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Best Relay Selection Scheme in Wireless Cooperative Communication

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***Abstract*—In this research, the combination of the relay selection and network coding is used to measure the performance in LOS and NLOS condition over cooperative communication. The research aims are to select the best relay as assisted relay as well as to improve performance system. The research method used four nodes, two nodes as source and destination and two nodes as relays. The single relay selection is used to select best relay of several relays. Measurements are conducted by altering the positions of the relays to achieve optimal outcomes. The findings indicate that the relay with the lowest Bit Error Rate (BER) and the shortest distance is chosen. The study's outcomes, when measuring throughput, reveal that network coding throughput is 21.8% higher than that without network coding in Non-Line of Sight (NLOS) conditions. In Line of Sight (LOS) conditions, the throughput is increased by 23%.**

***Keywords*— Bit Error Rate, Relay Selection, Signal to Noise Ratio, Throughput, Wireless Communication.**

I. INTRODUCTION

In the realm of wireless communication, signal fading emerges as a consequence of the multipath phenomenon, wherein information is transmitted from the transmitter to the receiver through various paths. Multipath fading is a type of signal interference that transpires when a signal travels over numerous pathways from the transmitter to the receiver [1]. Because of these diverse pathways, the signal intensity at the receiver varies, which might amplify or diminish the received signal [2]. Fading affects the performance of the communication system. Furthermore, more extensive the transmission distance, the greater the energy required at the transmitter. One convincing strategy for overcoming these issues is cooperative communication using relays in data transfer. Cooperative communication is used to enhance energy efficiency by employing relays between the transmitter and receiver, hence reducing transmission distance and minimizing transmission energy [3]. And a relay selection method can increase cooperative communication system efficiency [4][5]. Moreover, additional network coding may strengthen data security while also saving bandwidth [6-11]. Network coding is an approach in enhancing throughput, diminishing delays, and establishing stronger networks [3][12].

Prior research simulated the best relay selection approach, single relay selection amalgamated in network coding. The biggest SNR is utilised to pick the relay, which utilises the BER and throughput parameters to assess system performance. The simulation findings demonstrate that combining the optimal relay with network coding may boost throughput by 34% when compared to relay selection without network coding [5]. Other research has employed simulations to accelerate network capacity and performance by combining relay selection with network coding. The optimal relay is determined using Single-Relay Selection-Network Coding (S-RS-NC) and Dual-Relay Selection-Network Coding (D-RS-NC). When $2E_s > E_R$, the relay selection along with network coding approach performs better than relay selection without network coding. [8]. Younghui Li et al. conducted research on Relay Selection Simulation with Network Coding (RS-NC) and the Min Max approach in selecting the optimal relay verifying by Monte Carlo simulation. The goal of this research is to increase gearbox efficiency and system performance. The results revealed that the RS-NC scheme outperformed the RS-No-NC system. [9]. In accordance with this study, the DF (Decode and Forward) protocol was used to conduct a network coding simulation with relay selection [3]. The max min approach and the greatest SNR are used in the relay selection technique. The simulation use Monte Carlo [13-14]to validate the correctness of the mathematical calculations performed and the recommended diversity analysis [3].

This study simulates single relay selection and multiple relay selection with network coding [15] in wireless communication through MATLAB Software, by comparing throughput and Bit Error Rate (BER) as the performance analysis.

II. METHOD

A. System Overview

In this study simulates relay selection for multiple nodes, single relay selection and dual relay selection combined with network coding, which is depicted in Figure. 1. The single relay selection approach is used to determine the best relay from a set of n-relays. Whereas, dual relay selection involves attempting to identify the two best relays from a number of several relays. Subsequently, both of them are combined with network coding to secure data transfer.

The users consist of S_1 as source node and S_2 as destination node. Multiple relays are employed in this study. We assume QPSK as modulation method, flat fading with gaussian noise as well as Rayleigh channel in this research.

The block diagram of the system is shown in Fig 2.

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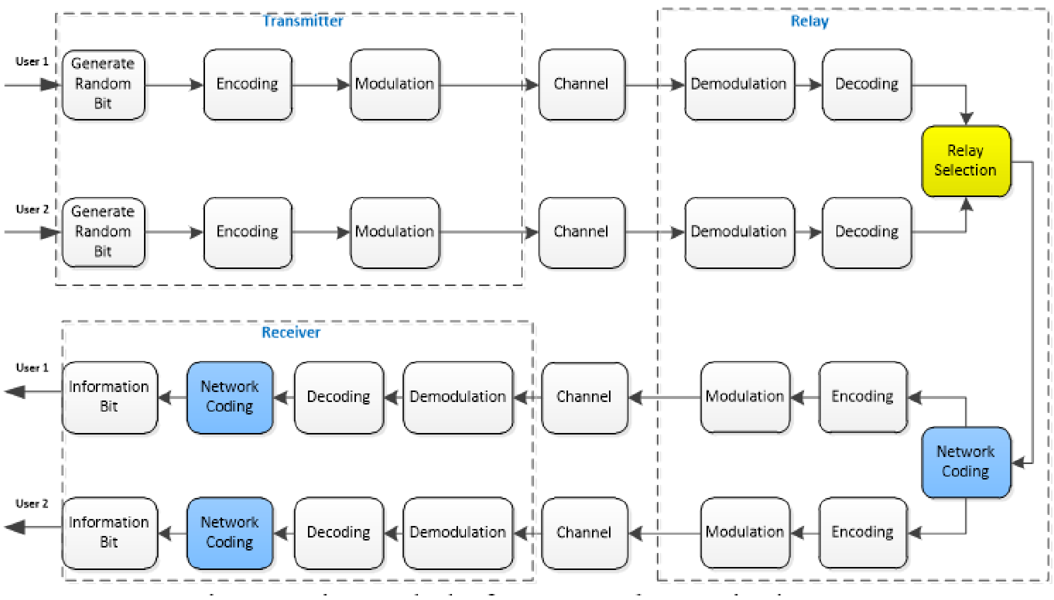

Figure 1. Diagram Block of System

Fig 1. depicts that the system consists of three parts, transmitter, relay and receiver. Regarding on transmitter stages, there are random bit generation, encoding process, modulation, channel, demodulation and decoding.

The process of generating random bits, encoding, modulation append preamble, upsample and upconvert. In generating random bits, the generation of information bits is random and equiprobable. The encoding process begins by encoding the bits of information that have been generated previously with a convolution code. In matlab use the "convenc" function. Bits are encoded using the convolution code method with trellis, employing a specific code rate. In modulation, the generated bits are mapped into symbols using the QPSK modulation technique with M = 4, so the number of bits per symbol (k) is 2.

The modulation result is in the form of complex IQ (Inphase Quadrature) symbols. The row of symbols is added to the preamble. The creation of pulses and the upsampling process in Upsample involve passing through the Square Root Raised Cosine (SRRC) filter. During upconversion, the signal is elevated to a frequency of 5 MHz to prevent signal attenuation from the DC radio.

At the relay node, the best relay selection process (single relay selection) occurs from the 2 relays used. After that, the network coding process is carried out for the information bits from node 1 and node 2. The information bits from the network coding results in the relay are transmitted to each node, according to the stages in Figure 1. And after arriving at nodes 1 and 2, the network coding process is carried out again to get bits of information from the source node.

B. Relay Selection

The relay communication system consists of 3 parts, namely Source, Relay, and Destination. The single relay selection method is used in selecting the best relay. In Single Relay Selection (SRS), one relay is selected from the available multiple relays (n-relay). There are nodes 1 - S1 (can be source or destination), node 2 - S2 (can be source or destination) and Relays (as many as N relays), which are shown in Figure 1.

The Single Relay Selection stages are as follows:

a) Node 1 (S_1) sends information bits to each relay, $b_1(k)$, $b_2(k)$;
b) Bits are generated randomly, encoding, and modulating. Then it is sent through the channel. Information is received on the relay, which goes through the timeslot.
c) In the relay, decoding and demodulation processes are carried out. The calculation of the demodulation bit on each relay is determined based on the Bit Error Rate (BER) value.
d) Compared BER S1-R_1 and BER S1-R_2
e) The smallest BER is selected between each relay, and the relay with the smallest BER is selected as R_s

Selection of the best relay using Min BER Selection, with equation [7]:

$$R_s = \arg min\,\{P^b_{R_i}(\gamma_{S',R_i})\} \qquad (1)$$

where R_s is best relay. $P^b_{R_i}$ is the error probability of the XOR signal in the relay. Equivalent SNR in XOR signal at relay R_i is γ_{S',R_i}.

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C. *Network Coding*

Network coding is a method for encoding and decoding delivered data in order to enhance throughput and decrease latency. Network coding enhances performance and efficiency in comparison to scenarios without it, as it involves combining data from multiple nodes (S_1 dan S_2) into a single data transmission. Node 1 sends information to node 2, and node 2 sends information to node 1. The transmission process in the scheme without network coding uses 4 time slots. In time slot 1, node 1 sends packet $S_1$to relay R. In time slot 2, Relay R sends back $S_1$to node 2. In time slot 3, node 2 sends packet $S_2$to relay R and at time slot 4, relay R sends return information S_2 to node 1, shown in Figure 2.

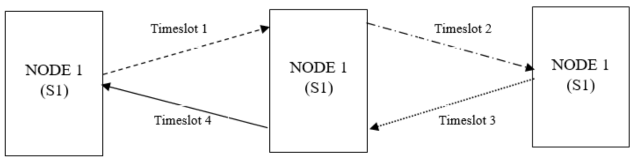

Figure 1. Data Transmition without network coding

The network coding scheme uses 3 timeslots as shown in Figure 4. In time slot 1, Node 1 sends S_1 to the relay. Then in time slot 2, node 2 sends information S_2 to the relay. After receiving information from S_1 and S_2, the relay then creates a network coding mapping $S_R = S_1 \oplus S_2$. Meanwhile, S_1 and S_2 consist of modulation symbol and $S_1 \oplus S_2$ is XOR. The symbol is the XOR symbol. In relay, the network coding process for node 1 and node 2 as follows:

$$S_R = S_1 \oplus S_2 \quad (1)$$

Time slot 3, Relay R broadcasts S_R to node 1 and node 2. When node 1 receives information from S_R, S_1 extracts information from S_R to get bits of information from S_2. It can be written as follows:

$$S_1 \oplus S_R = S_1 \oplus (S_1 \oplus S_2) = S_2 \quad (3)$$

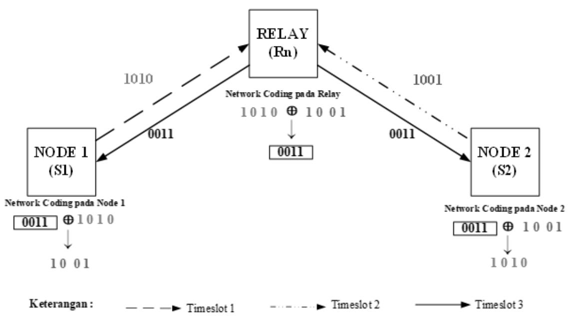

Figure 2. Data Transmit with network coding

Likewise at node 2, the result of the information bit S_1comes from $S_2 \oplus S_R$. The relay engages in network coding once it undergoes the decoding process of packets from nodes 1 and 2 during separate time slots.

D. *Measurement Scenario in Outdoor Environment*

In this research, measurements were carried out Line of Sight (LOS) condition, shown in Figure 3.

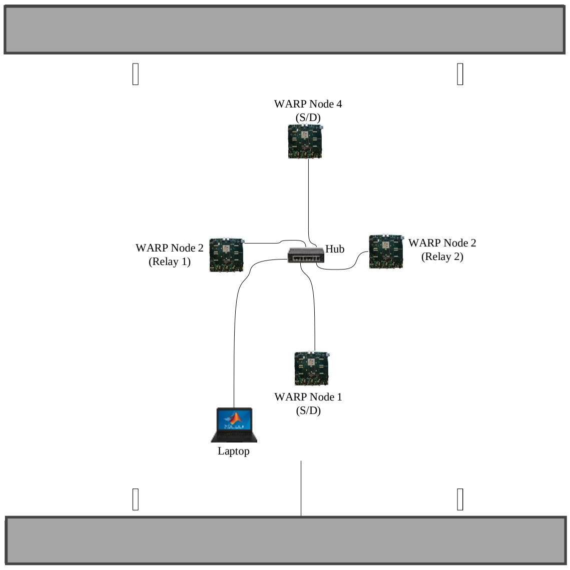

Figure 3. LOS Measurement Plan

In the first scenario, measurement with LOS conditions. The distance from User 1 to the relay is equal to the distance from User 2 to the relay, and it varies at intervals of 2, 4, 6, 8, and 10 meters, as depicted in Figure 3.

In the second scenario, the separation between User 1 and the relay is identical to that between User 2 and the relay, measuring 10 meters. An obstacle is situated between User 1 and User 2, extending towards the relay. Obstacles in the form of wire (1 meter x 1 meter) are shown in Figure 4

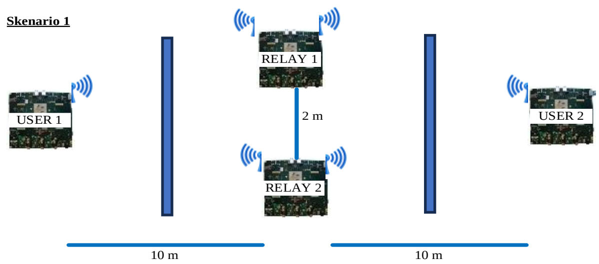

Figure 4. NLOS measurement

III. RESULTS AND DISCUSSION

The simulation involves the optimal relay selection through the utilization of both single relay selection and network coding

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in both Line of Sight (LOS) and Non-Line of Sight (NLOS) conditions. The parameters being compared include the Bit Error Rate (BER) for the single relay selection with the network coding scheme and the corresponding scenario without network coding.

A. Measurement Result in LOS Condition

Relay selection system with network coding for LOS conditions, at a distance of 4 meters, the BER value reaches 0 when the transmit power level is -16.75 dBm. At a distance of 8 meters, the BER value reaches 0 when the transmit power level is -13 dBm. Measurements at a distance of 12 meters BER value has reached 0 when the transmit power level is -9.25 dBm. And at a distance of 16 meters and 20 meters there is still an error in the received bit even though the maximum transmit power level is -4.7143 dBm, as shown in Figure 5.

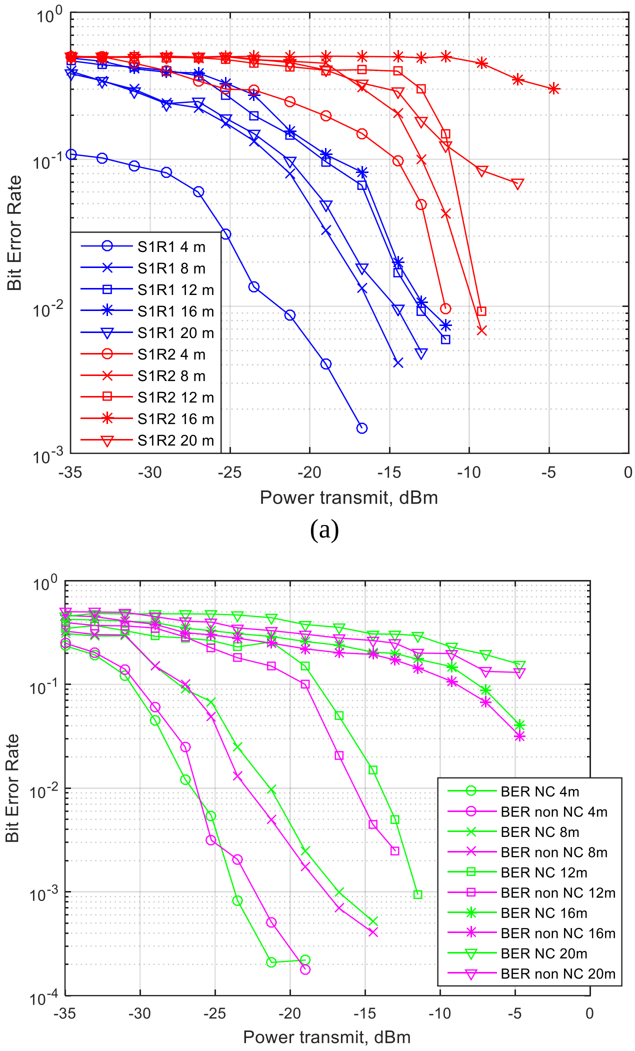

Figure 5. (a) Best Relay Selection for LOS condition, (b) Comparison of BER values using Network coding and without Network coding for LOS condition

The BER value in the scheme without network coding is slightly smaller than that of network coding. In the network coding approach, the symbol of node 1 experiencing noise undergoes XOR operation with the symbol of node 2 affected by noise prior to the decoding and demodulation steps. This contrasts with the network coding-absent scheme, where symbols from noise-affected node 1 are directly transmitted to node 2 through the optimal relay without XOR processing. On the other hand, network coding is superior in data transmission time, because it merely requires 3 timeslots to send data from S1 to S2 compared to without using network coding which requires 4 timeslots. In addition, network coding enhances the throughput.

B. Measurement Result in NLOS Condition

The Bit Error Rate (BER) is higher in Non-Line of Sight (NLOS) conditions compared to Line of Sight (LOS) conditions, because of obstacles. Moreover, an increase in distance results in a higher BER too, as shown in Figure 6.

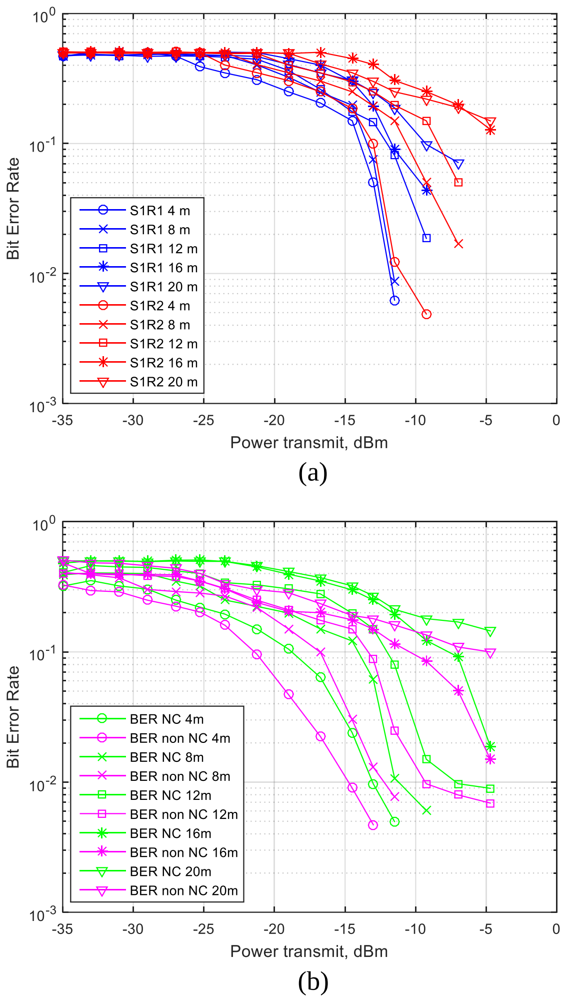

Figure 6. (a) Best Relay Selection for NLOS condition, (b) Comparison of BER values using Network coding and without Network coding for NLOS condition

C. *Throughput Analysis*

Throughput is a parameter that indicates network quality. Figure 6 is the throughput measurement in LOS condition. The

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network coding scheme has a throughput of 23% greater than without network coding, as shown in Figure 7. The higher the throughput value, the better the performance of a network in data transmission.

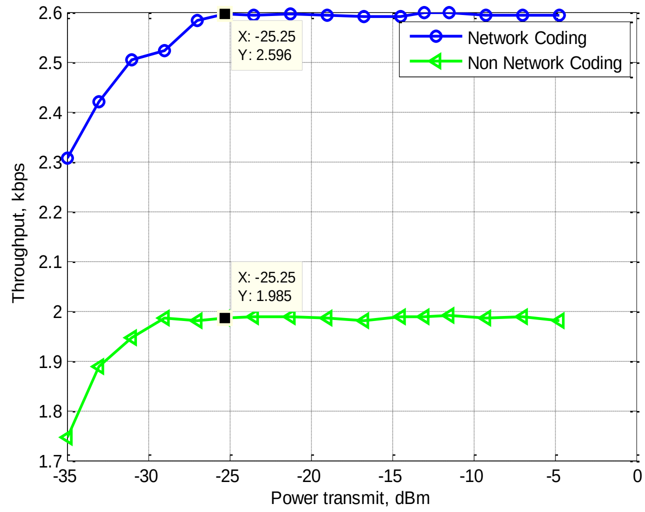

Figure 7. Throughput measurement in LOS

In NLOS condition, the network coding scheme has a throughput of 21.8% bigger than without NC, as shown in Figure 8. The throughput in NLOS condition is smaller than in LOS condition, because obstacles in NLOS conditions tend to affect the data transmission from transmitter to receiver.

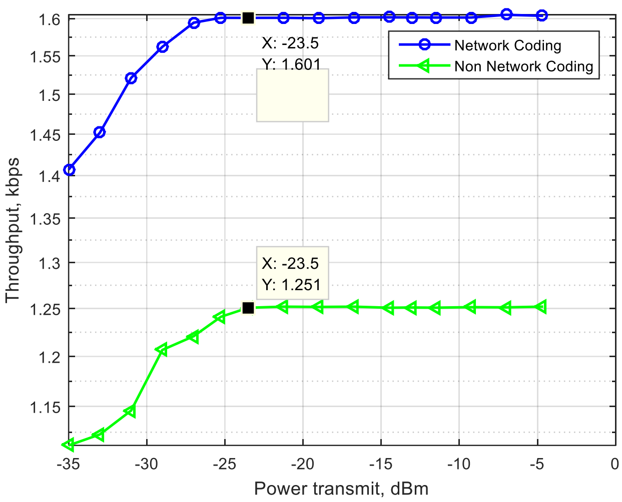

Figure 8. Throughput measurement in NLOS

IV. CONCLUSION

This research presented that under Line of Sight (LOS) and Non-Line of Sight (NLOS) conditions, the selection of relays is impacted by the criterion of the shortest distance. Selecting of the relay with the smallest distance from the source node reduces the power level emitted, resulting in a lower BER. In NLOS condition network coding also has a greater throughput of 21.8% than without network coding. Nevertheless, in LOS condition, throughput that using network coding is bigger 23% than without network coding.

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