,d} \cdot y_{r,d}[n] \quad (2.16)$$

Where, $SNR_{s,d}$ is the weighting coefficient of a direct link and $SNR_{s,r,d}$ is the weighting coefficient of relay link.

2.3.4. Enhanced Signal to Noise Ratio Combining (ESNRC)

Another plausible signal combining scheme is to ignore an incoming signal when the data from the other incoming channels have a much better quality. If the channels have more or less the same channel quality, the incoming signals are rationed equally. We can fix the SNR value of the channel for which this decision can be made. In this simulation study, a SNR value of 10 dB has been fixed up. The signal received at the destination can be expressed as

$$y_d[n] = \begin{cases} y_{s,d}[n] & \frac{SNR_{s,d}}{SNR_{s,r,d}} > 10 \\ y_{s,d}[n] + y_{s,r,d}[n] & 0.1 \le \frac{SNR_{s,d}}{SNR_{s,r,d}} \le 10 \\ y_{s,r,d}[n] & \frac{SNR_{s,d}}{SNR_{s,r,d}} < 0.1 \end{cases} \quad (2.17)$$

Where $SNR_{s,d}$ and $SNR_{s,r,d}$ are the sender to destination channel (direct channel) and the sender-relay-destination channel (relay channel) SNR values respectively.

2.3.5 Maximum Ratio Combining (MRC)

The maximum ratio combining technique achieves the best possible performance by multiplying each received signal with its corresponding conjugated channel gain. This assumes that the channel state information (CSI) is available at the receiver side.

$$y_d[n] = \sum_{i=1}^{K} h_{i,d}^{*} . y_{i,d}[n] \quad (2.18)$$

Using one relay system, the above equation can be written as

$$y_d[n] = h_{i,d}^{*} . y_{s,d}[n] + h_{i,d}^{*} . y_{r,d}[n] \quad (2.19)$$

2.4 Clustered Wireless Network

In this scenario, nodes $r1$ or $r2$ are selected as relays to forward the data from s to d. However, the channels of $s \rightarrow r2$ and $r1 \rightarrow d$ can be extremely poor due to the long transmission distance. In this case, the cooperation gain achieved by $r1(r2)$ is dominated by the channel gain of $r1 \rightarrow d(s \rightarrow r2)$. That is, the poor link becomes the bottleneck of the overall cooperative transmission.

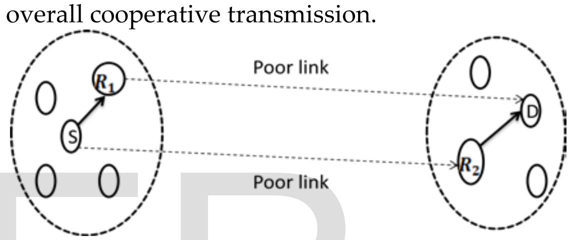

Fig.3 Dual-hop cooperation easily fails in clustered wireless networks.

However, in some clustered wireless networks whereby nodes tend to locate in proximity to the source and/or the destination, for long distance transmission of data the dual-hop cooperation is failed to achieve the optimal performance due to the absence of relays with balanced channels to both ends.

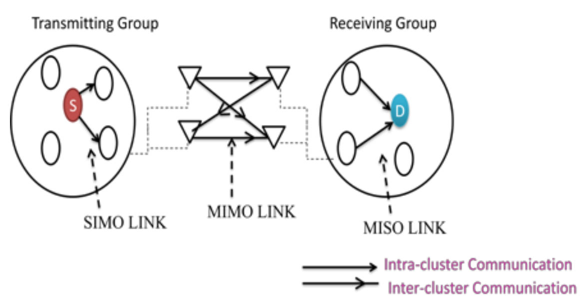

Fig.4 Virtual MIMO-based TSR for clustered wireless networks.

III.System Model

Here the work is calculating the bit error rate in three stage relaying scheme for Amplify and forward, Decode and forward protocols, along

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these made a comparison for different combining techniques.

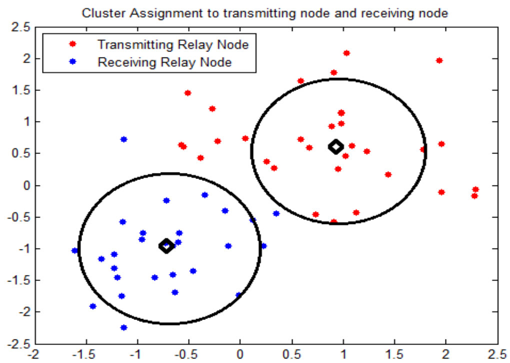

Fig.4 Cluster Assignment to transmitting node to receiving node.

The source knot broadcasts the message *'a'*, which can be received by transmitting relay nodes in S. The received signal at node $m \in S$ is

$$y_{a,m} = \sqrt{p_a} h_{a,m} x + N_m$$

Case I:

The transmitting relay nodes in S forward the received signal using the AF relay strategy sequentially, i.e., a node $m \in S$ simply amplifies the received signal with the amplification factor $\alpha_m = \sqrt{\frac{1}{p_a|h_{m,n}|^2 + N_0}}$ and forwards it to the receiving relays. In each time slot, only one relay is allowed to transmit. The receiving relay nodes in D receives the signal using the AF relay strategy sequentially, i.e., a node $n \in D$. Therefore, the signal received at node $n \in D$ is

$$y_{m,n} = \sqrt{p_m} h_{m,n} \alpha_m \left(\sqrt{p_a} h_{a,m} x + N_m\right) + N_n$$

The SNR of the combined signal at node n is given by

$$SNR_n = \sum_{m \in S} \frac{p_a|h_{a,m}|^2 p_m|h_{m,n}|^2}{1 + p_a|h_{a,m}|^2 + p_m|h_{m,n}|^2} \approx \sum_{m \in S} G_{m,n}$$

where

$G_{m,n} = p_a|h_{a,m}|^2 p_m|h_{m,n}|^2 / p_a|h_{a,m}|^2 + p_m|h_{m,n}|^2$ is an approximation of the channel gain in the AF relay strategy at the high-SNR region.

Case II:

. The receiving relay nodes in D receives the signal using the DF relay strategy sequentially, i.e., a node $n \in D$. Therefore, the signal received at node $n \in D$ is

$$y_{m,n} = \sqrt{p_m} h_{m,n} \alpha_m \left(\sqrt{p_a} h_{a,m} x + N_m\right) + N_n$$

We assume that the channels from different relays are independent, and the receiving terminals (including the destination as well as the relays) have perfect knowledge of channel state information (CSI). The received signals from all transmitting relays can be combined by various combining techniques (ERC, FRC, SNRC, ESNRC, and MRC) at node $n \in D$, and the SNR of the combined signal at node n is given by

$$SNR_{m,MRC} = \frac{(p_a|h_{a,m}| + p_m|h_{a,m}|)^2}{\sigma_m^2}$$

The SNR of the combined signal (MRC) is given by

$$SNR_d = \sum_{n \in D} p_n|h_{n,d}|^2$$

The outage probability can be evaluated as

$$p_{out} = 1 - \exp\left(-\frac{(2^{2R}-1)}{p_a|h_{a,m}|^2/\sigma_r^2}\right)\exp\left(-\frac{(2^{2R}-1)}{p_m|h_{m,n}|^2/\sigma_d^2}\right)$$

Relay Selection Depending on the relation between the network entities, relay selection mechanisms can be divided into two categories:

- Opportunistic Relay Selection
- Cooperative Relay Selection

The basic opportunistic relay selection scheme is based on local measurements. They can be further classified as

- Measurement-based relay selection
- Performance-based relay selection
- Threshold-based relay selection

Algorithm 1:(Transmitting Relay Selection)

Input:R ;
Output:T;
$b_m \leftarrow \eta, m \epsilon R;$
$T \leftarrow \emptyset;$
while $|\boldsymbol{T}| + |\boldsymbol{R}| < \boldsymbol{K}$ **and** $b_m > 0, \forall m \in R$ do
$\boldsymbol{k} \leftarrow arg\ max\ i \in N \backslash (T \cup R) m \in R \sum G_{m,n}:$
$T \leftarrow T \cup \{k\};$
for all $m \in R$ **do**
$b_m \leftarrow \max(0, b_m - G_{k,m});$
end for
$G_{k,m} \leftarrow 0, \forall j \in R$
$G_{i,m} \leftarrow \min(G_{i,m}, b_m), \forall i \in N \backslash R, m \in R;$
end while
if $b_m = 0, \forall m \in R$ ***then***
return T ;
else
return $\emptyset$;
end if

The receiving relay selection algorithm used at receiver is TSR-PCR finds the optimal receiving

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relays in CR obtained by the position based algorithm(11)

Algorithm 2*:* Receiving Relay Selection

Input: $(CR_{\tau 1}, \ldots, CR_{\tau\varphi})$;

Output: T , R;

$T \leftarrow \emptyset$;

$i \leftarrow 0$;

while $T = \emptyset$ and $i \leq \tau\varphi$ **do**

$i \leftarrow i + 1$;

$R \leftarrow CR_{\tau i}$;

if $|T|^L > K - |R|$ ***then***

continue; /* see lemma 1*/

end if

$T \leftarrow Algorithm\ 1(R)$;

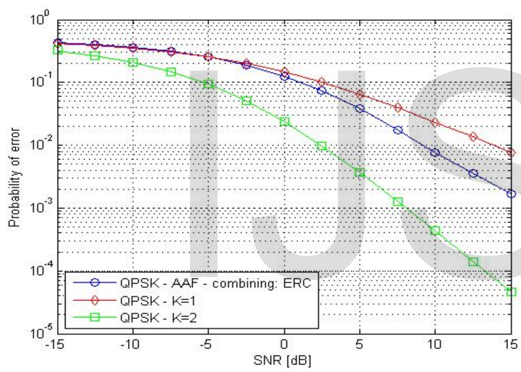
end while

return $\{T , R\}$;

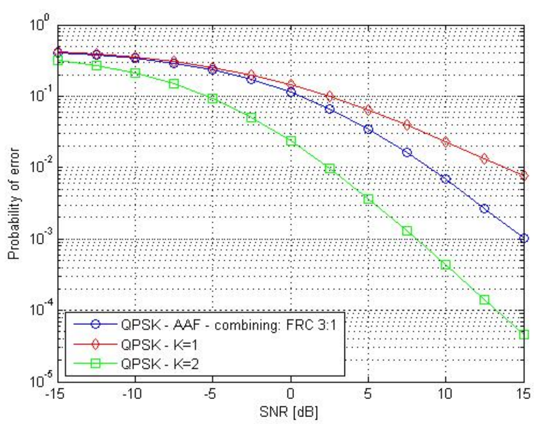
IV.Simulation Results and Comparison

4.3.1 Amplify and Forward

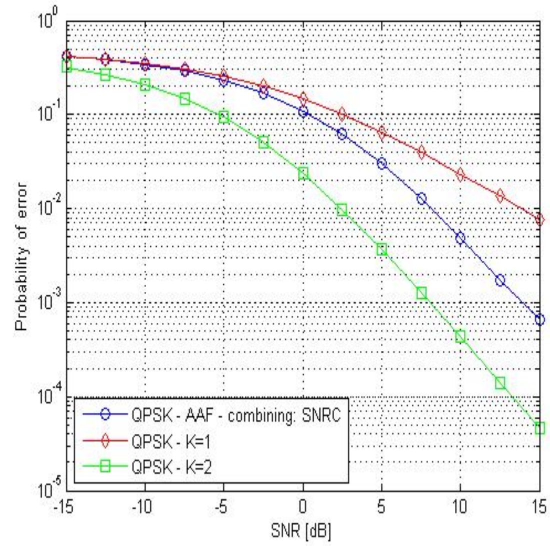
(a)



(b)



c)



(d)

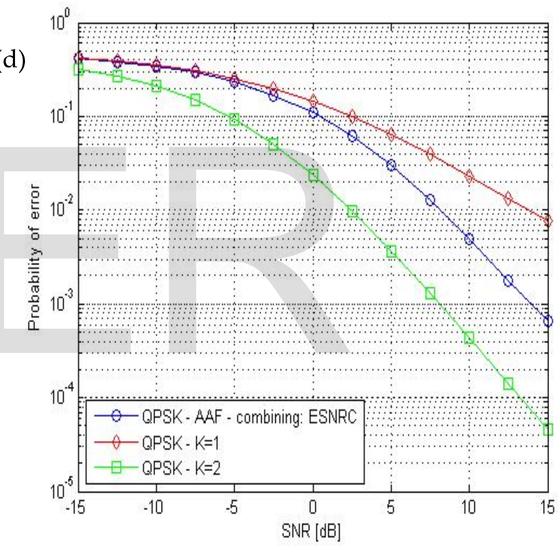
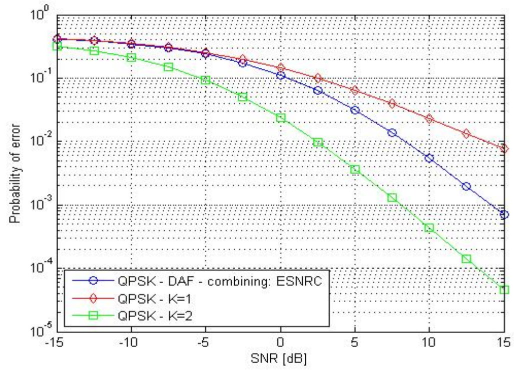


Fig.5 shows the probability of error versus Signal to Noise Ratio of AF Protocol.(a)ERC, (b)FRC, (c) SNRC, (d) ESNRC.

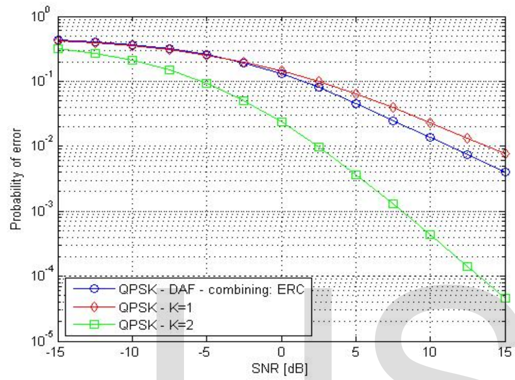
The probability of error is calculated for three different cases. In Case I the modulation Technique used is QPSK, the Protocol is Amplify and Forward, and Combining Technique. The Equal Ratio Combining Technique is providing the less Probability of Error compared with single link transmission (K=1).Whereas the two senders (K=2) provides less Probability of Error compared with ESNRC Values

4.3.2 Decode and Forward

(a)



(b)



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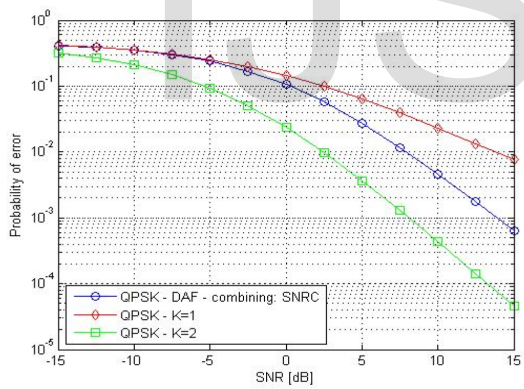
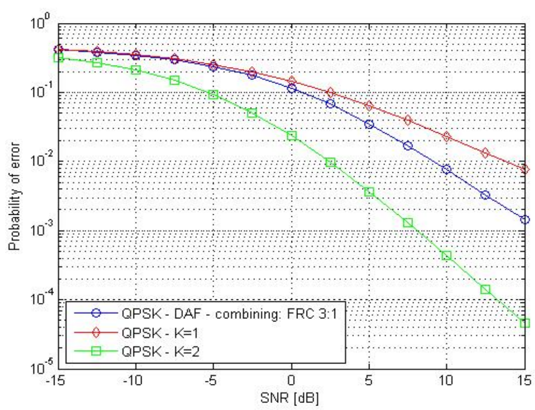


(d)



(e)

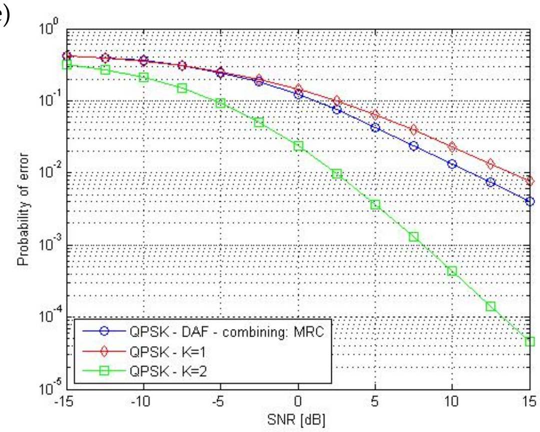


Fig.6 shows the probability of error versus Signal to Noise Ratio of AF Protocol.(a)ERC, (b)FRC, (c) SNRC, (d) ESNRC, (e) MRC

The probability of error is calculated for three different cases. In Case I the modulation technique used is QPSK, the Protocol is Decode and Forward, and Combining Technique. The Maximal Ratio Combining Technique is providing the less Probability of Error compared with single link transmission (K=1).Whereas the two senders (K=2) provides less Probability of Error compared with MRC Values.

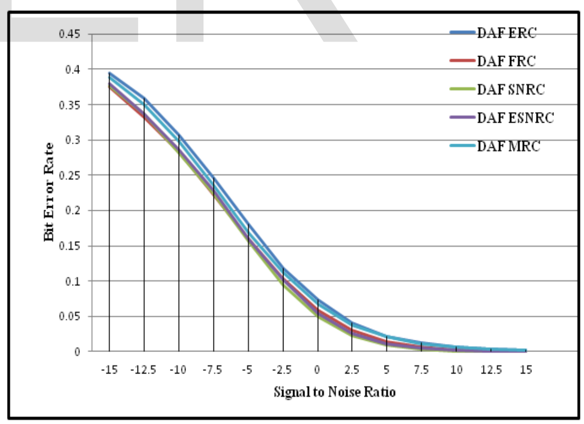


Fig. 7 shows Bit Error Rate Comparison of different combining techniques for Amplify and Forward.

In Cooperative Communication Protocol Amplify and Forward. Here we can observe the Equal Ratio Combining (ERC) giving high Bit Error Rate Compared with the other combining techniques. The Enhanced Signal to Noise Ratio Combining provides the less Bit Error Rate, where it is compared with the other techniques.

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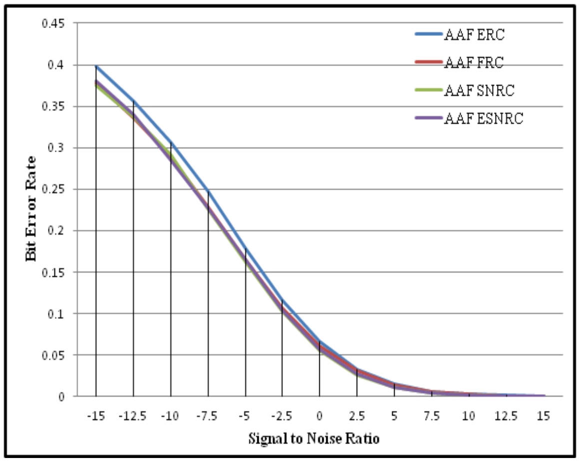

Fig. 8 shows Bit Error Rate Comparison of different combining techniques for Decode and Forward.

Cooperative Communication Protocol Decode and Forward. Here we can observe the Equal Ratio Combining (ERC) giving high Bit Error Rate Compared with the other combining techniques. The Maximum Ratio Combining provides the less Bit Error Rate, where it is compared with the other techniques.

V. Conclusion

The possible benefits of a wireless transmission using cooperative diversity to increase the performance i.e., lower the bit error rate (BER) and reduce the outage probability. The diversity is realized by building an ad-hoc network using a third station as a relay. The data is sent directly from the base to the destination or via the relay station. Such a system has been simulated to see the performance of different diversity protocols and various combining methods. As a scope of future work the hybrid method employing both decode and forward and amplify and forward can be implemented with the higher Modulation.

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