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An efficient cooperative technique for power-constrained multiuser wireless network

"Investigation of cooperation strategies in multiuser wireless network with the power constraint"

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Abstract
Cooperative communication plays an important role in wireless networks by improving network connectivity, spectrum efficiency, power, and communication reliability. Moreover, cooperative communication also facilitates the development of a well-organized approach in order to improve the quality of wireless terminals. Besides, it enables the utilisation of communication resources by allowing the nodes and pathways in a network to cooperate with one another via data transmissions. To control a wireless network, cooperative communication must manage its power to improve a network's energy efficiency, capacity and reliability. When information is transmitted at a higher power, this decreases the lifespans of both the nodes and the network itself. Thus, controlling over the transmission of power is essential to obtain a sufficient level of bit-error-rate (BER) performance at the receiver. Relay nodes can improve system performance by reducing power consumption. Moreover, the decode-and-forward method is one of the best cooperative relay protocols that can be used to achieve better system performance in power constraints and BERs. In the present paper, system model containing source, destination and relay node is analysed. One cooperative scheme which including decode and forward is employed and investigated. At the experimental and simulation levels, the present paper showed that the power in the transmitters was observed and calculated in order to show the savings which are resulting from the use of relay nodes.

Keywords Bit-error-rate · Cooperative communication · Decode-and-forward · Rely nodes

1 Introduction

Recently, cooperative communication in wireless networks has become an attractive research topic. New-generation wireless networks have encouraged recent growth in research in the field of cooperative communication [1]. Requests for increasing numbers of wireless applications have caused significant development in wireless networks, especially cellular voice and data networks. More recently, this growth has been expanded to ad-hoc networks for wireless computers, homes and personal lives [1]. The next wireless network inspirations will overreach the point-to-point or point-to-multi-point models of classical cellular networks. Instead, these inspirations will be based on interactions among nodes in which they must cooperate with one another in order to improve their communicative performance [2]. Cooperative communication based on relay nodes has become useful for increasing spectral and power efficiency and network coverage, as well as for decreasing the probability of outages [3]. Cooperative communication influences the spatial diversity available in wireless networks by allowing two nodes to work together in order to improve overall system performance [3]. BER performance will be improved significantly when the destination chain includes both the signal received from the source and the signal received from the relay node [3].

Power control management plays an important role in wireless networks in terms of improving a number of key performance factors, including energy usage, network

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reliability and network capacity [4]. Transmitted power control has significantly improved a number of serious constraints in wireless communication networks such as reducing energy usage and improving network capacity usage.

The problem with cooperative communication stems from unreliable channels through which signals travel [5]. To reduce the effects of wireless channels, the idea of diversity has been developed for various wireless systems [5]. Diversity involves communication techniques through which transmitted signals undergo several independent path. This leads to a high probability that all paths will fade and be made insignificantly [5]. Diversity offers the destination node with several copies of the transmitted signal, so that, if any of these copies experiences deep fading, then the destination can still detect the signal successfully by using the other copies [5]. There are three essential techniques for a wireless network diversity: time diversity, frequency diversity and space diversity [5].

Cooperative protocols increase the throughput of multi-hop wireless networks and quantify the appropriate level of cooperation among users in order to improve the QoS [6]. The source sends information to the relay, and then the relay either forwards the information immediately or decodes information first before forwarding it to the receiver. This is called the decode-and-forward (DF) cooperative relay protocol. According to this protocol, the relay operates based on channel information [6]. In addition, transmission begins with the first stage of sending information from the source to the relay and to the destination. In the second stage, the relay node detects, encodes and re-transmits the received signal at the destination node [6]. The DF relay system involves two standard links, both of which create decoding errors. The errors of the two links are not correlated. DF protocol is used in cooperative systems to reduce channel fading and to achieve information transmission security [7]. Usually, in a DF system, the source sends a signal to the relay and the destination using 16-QAM, and each relay detects the successfully decoded signal and transmits it to the destination using QAM, as previous research papers have shown [7].

Power management is one of the issues in wireless networks, since the lifespan of the network depends on the power node. When signals are transmitted at a high power, the lifespan of the node decreases [8]. To improve the performance of the network or system, the power at the node that transmitted must be improved. This can be achieved by increasing the SNR in the system that uses DF scheme containing more than one relay node. BER in the purpose system should be the same as in the system without relay node. This paper examines how cooperative techniques saved the transmitted power in wireless network In addition, it analyses the relation between the link distance and saving power.

2 Goals and objectives

The main goal of this paper is to study the power transmissions of wireless networks using cooperation relay protocols. Specifically, this paper tries to achieve the following objectives:

- Studying and applying cooperative techniques and diversity.
- Studying the cooperative relay protocols that can be suitable for use in the system model to save power.
- Manipulating MATLAB scripts for direct link (point-to-point) systems as in the initial stage, and comparing this to related theory. This including manipulating single relay link system by using the same structure of the former software.
- Adding more than one relay node to create a multiple-relay-link system to improve the transmitted power.
- Applying an SNR formula to observe how power is saved during the use of network relay nodes
- Improving the total BER performance as a result of power saving.
- Identifying how distance will effect the transmitted power.

2.1 Related work

Several published papers have been motivated by the usage of cooperative techniques in wireless networks. The effects of cooperative transmissions on the quality of the wireless paths have been argued to occur at the physical layer, where the independent function reduces the total power consumption while restricting the end-to-end reliability of ad-hoc networks [9]. In order to improve the security of physical layers, different diversity techniques in wireless cooperative communication have been introduced [10]. In addition, the authors [10] argued that diversity plays an important role in cooperative communication since it does not consume power as noise generation does. In [11], the authors analysed the performance of cooperative techniques in relation to transmission power and related performance. The work of [11] showed that, in order to achieve better BER performance at the destination point, cooperative systems can be employed to achieve overall power efficiency. However, gains in power efficiency can be affected by synchronization errors. The research paper [12] showed that cooperative diversity can facilitate spatial diversity, if each link had as many transmission antennas as the complete set of cooperating links. This diversity gains translates to greatly improved strength of the fading for the same transmission powers. Significantly, reduced transmission powers produce the same performance [12]. Several cooperative techniques have been used for spectrum sharing in order to reduce transmission power via cooperative routing and transmission interference via network coding and wireless broadcast advantage (WBA), as discussed in [13]. Another research paper [14] argued that the same area of the cooperation diversity scheme relies on distribution path selection, focusing on instantaneous end-to-end wireless channel conditions. Accordingly, coordination among the cooperative terminals with the lowest overhead and a simplified physical layer for communication transceivers, resulting from decreased requirements related to space–time codes.

Most published research papers focus on the performance of DF in different areas. In [15], the performance of three nodes applying DF communication, power constrained communication and cooperative communication over a Rayleigh fading channel with timing errors using an SNR technique are explored. The authors argued for the power allocation of cooperative and non-cooperative systems [15]. This research paper showed that the power allocation at the source and relay nodes was used for transmission [15]. Moreover, the timing errors at the relay and receiver nodes significantly affected the BER performance for the power constraints of cooperative communication [15]. Another research paper [16] considered small, mobile, cellular relay system downlinks, in which two mobile users are connected to the two nearest DF relays simultaneously using the same frequency channel. This research paper showed that the diversity of each user receiving the data can be enhanced if the information is received by multi-relay nodes. In this case, the received signal is free from interference from each user [16]. In [17], the authors determined the energy consumption features of DF cooperative communication from different angles. The authors first introduced the DF scheme in terms of outage probability and power consumption [17]. Then, they suggested that a cooperative mechanism could aid in suitable relay selection for higher levels of energy savings for each node in multiple-node networks [17]. The authors concluded that cooperative transmissions have an advantage in reducing total power consumption while maintaining the level of QoS [17]. Another study examined an adaptive DF cooperative diversity algorithm and an enhanced relay selection strategy in the context of BER routine for DF cooperative diversity with multiple-antenna terminals [18]. This study investigated the BER execution and energy gain performance of DF cooperative diversity. It also demonstrated that DF cooperation could spare more energy and time and further enhance BER performance in comparison to classical DF collaboration [18]. The authors in [19] explored the performance of DF cooperative relay networks with adaptive M-QAM. They proved that system outage probabilities are lower when a system includes an under-optimized switching level, compared to a system with a corrected switching level.

In [20], the authors focused on the power-saving perspective of cooperative communication for a two-dimensional user distribution approach. This paper compared the total transmission power of cooperative communication with the total transmission power of direct communication [20]. The aim of this comparison was to accomplish the same SNR levels at the receiver nodes of both cases. The authors concluded that low transmission power is caused by increasing the path loss exponent while also increasing the number of users inside the cell [20]. In [21], the authors recommended an applicable approach for increasing relay nodes' optimal power consumption in wireless sensor networks with respect to data rates. They studied the trade-off between distance (source-to-destination) and power consumption in order to define the optimal power consumption for the network [21]. Another published paper demonstrated a strategy to minimize the power transmissions of DF, multi-user, and multi-cooperative uplinks, in which each user satisfies the QoS data rate [22]. The results of the simulation showed that major power savings over non-cooperative uplinks taken place. In the following section, a combination of relay selections and decreased power algorithms in DF cooperative uplinks using space–time coded cooperative diversity is suggested [23].

3 Methodology

3.1 System model

In general, the DF cooperation relay system model has three nodes: source, relay and destination. In a DF relay, the process of transmission is divided into two steps: first, the source transmits information to the relay and destination, and the relay decodes the information. Second, the relay forwards the information to the destination. Finally, the destination combines the signal transmitted from the source and the relay and then decodes the information. Throughout the use of the relay node between the source and the destination, transmission power will be saved. This is the primary goal of cooperative communication in wireless networks (Fig. 1).

However, the current paper considers system model with three node as it in the general model. During the process of the transmission, the source transmits the information to the relay, and the relay decodes the information. After this, the relay retransmits and forwards the information to the destination node. In this model as shown in Fig. 2, AWGN is assumed for the S–R and R–D channels. The relay used in the system model is assumed to be a DF cooperative relay protocol. The signal transmitted from a source is expected to be x with a unit energy. In this model, it is assumed that transmissions by S and R have a fixed power. In addition, in the model, $Y_{S,R}$ is the signal received from the source at the destination (point-to-point) signal, and $Y_{R,D}$ is the signal received at the relay from the source. $n_{S,R}$ is the additive

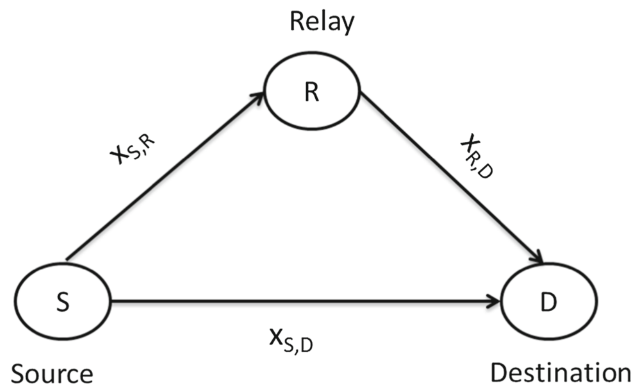

Fig. 1 General system model

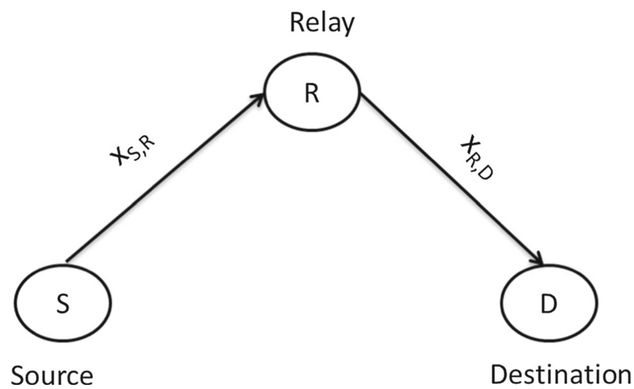

Fig. 2 System model

noise in the S–R link with a variance of σ_R^2, and $n_{R,D}$ is the additive noise in R–D link with a variance of σ_D^2. Moreover, $x_{S,R}$ is the distance for the S-R link, and $x_{R,D}$ is the distance for the R-D link. The additive noise is zero, which implies a complex Gaussian random variable with a variance of $N_0 = \sigma_R^2 = \sigma_D^2$. $Y_{S,R}$ and $Y_{R,D}$, which are the signals received at the destination and relay, correspondingly, is set up as follows:

$$Y_{S,R} = \sqrt{P}\frac{K}{x}S, R + n_{S,R} \tag{1}$$

$$Y_{R,D} = \sqrt{P}\frac{K}{x}R, D + n_{R,D} \tag{2}$$

where P represents the transmitted power.

The SNR at the transmitter is $\gamma = \frac{P}{N0}$. Moreover, the SNR for the S–D link is $\gamma_{S,D} = \frac{P}{N0}|h_{S,D}|^2 \ldots$. The BER for the DF cooperation in this system model can be written as:

$$Pe - DF = Pe1 + (1 - Pe1) \times Pe2 \tag{3}$$

where p_{e1} is then the BER for the first link of cooperation, as follows:

$$P_{e1} = 3/8Q\left(\sqrt{\frac{2\gamma S, R}{5}}\right) \tag{4}$$

where $\gamma_{S,R}$ is the SNR for the S–R link and Q (·) is defined as:

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^\infty e^{\frac{t2}{2}}dt \tag{5}$$

P_{e1} is the BER for the second link of cooperation, such that the relay correctly decodes the data received from the source in the first link of cooperation.

$$Then,\ p_{e2} = 3/8Q\left(\sqrt{\frac{2(\gamma S, R + \gamma R, D)}{5}}\right) \tag{6}$$

where $\gamma_{R,D}$ is the SNR of the R–D link. Cooperation is required when the SNR of the S–D link is low. In this case, a cooperative relay is needed to improve system execution.

The system should contain the following:

Source Transmits the signal to the channel.
Source signal Generates the data randomly as binary data.
QAM modulator The QAM used in the paper is 16-QAM (4 bits/symbol).
Channel The path through which the signal will move. AWGN is used as the channel mode in this study. The noise method is simply a transmitted signal plus noise. This type of noise is statistically independently from the original signal.
Relay The DF cooperative relay protocol. This node detects and decodes the signal, and then re-transmits it to the receiver. This protocol describes how the received signal is processed at the relay node before being sent to the destination. This node will not exist in a direct link system.
Destination Where the signal is received and decoded. In addition, the destination combines the signals received from the source and relay nodes.
Received signal The recovered signal, which contains noise due to the channel and transmission process, through which noise is added to the original signal.
QAM demodulator Takes the received signal after transforming to the frequency domain as a 16-QAM constellation map.

BER is measured in association with SNR.

3.2 Simulation tool

The initial tool environment that will be used to evaluate the research paper and simulate the system model is the MATLAB environment. MATLAB is a high-level programming language and interactive environment that can be used in different areas, such as engineering, signal processing, and physics. The simulation of this paper is completed by writing three scripts, saving them as .m file and then running them using a run tool in order to produce the graphs. The communication toolbox is one of existing MATLAB toolbox was used in the paper simulation to prevent the need for writing lots of detailed code. This communication toolbox provides and runs many built-in functions, such as modulation, demodulation, noise generation and error number computing. The researcher of this paper used this toolbox by connecting to her M drive from the university account remotely.

3.3 Implementation

3.3.1 Direct link system

As the initial stage of the system, the direct link is built. This contains only a source and a destination. First, the source data should be generated randomly and in binary form using the randi function `randi ([0 1], n, 1)`, where n is the number of bits to be processed and one refers to a single-column vector. Then, the modulation scheme should be set up as a 16-QAM modulation using the `modem.qammod()` function. When the modulation is set up, the size of the signal constellation must be set at 16, as required in this paper. After the signal is modulated, it will travel through the channel. The channel should be put into AWGN mode using the `awgn ()` function. The signal is then transferred to the 16-QAM demodulator set up using `modem.qamdemod ()` function to produce the received signal. As a result, this signal contains noise. The SNR is set up for the range between 0 and 15 dB, and it is added to 10log10 (K) to produce a linear SNR where $k = 4$. After the signal is received, the BER is computed using the `biterr ()` function to produce a BER versus SNR curve using (for) loop. The iteration's start depends on the SNR length. The software is tested and analysed using the QAM theoretical BER formula, which is:

$$(1/k) * 3/2 * erfc(sqrt(k * 0.1 * (10.\hat{}(EbNo/10)))). \tag{7}$$

After this, a curve is plotted, and whether the curve of the direct link is correct is determined. The direct link curve should be similar to the theoretical curve, as shown in Fig. 3. This was successfully achieved.

The axis of the graph is set up such that the x-axis is in the 0–15 range, which implies SNR in dB, and the y-axis is in 1 to 10^{-5} range, which is BER. In addition, two functions were added to make it easy to read and analyse the graph: `grid on` adds grid lines to the current graph, and `grid minor` makes the minor grid visible in the current graph. These two

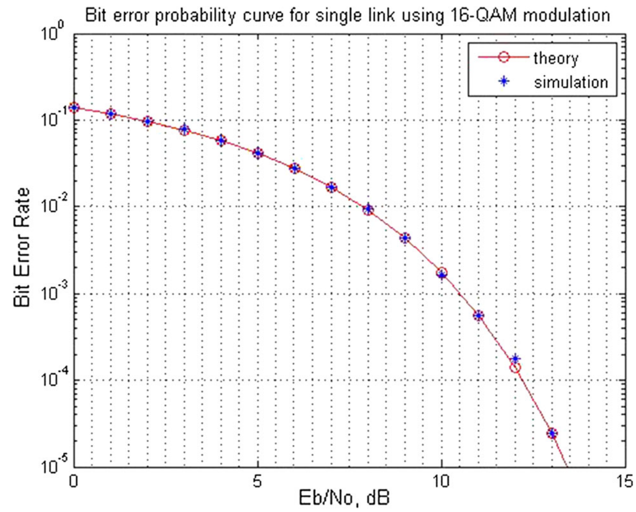

Fig. 3 BER for direct link system

functions helped in deducing the exact actual value of the SNR.

3.3.2 Single relay system

In the next stage, the system is expanded by adding a relay node halfway between the source and the destination with the same SNR. Then, the BER is computed to facilitate comparison with the direct link. This set up can be accomplished by making two copies of the direct link and then putting the output stream of the first link (which is the signal produced by the `rx_demod` variable) into the input of the second link to make the appropriate changes run correctly. The changes occur in the second link, where it attempted to modulate the signal. Here, the input stream has to be changed into a matrix. This must also occur in the BER calculation in order to make the input stream equals to the value of the first link. Before the graph is plotted, the bit error should be calculated for both links by combining the first input stream and the output stream of the second link. The program plots two BER curves—one for the direct link (in red) and the other for the link with existing of the relay (in blue), as shown in Fig. 4. It can be seen that the BER for the single relay link is worse than the BER in the direct link. Thus, the SNR in the single relay link has to be more than SNR in the direct link in order to achieve the same BER.

Next, the single-relay system is modified by increasing the SNR slightly. This achieves the same bit error rate as in the direct link and shows that the use of the relay node saves power. The SNR is increased by 0.5 dB which is converted to the power ratio by using [10 log 10(0.5)] to be able to calculate the transmitter power which is equal to 1.12. Thus, the total transmitter power is P $1.12/2 = \mathrm{P} \times 0.56$. In Fig. 5 the produced graph, the scale of the x-axis is changed to

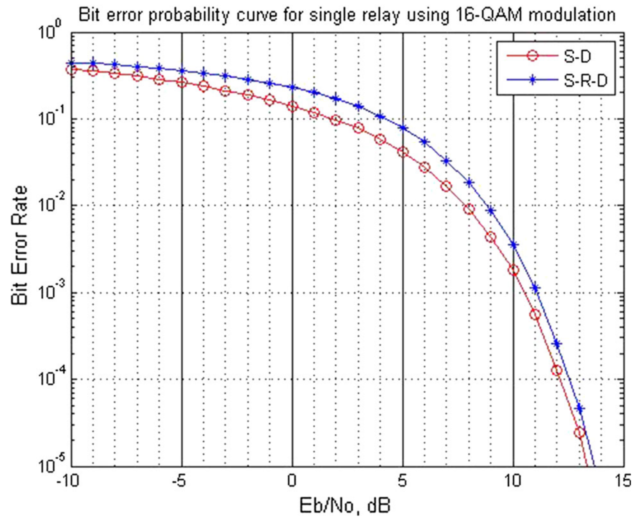

Fig. 4 BER for single-relay system

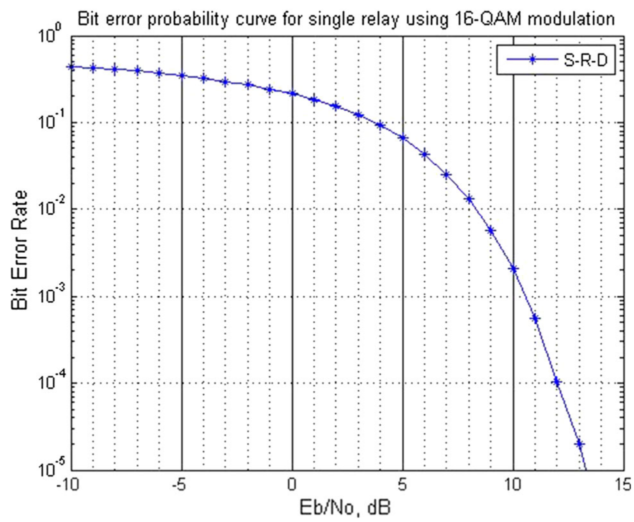

Fig. 5 BER for single-relay system after adjusting SNR for power efficiency

exist in the range of [− 10 − 10], which allows us to observe and compare the BER performance with that in the previous graphs. The BER curve has shown the same direct link curve, as presented in Fig. 5:

3.3.3 Multi-relay system

The single-relay system is expanded through adding of more than one relay. The BER curve is then observed. Moreover, the amount of power that can be used to achieve a BER curve similar to that in the direct link is calculated. The SNR is increased by 0.8 dB which has to be converted to power ratio by using [10 log 10(0.8)] = 1.20. Because there are three links, each of which is 1/3 of the way along the direct link the power is p/9 in the transmitter. The total of the transmitted

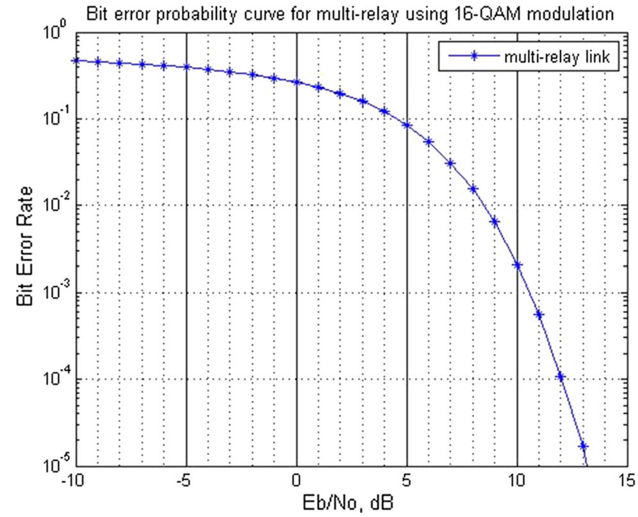

Fig. 6 BER for multi-relay system

power is P 1.20/3 = P × 0.40. It can be observed the total transmitted power is smaller than the single relay system, thus, by using more relay nodes the transmitted power saving would be better. The change in the x-axis scale is done in the same way as that in the single relay graph. It can be seen from Fig. 6 that the BER is the same as BER for direct link because it contains more than one relay node, each of them playing a role in saving the transmitted power.

To investigate power relations, the following equation is used in both the single-relay and multi-relay SNRs:

$$SNR = \frac{signal\ power\ at\ receiver}{noise\ power} = \frac{K \times \frac{1}{x^2} \times power}{noise\ power} = \frac{K}{x^2} \times\ power\ of\ transmitter. \quad (8)$$

In this equation, x is the distance between the source and relay nodes, which are explained as two transmitters. Power is the transmitted power, and k is the constant factor.

The application of this formula reveals that the overall BER in the direct link is equal to the BER in the single relay system. Thus, the power should be reduced by four to produce a quarter of the power (P/4) in the source and relay nodes. The same observation holds for the multi-relay system, in which the power in the source and relay nodes is P/9. In the above system, the power is analysed when the distance is the same for the source relay link and the relay destination link. On the other hand, to prove that relay nodes save power in cooperative communication, the power of single-relay systems is examined, and the different distances are used for both links. This demonstration is accomplished by using the same SNR formula for both links.

As an additional exploration, the relay node location is changed to determine the effect of the total BER performance and the transmitted power consumption. Previous research has shown that if a relay exists between a source and a destination, system performance will be optimized. However, if the relay node location is changed, it is better to move it closer to the source. When the relay is in the middle, equidistant from the source and the destination, the distance should not be longer than that in a direct link in order to achieve the advantage of limit power consumption.

Many attempts were done to using S–R and R–D links at different distances, but the relay node was not exactly in the middle. There are two approaches to accomplish this. First, the S–R link can be greater than the R–D link, such that the relay is far away from the source. Second, the S–R link can be smaller than the R–D, such that the relay is near the source. The distance for the first approach is set to 0.7 for S–R link and the distance for S–D link is 0.2 link with the same SNR amount as in single-relay system. Thus, the total power is $P \times 0.53 \times 1.12 = P \times 0.59$ for both transmitters. In the second approach, the distance for the S–R link is 0.2 and 0.7 for S–D link with the same SNR amount as in single-relay system. Thus, the power is $P \times 0.53 \times 1.12$, which equals to $P \times 0.59$. It can be observed that the total transmitter power is the same in both approaches in case of assuming that the BER is constant.

4 Results and evaluation

The purpose of this paper was to determine how a relay node in cooperation communication can reduce transmission power and improve overall performance through a low BER. This can be observed through the simulation of the single-relay and multi-relay system using the MATLAB environment. The first step in the simulation of the direct link using a 16-QAM modulation was completed. This link was tested using the theoretical BER formula. At the end, the link worked and ran correctly. It can be seen from Fig. 7 that the BER is 2.2×10^{-5} at 13 dB SNR.

The next step was to implementing a single-relay system. It can be observed that the overall BER performance was in bad condition. Thus, to improve overall BER performance, the SNR has to be higher than SNR in direct link system. After a graph is produced (as shown in Fig. 8), it is observed that the overall BER is 2×10^{-5} is achieved at SNR $= 13$ dB which is similar to the performance of direct link.

Compared to the results of the direct link system, the BER performance that is produced in the single relay is the similar to BER for the direct link. As can be seen in Fig. 9, which compares the two systems, the single relay system is achieved the same BER performance and produced lower transmitter power for both transmitters.

The single-relay system has better performance than the direct-link system with regard to energy efficiency and power control. It produces the same overall BER, but its performance is higher due to its power saving management. This means that transmitted power is saved using the relay node, thereby achieving good overall BER performance that is similar to the total BER achieved in a direct-link system. It can be seen in a single-relay system that the power used in the source and relay nodes should be approximately P/4 because the link between the source and the relay is half of the overall distance, and the relay node is in the middle of the link. The SNR for the both transmitter is greater than SNR in direct link, thus improving the overall BER for the single-relay system to achieve the same direct system performance.

The third stage involved adding more nodes to the system and observing their effect on the BER and the transmitted power. The addition of another node increases the SNR by 0.8 dB. Due to the existence of three links: the $S–R_1$ path, the

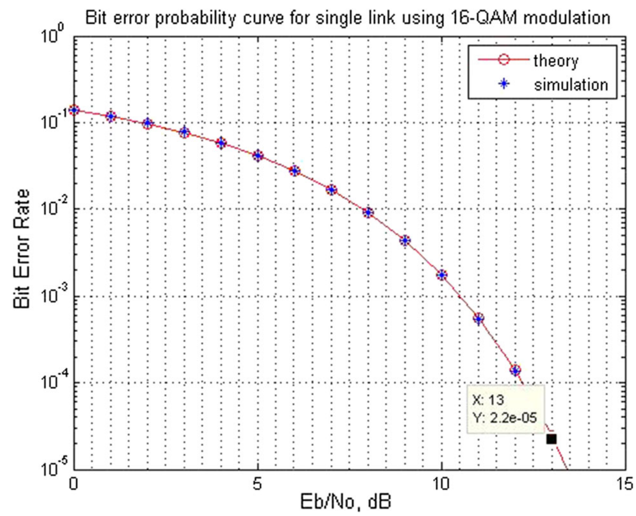

Fig. 7 Direct link system when SNR $= 13$ dB and BER $= 2.2 \times 10^{-5}$

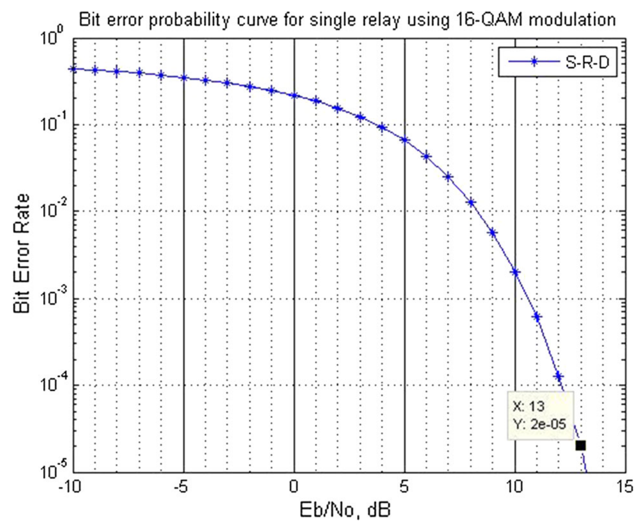

Fig. 8 Single-relay system when SNR $= 13$ dB and BER $= 2 \times 10^{-5}$

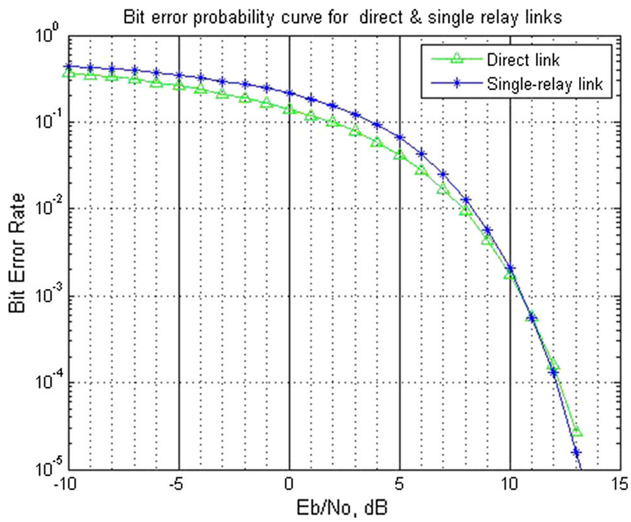

Fig. 9 Comparison between BER for the direct link system and BER for the single-relay system

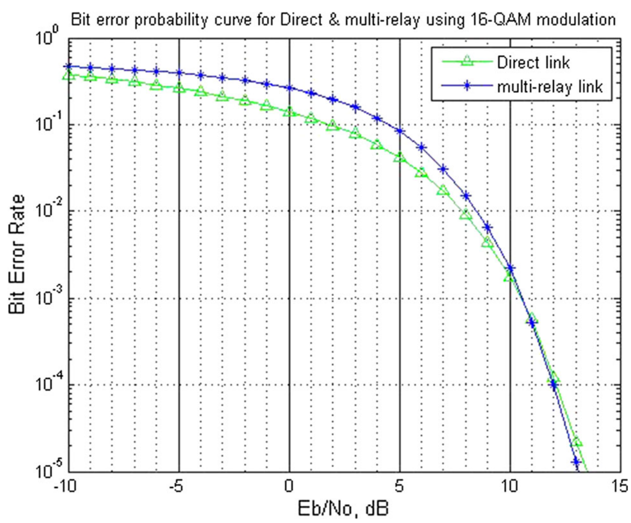

Fig. 10 Comparison between BER for the direct link system and BER for the multi-relay system

R_1–R_2 path and the R_2–D path, the total transmitted power is P/3. It can be shown that each time a relay node is added, the system's performance was improved, and power was saved. This result can be employed to facilitate cooperative communication in wireless networks. As shown in Fig. 10 that multi-relay system is produced BER performance that is similar to BER in direct link.

It can be seen form Fig. 10 that in the multi-relay the BER $= 1.2 \times 10^{-5}$ at SNR $= 13$ dB and in the direct link the BER $= 2.2 \times 10^{-5}$ and the SNR is also 13. In addition, BER for multi-relay $= 5 \times 10^{-4}$ and BER for direct link $= 5 \times 10^{-4}$ where the SNR is 10.96 dB for both curves. Therefore, the two curves are achieved similar performance.

If the distance between source, relay node, and destination is increased, then the noise and BER can also be increased. Therefore, there is a relationship between BER and SNR. If the noise power is fixed, the signal power will decrease in proportion to the square of the distance. The BER is constant and the transmitter power is depending on SNR for both transmitter. Thus, it can be concluded that when the relay node is located in other places with different destination, the total transmitter power is lower than when the relay is in the middle between source and destination.

Saving the power transmitted in wireless networks improves the average BER and increases communication reliability. This is the reason behind the employing of cooperative communication techniques.

5 Conclusion

This paper investigated cooperative techniques and strategies in wireless networks designed to save transmitted power by implementing the system model. The DF method is one cooperative relay protocol that is used in the relay system model. A simulation of a direct link between source and destination is provided, and overall BER performance is calculated and investigated. In addition, a simulation of a single-relay system using DF to save on power and produce BER performance same as direct link is evident. These goals of this paper are achieved successfully, and the results suggest that the SNR is increased slightly in order to produce a BER performance similar to that found in direct links. To expand the examination of the power transmitted through cooperative communication, more nodes are added to the system. As a result, more of transmitter power is saved with the BER. These evaluations prove that relay nodes save transmitted power and that the system performance will be directly improved through a perfect BER. On the other hand, the effects of different relay node locations are also demonstrated. The results showed that it is best for the relay node to be in the centre of the link (equidistant from the source and the destination). However, if the relay must be moved, then it is better for it to be closer to the source node, since this location achieves better system performance.

In order to expand the analysis area, future work should examine the BER performance of the system using the Rayleigh channel model, together with the AWGN. Future work can also add another digital modulation scheme besides the 16-QAM—that is, the BPSK. In addition, future research can explore cooperative relay effect by using two modulation schemes and observing the differences between them in wireless networks. The system performance can be analysed in terms of BER performance in order to study the transmitted power efficiency.

In cooperative communication, the relay node can have a negative effect on security. In other words, attacker can easily use a relay node to break the security of the system.

Thus, cooperative schemes are vulnerable to attackers and malicious acts. These attackers can masquerade as nodes and affect the information quality by sending incorrect information to the destination. Future research can analyse the factors affecting security and develop a scheme to improve system security using diversity techniques.

There are four combining techniques that are used in cooperative communication: switching combining, selection combining, maximal ratio combining (MRC) and equal gain combining. In recent research, MRC has been used heavily in cooperative communication because it uses the receiver to combine signals with good performance, especially in DF schemes. Thus, the researcher of this paper suggests that future research can use combining techniques with relay nodes and observing the differences in their performance.

In addition, if possible, future research can use more cooperative protocols like amplify-and-forward, to examine power and security constraints, and how the system performance can be improved to achieve the best BER for the wireless network. In addition, future research can seek to analyse the difference between AF and DF in this paper system to determine which is better for improving power and security in wireless cooperative communication.

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