Half-Duplex and Full-Duplex Performance Comparison for Different Fading Channel Using HMR Protocol in MIMO Technology

Daphney Joann
Department of Computer Science and Engineering, Global Institute of Engineering and Technology, India
daphneyjoann@gmail.com

Vayanaperumal Rajamani
Department of Electronics and Communication Engineering, Veltech Multitech Dr. Rangarajan Dr. Sakunthala Engineering College, India
rajavmani@gmail.com

Abstract: *This paper deals with the performance of Half Duplex (HD) and Full Duplex (FD) in different fading channels via relay networks. A new Heterogeneous Multiplex Relay (HMR) protocol is proposed for the achievement of spectrum efficiency over Multiple Input and Multiple Output (MIMO) using HD and FD. The Key idea of the protocol the relay selection among half duplex and full duplex for overcoming fading which achieves diversity and multiplexing gain. The protocol is projected in Massive MIMO with Opportunistic Relay Selection which requires limited feedback/signaling for relay and operation mode selection. The max-min criteria help in finding the best channel which leads to the best relay selection. Consideration of the Coded Cooperation and Successive Interference Cancellation helps recovery of the loss of Multiplexing Gain. Simulation result shows the throughput performance of Heterogeneous Multiplex Relay (HMR) protocol compared to HD and FD. HMR protocol provides 80% capacity performance due to its allotted channels between HD and FD. It also shows the performance of Bit Error Rate (BER) vs Signal to Noise Ratio (SNR) values compared to Rayleigh, Rician, and Nakagami Fading Channels.*

Keywords: *Relay network, HD, FD, HMR Protocol, MIMO, BER, SNR.*

Received October 14, 2020; accepted July 27, 2021
https://doi.org/10.34028/iajit/19/3/11

1. Introduction

Multiple Input Multiple Output (MIMO) provides additional capacity in the channel and it offers multiple antennas for ensuring improvement in multiplexing and diversity gain. Effective mitigation of multipath fading space diversity is available in MIMO as multiple antennas have different observations of the same signal. Relays that are used between source and destination with Channel State Information (CSI) recommend a subset of relays to forward data to improve the performance of cooperative communication. The advanced correspondence organization can be intended to accomplish a high information rate, upgraded link dependability, and further developed range. MIMO strategy can increment spectral effectiveness without utilizing additional transmission capacity. In this paper a new Heterogeneous Multiplex Relay (HMR) protocol is proposed for Diversity Multiplexing Tradeoff with both half and Full Duplex two ways relaying network. Due to its hybrid behavior, it differentiates between half duplex and full duplex based on Shannon Capacity assuming $C=B\log_2(1+SNR)$. The protocol chooses between half duplex and full duplex based on capacity and self-interference. Acceptable values of Bit Error Rate (SNR) in HMR protocol are between 15dB and 40dB and the Interference signal can be deducted from Received Signal to overcome Self Interference. The performance of the protocols is capable of comparing with channels like Rayleigh, Rician and Nakagami.

Rankov and Wittneben [23] proposed various Spectral efficient protocols on half duplex mode including Amplify or Decode and Forward relay and extended to multiple terminals through Orthogonalize and Forward (OF) relay using a distributed zero forcing algorithm. Ju *et al*. [12] proposed a new Full Duplex Relay (FDR) whichever formed on instance and antenna division by relay node and fundamental intervention. Li *et al*. [17] characterized a coded cooperation diversity policy with multiple relay channels. Riihonen *et al*. [24] suggested a MIMO that provides some mitigation schemes such as normal segregation, instance domain termination and spatial repression. Luo *et al*. [20] projected a Full Interference Cancellation (FIC) algorithm for the inter relay intervention termination in the two trail cooperative systems.

Karmakar and Varanasim [13] presented a situation where quasi-static, half duplex channel are distinguished and known for multiple antennas and an opportunistic scheduling of relay allowed. Gharan *et al.* [6] revealed Amplify and Forward Relaying along with multiantenna arrangement established a Random Sequential Relaying Scheme which accomplishes an improved Diversity-Multiplexing Tradeoff (DMT). Hong *et al.* [8] suggested that the Interference occurs during antenna selection in Full Duplex (FD) mode. Self-Interference termination takes place in both full duplex heterogeneous networks and doubles spectrum efficiency.

Shen *et al.* [25] revealed a evaluation of Full Duplex and Half Duplex that manifested a two-way relaying system called the Amplify and Forward Relay Networks. Kontik and Ergen [14] proposed a heuristic scheduling algorithm that assigns a time slot based on a unique metric measurement called Interference Effect (IE). Zhang *et al.* [30] explored a Opportunistic decode-and forward based relay assortment system above free and similar dispersed Rayleigh and Nakagami fading channels. Wang *et al.* [28] proposed a Hybrid Relay mode with entity node power constriction augments the data rates between terminating nodes.

Hong and Choi [7] suggested a novel Multiple Relay Coded Cooperation (MRCC) procedure using Decode and Forward relay for overcoming the signal loss in half duplex. Lee and Quek [16] suggested Hybrid-Duplex Heterogeneous Network Model (HDHN) the system intervention from Full Duplex Mode groups and the HDHN bandwidth are achieved by considering structural density. Fang *et al.* [5] investigated Massive MIMO with Full Duplex Cellular Two-Way Relay Networks (CTWRNs). The channel State Information which is imperfect in full duplex networks is expected to be considered in future. Chen and Zhao [4] proposed a Massive MIMO with Dual-Hop FD which is measured with Amplify and Forward (AF) hand on system attaining Ergodic rates maximizing band and power competence.

Afifi *et al.* [1] analyzed Relay selection scheme intended for Amplify and Forward (AAF) cooperative communication networks above Rayleigh fading channel. The Nakagami fading factor (m) provides high performance. Chen and Zhao [4] proposed a hybrid HD/FD communication method in a relay aided network employs the benefit of throughput and based on signal-to-noise interference ratio it handles the Half Duplex and Full Duplex. Singh and Chopra [26] demonstrated Reliable communication between the transmitter and the receiver during multipath propagation and comparison has been made between Rayleigh, Rician and Nakagami fading channels in terms of probability density function and source velocity. Vaezi *et al.* [27] revealed the communication rate of half and full duplex which is maximized by introducing the optimal beam former which aims to provide equilibrium between the direct connection and the cooperating connection. Wang and Chopra [26] developed a MIMO with flawed channel state data improves the spectral proficiency by utilizing Network Assisted Full Duplex communication (NAFD). To mitigate the upstream-to-downstream obstruction a novel Genetic Algorithm (GA) Based User Scheduling Strategy (GAS) is anticipated.

Jia *et al.* [11] proposed about Massive MIMO AF relaying system with dual hop full duplex. In this, the achievable Ergodic rates followed by an asymptotic performance that corresponds to three power scaling schemes is projected. Li *et al.* [18] states that transmit diversity is achieved through virtual multiple antenna range and a coded collaboration diversity strategy is considered appropriate for multiple relay channels through a wireless connection linkage. Loa *et al.* [19] emphasis on relay architectures in 16 m and LTE-A wherever the relay is fundamentally an orthogonal frequency-division multiple access through wireless connection linkage.

Hu *et al.* [10] considers the routine of full duplex mode in two-way AF relay channels by investigating Ergodic capacity and outage probability. Yun [29] proposes a radio resource organization system conveying downstream and upstream transference whereas taking into consideration of self-interference cancellation. The total utility sum is accomplished by conveying resource blocks and considering diffuse power levels. Lv *et al.* [21] proposed a Block Code Descent [BCD] algorithm that solves the optimization problem of basis precoding, relay augmenting, feed-forward and response conditions. Akif *et al.* [2] proposes a GA based Transmit Antenna Selection (TAS) scheme to promote with self-backhaul acknowledged as Integrated Access and Backhaul (IAB) that permits for sharing of resources between Small Cell Base Stations (SBS) and Main Base Station (MBS) users.

Hellings *et al.* [9] concentrate on the curved reformulation problem through an approximation with primitive disintegration is considered and the convergent algorithm provides the solution that discovers the optimal coefficient matrices in MIMO. Lee *et al.* [15] propose a multi-antenna relay with CSI that overcomes interference by presenting a novel relay-aided interference arrangement that consists of two junctures namely Side Information Learning and Overhead Equation substitution. Nordio and Chiasserini [22] discuss the Full Duplex with relay operational mode that reaches maximum achievable data rate. Two hops MIMO with analysis of a number of antennas is achieved to derive low complexity. Chae and Lee [3] suggests about Full Duplex that overcomes self-interference by focussing on line of sight and with multiple antennas achieves multiplexing gain.

The contributions of this paper are summarized as follows. This paper proposes a Heterogeneous Multiplex Protocol that allows both half duplex and full duplex relaying network. The collaborative relay selection switches among half duplex and full duplex formulated on Shannon capacity. Half duplex is selected when the capacity is lower than a stipulated threshold, while full duplex is selected when capacity is higher. Half duplex is preferred when there is self-interference due to full duplex.

This paper is arranged and organized in sections based on principles as follows. The System Model for MIMO is proposed in section 2. Section 3 describes Protocol Description, which explains Shannon Law Capacity, Relay System based on Heterogeneous Multiplex Protocol, Half duplex, Full duplex, Self-Interference cancellation based on Full Duplex is proposed, section 4 relates to the Comparison between HMR protocol in Rayleigh, Rician and Nakagami Fading Channels, section 5 indicates the Results and Discussions, section 6 provides the Conclusion.

2. System Model

The signals in wireless communication sometimes tend to fade due to the dispersion effects in time and frequency, path loss effect, co-channel interference, and limited availability of bandwidth. MIMO expands spectral efficiency and develops the reliability of the transmission link. This paper recommends Multipath propagation and spectrum efficiency based on MIMO. Massive Multiple Input and Multiple Output refer to base stations comprised of a large number of antennas that concurrently communicate with numerous spatially separated user terminals. MIMO beam forming using phased-array systems having a predefined pattern requires the overall system to determine the direction of the signal

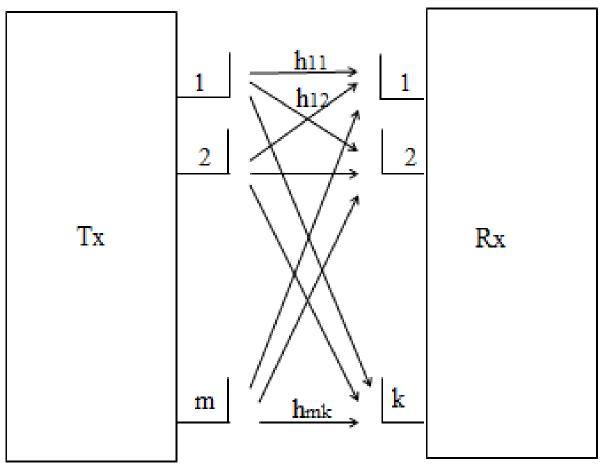

Figure 1. MIMO system model.

Figure 1 shows the communication by MIMO of the Data Stream from the transmitter to the receiver. It has M inputs after transforming possess K outputs. The spatial channel among antenna elements and user terminals characterizes proceeding with multiple paths. The channel information provides a spatial transmit among every antenna and each user terminal. Spatial information is shown in the form of a matrix.

$$H = \begin{bmatrix} h_{1,1} & \cdots & h_{1,k} \\ \vdots & \ddots & \vdots \\ h_{m,1} & \cdots & h_{m,k} \end{bmatrix}$$

$h_{m,k}$ is a Complex Gaussian random variable that models fading gain between the m^{th} transmit and K^{th} receive antenna. Multiple antennas in a system indicate different propagation paths referred to as spatial diversity. The data rates of the system can be improved by spatial multiplexing providing multiplexing gain.

2.1. MIMO Flat Fading Channel Model

The MIMO Flat Fading Channel Model typically comprises N_t antennas at the transmitter and N_r antennas at the receiver. The receiver antenna accepts signals from propagation paths. Subsequently, the channel response is conveyed as transmission Matrix H. The received vector $Y(N_r \times 1)$ is expressed in terms of matrix $H(N_r \times N_t)$ which is the channel transmission matrix and the input is x with noise n and represented in complex baseband notation

$$y = Hx + n \tag{1}$$

Signals are represented on the assumption Gaussian Signals X~N (0, kx) Where kx≜E[XXH] is the covariance matrix of the transmit vector X.

3. Protocol Description

The protocol is based on MIMO DF relay networks, which, in turn, are based on the max-min criterion. The max-min criteria help in finding the best channel which leads to the best relay selection. The protocol requires only limited feedback/signaling for the relay and selection of the operation mode. The HMR protocol has two modes, namely, Half Duplex Mode and Full Duplex Mode in a two-way relaying scheme. Reliability and capacity are compared and Shannon Law Capacity is compared here for switching the relaying scheme between Half Duplex and Full Duplex Mode.

When switching to full duplex mode, the coded cooperation of the wireless system suffers from Self Interference due to concurrent transmission of signals. The interfering signals can be handled by downsizing its overall signal from receiving signals so that the interference can be reduced and concurrent transmission is possible. The outage probability can be improved by HMR protocol providing high Data rate and multiplexing gain.

3.1. Relays in Duplex Section

Relays are used for receipt and retransmission of the signals between the sender and the receiver. The HMR relay is grounded on Decode and a forward relay, which encodes and decodes signals. The relay has two antennas, namely, transmit antenna and receive antenna as it deals with basic operations, the basic relay operation is explained in Figure 2.

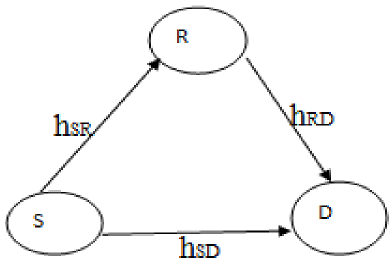

Figure 2. Relays in duplex system.

In the first step, the source S terminal will transmit the data through signal X to the relays and to the destination terminal that is from either through h_{SR}, h_{RD} or through h_{SD}. The following represents the signals received at the relay and the following destination terminal are given by

$$Y_{SR} = h_{SR}X + Z_{SR} \tag{2}$$

$$Y_{SD} = h_{SD}X + Z_{SD} \tag{3}$$

Where Y_{SR} and Y_{SD} demonstrate communication starting at the source to relay and from source to destination. From Equations (1) and (2) Y_{SR} the relay terminal will decode the received signal and then in Y_{SD} it again re-encodes and forwards it to the destination. The representation of Y_{RD} is given as

$$Y_{RD} = gh_{RD}Y_{SR} + Z_{RD} \tag{4}$$

Where gh_{RD} is the channel gain between the relay and destination. Z_{RD} is the independent Gaussian noise with the channel gains from the relay to the endpoint.

3.2. Shannon Law Capacity

The Shannon law shows the computation of channel capacity averaged received signal power and bandwidth which decides the switching the relaying scheme between half duplex and full duplex. It is denoted as

$$C = Blog_2(1 + SNR) \tag{5}$$

Where channel capacity is calculated based on bandwidth B concerning noise and interference over bandwidth.

- If C>R then the two-way relaying scheme will be in Full Duplex Mode and
- If C<R then the relaying scheme is in Half-Duplex Mode
- The SNR performance levels in HMR protocol between 15dB to 40 dB achieves better spectrum efficiency so that the Interference signal can be deducted from Received Signal to overcome Self Interference.

3.3. Heterogeneous Multiplex Relay Protocol

The two-way relaying scheme of HMR protocol has user 1 and user 2 whose information is in MIMO is exchanged with the help of relays (X_1,Y_1) for Relay 1 and similarly for R_i where (i=1…N_R) relays as shown in Figure 3. There are two sets of messages, namely, M1 and M2 between the sender and the receiver as they move from source to relay and relay to destination denoted as request and response messages. The links are characterized by channel coefficient h_i which is given under Gaussian distribution with zero mean and unit variance. The HMR protocol uses the decode and forward system which usually encodes the message from source, decodes the message in relay and then again in relay it is encoded and as a final point the decoded message reaches the destination.

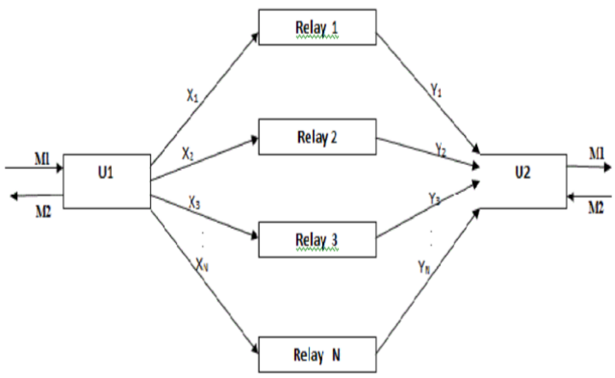

Figure 3. Half duplex and full duplex relay system.

3.3.1. Two Way Relaying Scheme with Encoding and Decoding

The sender and the receiver are considered here as user U1 and user U2. Two sets of messages M1 and M2 which range from 1 to N_R generally symbolize the code which possess $(2^{N_{R1}}, 2^{N_{R2}}, N, P_e)$. The encoding functions denoting as e_i with two decoding functions d1 and d2 is defined as

$$X_i = e_i(M_i, X_1, X_2 \ldots . X_{i-1}) \text{ where } i = 1 \ldots n \tag{6}$$

Where e_i denotes the encoding from source to relay. Then it decodes in relay and then again encodes and proceeds to destination.

$$X_{r_i} = e_{r_i}(M_i, Y_1, Y_2 \ldots . Y_{i-1}) \text{ where } i = 1 \ldots n \tag{7}$$

Where e_{r_i} denotes the encoding of message from relay to destination. The decoding function which takes place in relay and destination is given as

$$d1 : X_i \times e^m \rightarrow M \tag{8}$$

Where *d1* denote the decoding function done in the relay in which the message arrives from a source. The decoding function

$$d2: Y_i \times (e^m) r_i \rightarrow M_{i-1} \tag{9}$$

Denotes the Y_i relay with M_{i-1} messages from relay to destination .The actual message in the destination is achieved only if there exists a $(2^{N_{R1}}, 2^{N_{R2}}, N, P_e)$ code such that $P_e \rightarrow 0$ as $n \rightarrow \infty$.

3.3.2. Selection of Best Relay

The transmission is done in frame of *Z* symbols which is represented as .The received signal of relay is given as

$$Y_{R_j} = \sqrt{PS_i}\ hZ_iX_i + K_{X_i} \tag{10}$$

Where Y_{Rj} signifies the signal received in the relay, PS_i denotes the power scaling of the duplex. X_i represents the user that directs the message from source to destination. The channel coefficients between source to relays, relays to destinations with respect to the channel gain h and Gaussian Noise Vector Z_i. The decode and forward protocol uses the encoding and decoding procedure for transmission and receipt of data using the coding symbols K_{Xi}..The overall received signal in destination is given as

$$Y_{D_i} = \sqrt{PR_j}\, hZ_i\, f\left(Y_{R_j}^{best}\right) + K_{Y_i} \tag{11}$$

Where Y_{Di} symbolizes the overall signal received at the destination. Where P_{Rj} denotes the power constraint concering relay. The $f(Y_{Rj}^{best})$ designates the function applied to find the best relay among Y_i. The K_{Yi} symbol represents the encoding and decoding functions with admiration to Y_i. Table 1 denotes the symbols used in HMR protocol.

Table 1. Symbols used in HMR protocol.

Symbols	Description
X_i	Path between source to relay
Y_i	Path between relay to destination
M_i	Messages or datas
$\sqrt{PS_i}$	Power Scaling of Duplex
H	Channel gain
Z_i	Gaussian Noise Vectors
K_{X_i}, K_{Y_i}	Encoding and Decoding Functions
$f\left(Y_{R_j}^{best}\right)$	Best Relay Selection
E_b/N_o	Energy per bit to Noise Power
BER	Bit Error Rate

3.3.3. Half Duplex Relay System

In two-way Half Duplex relaying two time slots is necessary for forwarding data from source to destination as it does not accept the simultaneous transmission of data. The first time slot represents the communication from source to relay. The second represents the sending of data from relay to destination.

The first time slot is

$$Y_{SR_i} = \sqrt{PS_i} hZ_iX_i + K_{r_i} \tag{12}$$

The Second time slot is

$$Y_{RD_i} = \sqrt{PS_i} hZ_iY_i + K_{Y_i} \tag{13}$$

Where Y_{SRi} and Y_{RDi} denotes the timeslots from source to relay and relay to destination. Figure 4 denotes the operational flowchart of HMR protocol. It symbolizes the operation of initiation between Half Duplex and Full Duplex.

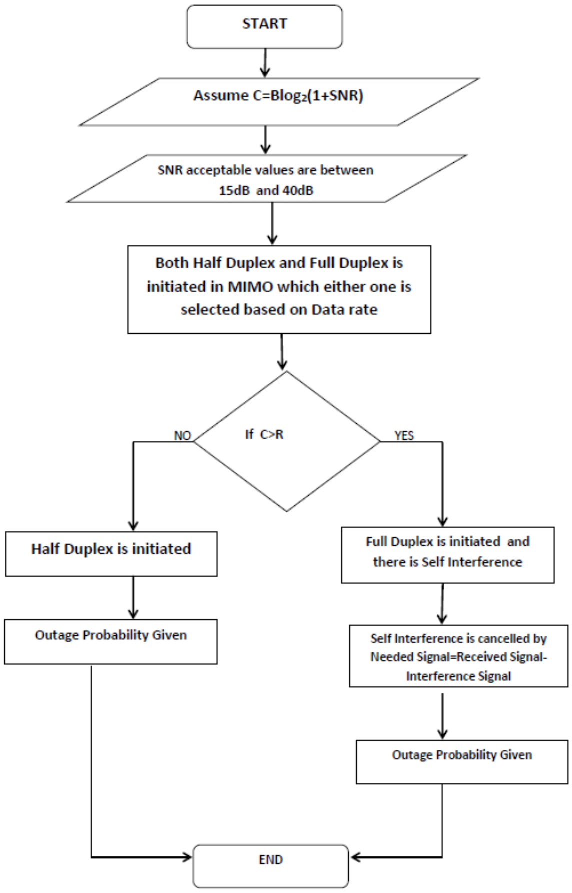

Figure 4. An operational flowchart of HMR protocol.

Algorithm for Heterogeneous Multiplex Relay Protocol

Step 1: Let $U_i=[U_1,U_2\ldots\ldots U_n]$ be the users in MIMO
Step 2: $X_i=[X_1,X_2\ldots.X_n]$ be the path from source to relay
Step 3: $Y_i=[Y_1,Y_2\ldots.Y_n]$ be the path from relay to destination
Step 4: Let $f\left(Y_{R_j}^{best}\right)$ be the selecting relay from $[Y_1,Y_2\ldots.Y_n]$
Step 5: Assume $C=Blog_2(1+SNR)$
Step 6: Based on Channel Capacity Calculation there are two modes in Protocol Half Duplex and Full Duplex
Step 7: if C>R
Step 8:Then("Full Duplex")
Step 9:else
Step 10: if C<R

Step 11: then ("Half Duplex")
Step 12: When Full Duplex("Self Interference is Initiated")
Step 13:Self Interference Cancellation is done to improve Capacity
Step 14: Needed Signal=Received Signal-Interference Signal
Step 15: End

3.3.4. Full Duplex Relay System

In two-way Full Duplex relay of a single time slot requires only transmission of data in full duplex .Simultaneous data flow may occur on the same frequency. The two-way FD relaying can attain high spectrum competence, but it has also a big processing complexity. This is due to the occurrence of the self interference arising from the co-channel conveyance. Self interference cancellation is done by cancelling the interference signal with the overall received signal. The Signal received at relay is

$$Y_{D_i} = \sqrt{PS_i}hZ_iX_i + \sqrt{PS_i}hz_{i-1}Y_i + f\left(YR_j^{best}\right) + K_{r_i} + K_{Y_i} \tag{14}$$

Y_{Di} represents the signal of full duplex received in the time slo, X_i and Y_i are the users between the sender and the receiver. $f(Y_{Rj}^{best})$ designates the function applied for finding the best relay among Y_i. The K_{Yi} and K_{ri} symbol represents the encoding and decoding functions.

3.3.5. Performance of Interference Cancellation in Full Duplex

An interference between users is seen during the use of Full duplex transmission due to simultaneous transmission at a given time slot. This leads to the occurrence of collision or delay. Successive interference cancellation is performed for avoiding collision. As a result, transmission becomes possible of packets with no delay.

Successive Interference Cancellation (SIC) increases the overall throughput at the cost of peak individual rate. It also provides reliability between users. Reliable communication can be attained at any rate C>R. In the event of simultaneous communication between users 1 and 2, reliable communication between users 1 and 2 is possible at rates R1 and R2. The total capacity can be represented as

$$Csum := maxR1 + R2 \tag{15}$$

The symmetric capacity is represented as

$$\mathrm{Csym} \coloneqq \max_{(\mathrm{R,R})C}\mathrm{R} \tag{16}$$

The rate of the individual user with power is represented as

$$\mathrm{R1} < \log\left(1 + \frac{\mathrm{P1}}{\mathrm{No}}\right) \tag{17}$$

$$\mathrm{R2} < \log\left(1 + \frac{\mathrm{P2}}{\mathrm{No}}\right) \tag{18}$$

Where *R1* and *R2* represent the rates *P1* and *P2* represent the power for user 1 and user 2 respectively. The overall throughput can be represented when combining the user capacity with the sum of the power which can be given as

$$\mathrm{R1} + \mathrm{R2} < \log\left(1 + \frac{\mathrm{P1+P2}}{\mathrm{No}}\right) \tag{19}$$

User 1 can achieve its actual data rate cancelling the high data rate of user 2 to avoid interference and at the same time user 2 achieves a non zero rate and its continued transmission so that R2 can be represented

$$R2^* = log\left(1 + \frac{P1+P2}{N_0}\right) - log\left(1 + \frac{P1}{N_0}\right) = log(1 + \frac{P2}{P1+N_0}) \tag{20}$$

Similarly user2 can achieve its actual data rate cancelling user 1 and it also has non zero rate so that R1 can be represented as

$$R1^* = \log\left(1 + \frac{P1+P2}{N_0}\right) - \log\left(1 + \frac{P2}{N_0}\right) = \log\left(1 + \frac{P1}{P2+N_0}\right) \tag{21}$$

4. Performance of Rayleigh, Rician and Nakagami Fading Channel

4.1. Rayleigh Fading Channel Distribution

Rayleigh Fading Model supports wireless environments that have multiple scatters and no Line of Sight (LOS) Path. When the components of h(t) are independent, the probability density function of the amplitude $r = |h| = \alpha$.The phase is uniformly distributed independent of the amplitude. The power of Rayleigh is exponentially distributed.

The BER performance can be given by

$$P_b = \frac{1}{2}(1 - \sqrt{\frac{E_b/N_0}{1+E_b/N_0}}) \tag{22}$$

The BER performance for Rayleigh is specified, in which SNR value is symbolized as E_b/N_o Energy per bit to Noise Power Spectral Density Ratio. Rayleigh provisions small scale fading and performs better with incoherent detection.

4.2. Rician Fading Channel Distribution

Rician fading channel is chosen for a path that prefers a line of sight signal and the signal is stronger. The channel distribution of rician is r= |h|. The h is denoted as $\alpha e^{j\o} + ve^{j\theta}$ where α follows the Rayleigh distribution and v>0 is a constant. The angles ø and θ are assumed to be mutually independent and uniformly distributed. .When K->∞ no LOS component and Rayleigh=Rician. The average BER of the QAM modulation scheme over Rician fading is

$$P_b = \frac{1}{2}erfc\left[\sqrt{\frac{k(\frac{E_b}{N_0})}{(k+\frac{E_b}{N_0})}}\right] \tag{23}$$

The average Bit Error Ratio is obtained by calculating the phase detection P_b which detects the error function *erfc* which is characterized by *k* factor and E_b/N_o. The k factor decides the power ratio of fading and E_b/N_o denotes the SNR values which affords the signal strength.

4.3. Nakagami Fading Channel Distribution

The Nakagami fading model describes the generosity of the signal received and the sum of the distributed Rayleigh fading signals which are independent and have a Nakagami distribution. The Rayleigh signal which has a K maximal ratio combining gives m factor signals where k=m. The Bit Error Rate of Nakagami Channel with Quadrature Amplitude Modulation (QAM) modulation is given as

$$P_e = \int_0^\infty \varphi Q\left(\sqrt{K_\gamma}\right) P_\gamma(\gamma) d_\gamma \tag{24}$$

Where $\varphi Q(\sqrt{K\gamma})$ represents the symbol error rate of QAM modulation scheme, $p_\gamma(\gamma)$ represents the fading which varies due to Variable expressions given in nakagami channel.

5. Results and Discussions

The numerical results between Bit Error Rate (BER) with EB/No based on SNR values are compared. The variations in the performance of Half and Full Duplex relaying system is seen as a result of the self-interference which occurs in Full Duplex. The radio frequency is 2.5 GHz with 64 QAM modulation is considered. The Signal to Noise Ratio is compared as an average from 0dB to 30 dB. The Signal Strength is good when it ranges from 20 dB to 30 dB. The average acceptable values of Bit Error Rate will range from 10^{-1} to 10^{-9}. The initial values corresponding to number of antennas will start from 2 antennas with 2 users reaches 3 SNR with capacity 2 bits/S/Hz, 4 antennas reaches 10 dB with capacity 3.2 bits/S/Hz, 8 antennas reaches 15 dB with capacity 5.5 bits/S/Hz, 16 and 32 antennas reaches 20 to 30 dB with capacity 5.5 to 8 bits/S/Hz. Simultaneous transmission, helps getting a performance for Full Duplex, better than that for Half Duplex. Performance degradation occurs due to Self-Interference (SI) and improves based on the Successive cancellation/ Suppression. The BER analysis is usually derived in Rayleigh, Rician and Nakagami-m fading channels.

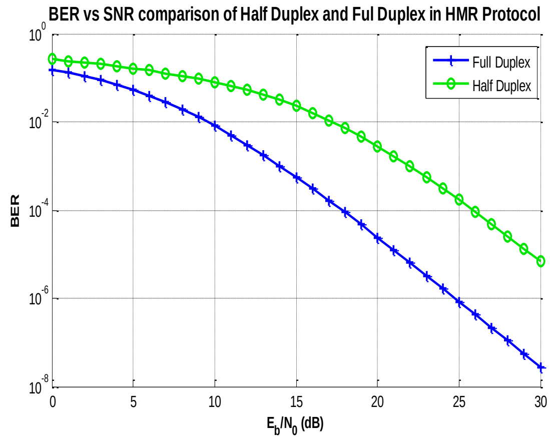

Figure 5. BER vs EB/No performance of half duplex and full duplex in HMR Protocol.

Figure 5 shows the BER vs EB/No performance in which the HMR protocol defines the hybrid behavior that switches between Half Duplex and Full Duplex Mode based on Shannon law capacity and Time Division Multiple Access (TDMA) approach achieves a good performance. The results show the Half Duplex and Full Duplex performance in HMR protocol where an average of 0 to 30 dB is achieved with the BER ranging from 10^0 to 10^{-5} in Half Duplex and 10^0 to 10^{-7} in Full Duplex.

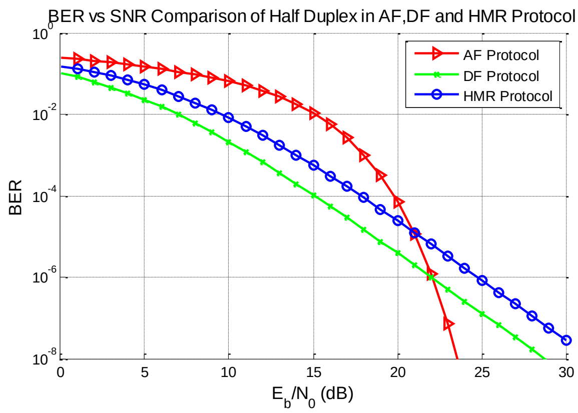

Figure 6. BER vs SNR Comparison of Half Duplex in AF, DF and proposed HMR Protocol.

Figure 6 shows the BER vs SNR comparison of Half Duplex in AF, DF, and HMR protocol. The 64 QAM, provide faster data rates, which increases the bit error rate leading from 10^0 to 10^{-8}. The SNR value has good signal strength from 0dB to 30dB. The Amplify and Forward AF Protocol in the half-duplex with 64 QAM modulations reaches the SNR value from 24 dB, providing acceptable signal strengths with a bit error rate of 10^{-8}. The Decode and Forward DF protocol in half-duplex relays with MIMO asymmetric relays has a BER analysis that reaches nearly 28 dB. The current proposed protocol HMR provides a better outage comparison between AF and DF protocols offering good signal strength accepting SNR value of 30 dB with BER 10^{-8}.

Figure 7 shows the BER vs SNR comparison of

Full Duplex in AF, DF and HMR protocol. Full Duplex with Amplify and Forward protocol provides transmission of data up to the SNR of 28 dB. The modulation applied here is 64 QAM modulation. SNR values going up to 30 dB in Decode and Forward Protocol. The HMR protocol with Full Duplex allows simultaneous transmission and has coded cooperation with successive interference cancellation. BER transmission is accepted to the SNR values of 30 dB performing better data rates through 64 QAM modulation that ranges till 10^{-7}.

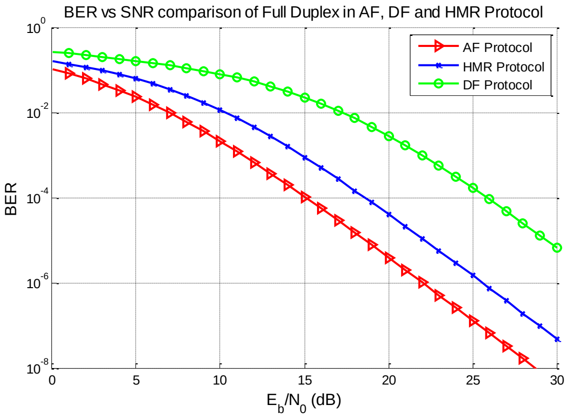

Figure 7. BER vs SNR comparison of full duplex in AF, DF, and proposed HMR protocol.

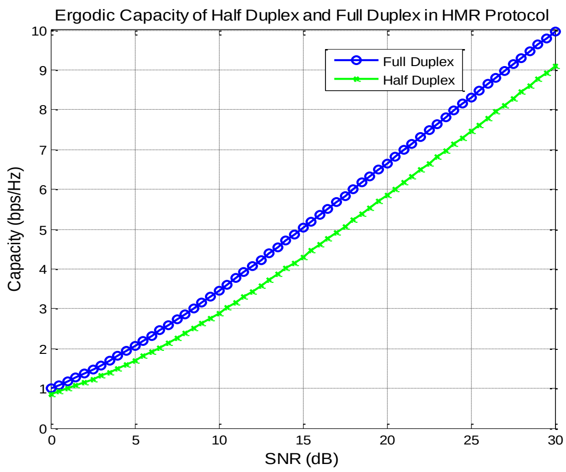

Figure 8. Ergodic Capacity of half duplex and full duplex in HMR protocol.

Ergodic capacity deals with channel capacity and compares the performance of Half Duplex and Full Duplex Relaying System. The main aim of the capacity analysis is to provide a performance measure for wireless communication for getting the maximum achievable rate. Figure 8 shows the Ergodic Capacity of Half Duplex and Full Duplex in HMR protocol. Here the outage capacity reaches 8 to 9 bps/Hz in Half Duplex and in Full Duplex it reaches 9 to 10 bps/Hz. The full duplex provides better performance than half duplex which is represented in Hertz.

Figure 9 shows the Ergodic capacity of Full Duplex in comparison with AF, DF and HMR protocols. The performance of Full Duplex compared to Half Duplex is improved due to simultaneous transmission and coded cooperation with self-interference cancellation. The performance of Ergodic capacity with channel capacity for Full Duplex with QAM modulation shows an average of 5.4 bps/Hz in AF protocol and 5.8 bps/Hz in DF protocol. The proposed HMR Protocol reaches nearly 7 to 8 bits/Hertz capacity showing a performance better than AF and DF protocol due to its allotment of channels in Full-Duplex Mode.

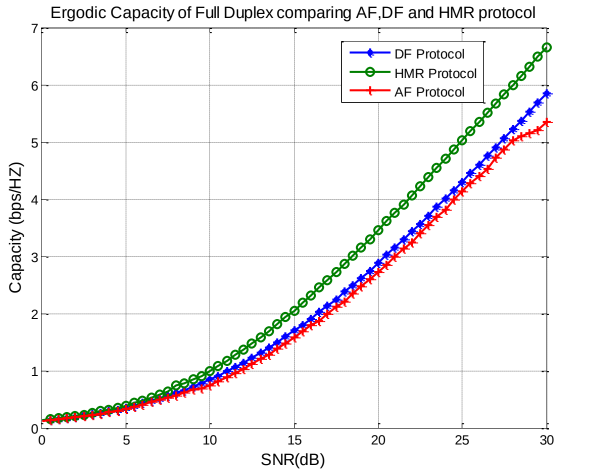

Figure 9. Ergodic Capacity of full duplex comparing AF, DF, and proposed HMR protocol.

Figure 10 represents the Rayleigh distribution corresponding to AF, DF, and HMR protocol. The Rayleigh distribution provides the diversity of order one and supports a scattering environment so that no Line of Sight Component exists. The BER Performance of QAM in Rayleigh fading which generates from orthogonal Gaussian random variables is discussed in HMR Protocol. The Amplify and Forward protocol show a performance up to 27dB. The Decode and Forward Protocol relay with the current scenario shows 30 dB. The proposed HMR protocol that reaches to a SNR of 30dB with the BER of 10^{-7} in Rayleigh distribution.

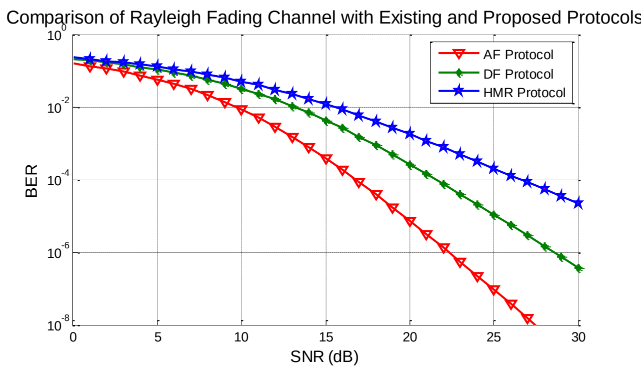

Figure 10. Comparison of rayleigh fading channel with existing protocols and proposed HMR protocol.

Figure 11 shows the Rician Comparison between different protocols. The rician distribution symbolizes the environment where Line of Sight exists. The rician with QAM modulation provides identically distributed channels and uses space diversity for the enhancement of coverage and capacity.

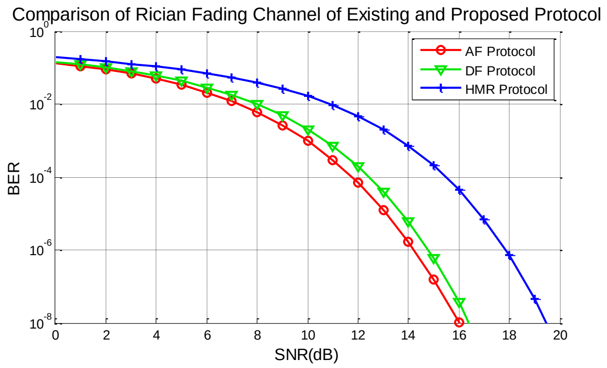

Figure 11. Comparison of rician fading channel with existing protocol and proposed HMR protocol.

The Amplify and Forward protocol with Rician fading channel reaches to 16dB. In the decode and forward protocol, rician fading environment using hardware impairment with delay-tolerant transmission modes proposes an SNR as 17 dB. The proposed HMR protocol with the Rician reflection, signals its performance, which ranges SNR from 15 dB to 20 dB as it performs on strong signals.

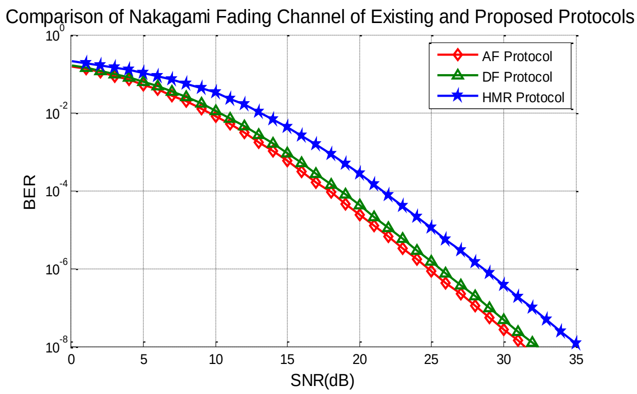

Figure 12. Comparison of nakagami fading channel with existing protocols and proposed HMR protocol.

Figure 12 shows a comparison of the Nakagami channel with different protocols. Nakagami fading is equally applicable to any fading environment which could be either scattered or a Line of Sight environment. In Amplify and Forward Protocol, QAM modulation provides the SNR up to 32 dB. In the decode and Forward protocol, it shows SNR with QAM it reaches 33 dB. In the proposed HMR protocol with QAM modulation and supporting both half and full duplex, it reaches nearly to 35 dB. Nakagami channel has a strong component from both scattering and diffuse environments and so it adapts all environments and supports SNR up to 35 dB with the BER of 10^{-8}.

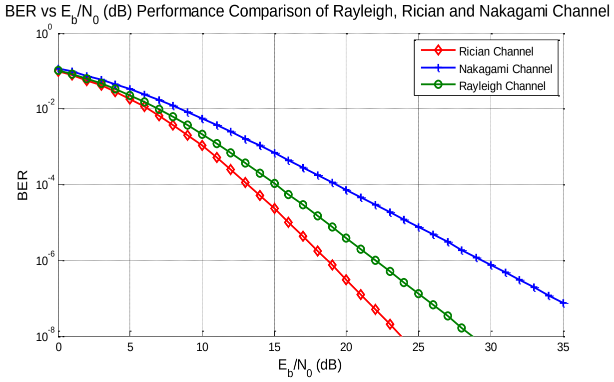

Figure 13. BER vs EB/No performance comparison of rayleigh, rician and nakagami channel.

Figure 13 provides an overall comparison between Rayleigh, Ricain and Nakagami Channels. The BER vs SNR values denote the average data rates achieved with the corresponding signal to noise ratio. Rayleigh provides a scattering supporting signals upto 25 to 30 dB while the rician fading channel supports the line of sight diffusion and has a SNR of 20 to 25 dB and finally Nakagami provides the sum of strong components between scattering and the line of sight environment. The Nakagami distribution shows a better performance with SNR 35 dB with an error rate less than other channels.

6. Conclusions

In this paper, we proposed a new Heterogeneous Multiplex Relay Protocol in MIMO that achieves maximum spectrum efficiency between Half Duplex and Full Duplex. The proposed protocol which retains half Duplex and Full Duplex with time slots properly allocates the time to ensure no relay loss. The DMT analysis of the HMR protocol with multiple antenna scenarios shows the achievement of high multiplexing gain and improvement of throughput. A performance comparison of BER vs SNR between Rayleigh, Rician and Nakagami channels is compared in which Nakagami achieves better performance. Simulation results show HMR performance by comparing BER vs SNR and Ergodic capacity between Half Duplex and Full Duplex. HMR protocol provides 80% capacity performance due to its allotted channels between Half and Full Duplex. Each fading channel has its own characteristics and achievement of SNR values helps Nakagami and Rayleigh to prove a good diversity gain. Therefore HMR protocol provides a good relay network that achieves maximum capacity.

References

[1] Afifi W., Mohammad J., Rahman A., Krunz M., and MacKenzie A., “Full-duplex or Half-

Duplex: A Bayesian Game for Wireless Networks with Heterogeneous Self-interference Cancellation Capabilities," *IEEE Transactions on Mobile Computing*, vol. 17, no. 5, pp. 1076-1089, 2018.

[2] Akif F., Malik A., Qureshi I., and Abassi A., "Transmit and Receive Antenna Selection Based Resource Allocation for Self-Backhaul 5G Massive MIMO HetNets" *The International Arab Journal of Information Technology*, vol. 18, no. 6, pp.755-766, 2021.

[3] Chae S. and Lee K., "Cooperative Relaying for Multi-User MIMO Wireless Backhaul Networks," *IEEE Transactions on Vehicular Technology*, vol. 70, no. 3, pp. 2794-2806, 2021.

[4] Chen H. and Zhao F., "A Hybrid Half-Duplex/Full-Duplex Transmission Scheme in Relay-Aided Cellular Networks," *EURASIP Journal on Wireless Communications and Networking*, vol. 1, pp.1-10, 2017.

[5] Fang Z., Ni W., Liang F., Shao P., and Wu Y., "Massive MIMO for Full-Duplex Cellular Two-Way Relay Network: A Spectral Efficiency Study," *IEEE ACCESS*, vol. 5, pp. 23288-23298, 2017.

[6] Gharan S., Bayesteh A., and Khandani A., "Diversity-Multiplexing Tradeoff in Multi-Antenna Multi-Relay Networks: Improvements and Some Optimality Results," *IEEE Transactions on Information Theory*, vol. 59, no. 6, pp. 3892-3914, 2013.

[7] Hong B. and Choi W., "Overcoming Half-Duplex Loss in Multi-Relay Networks: Multiple Relay Coded Cooperation for Optimal DMT," *in IEEE Transactions on Communications*, vol. 63, no. 1, pp. 66-78, 2015.

[8] Hong S., Brand J., Choi J., Jain M., Mehlman J., Katti S., and Levis P., "Applications of Self-Interference Cancellation in 5G and Beyond," *IEEE Communication Magazine*, vol. 52, no. 2, pp. 114-121, 2014.

[9] Hellings C., Gest P., Wiegart T., and Utschick W., Maximizing the Partial Decode-and-Forward Rate in the Gaussian MIMO Relay Channel, *IEEE Transactions on Signal Processing*, vol. 69, pp. 1548-1562.

[10] Hu R., Hu C., Jiang J., Xie X., and Song L., "Full-Duplex Mode in Amplify-and-Forward Relay Channels: Outage Probability and Ergodic Capacity," *International Journal of Antennas and Propagation*, pp.1-8, 2014.

[11] Jia X., Deng P., Yang L., and Zhu H., "Spectrum and Energy Efficiencies for Multiuser Pairs Massive MIMO Systems with Full-Duplex Amplify-and-Forward Relay," *IEEE Access*, vol. 3, pp. 1907-1918, 2015.

[12] Ju H., Oh E., and Hong D., "Improving Efficiency of Resource Usage in Two-Hop Full Duplex Relay Systems Based on Resource Sharing and Interference Cancellation," *IEEE Transactions on Wireless Communications*, vol. 8, no. 8, pp. 3933-3938, 2009.

[13] Karmakar S. and Varanasim M., "The Diversity-Multiplexing Tradeoff of The MIMO Half-Duplex Relay Channel," *IEEE Transactions on Information Theory*, vol. 58, no. 12, pp. 7168-7187, 2012.

[14] Kontik M. and Ergen S., "Scheduling in Successive Interference Cancellation Based Wireless Ad Hoc Networks," in *IEEE Communications Letters*, vol. 19, no. 9, pp. 1524-1527, 2015.

[15] Lee B., Lee N., Ha N., and Shin W., "On the Degrees-of-Freedom for Relay-Aided MIMO Interference Channels With Partial and Delayed CSI," *in IEEE Wireless Communications Letters*, vol. 10, no. 2, pp. 306-310, 2021.

[16] Lee J. and Quek T., "Hybrid Full-/Half-Duplex System Analysis in Heterogeneous Wireless Networks," *IEEE Transactions on Wireless Communications*, vol. 14, no. 5, pp. 2883-2895, 2015.

[17] Li C., Wang Y., Xiang W., and Yang D., "Outage Probability Analysis of Coded Cooperation with Multiple Relays," *in Proceedings of IEEE Vehicular Technology Conference*, San Francisco, pp.1-5, 2011.

[18] Li Y., Wang T., Zhao Z., Peng M., Wang W., "Relay Mode Selection And Power Allocation for Hybrid One-Way/Two-Way Half-Duplex/Full-Duplex Relaying," *IEEE Communications Letters*, vol. 19, no. 7, pp. 1217-1220, 2015.

[19] Loa K., Wu C., and Sheu S., Yuan Y., Chion M., Huo D., Xu L., "IMT-advanced Relay Standards [WiMAX/LTE update]," *IEEE Communications Magazine*, vol. 48, no. 8, pp. 40-48, 2010.

[20] Luo C., Gong Y., and Zheng F., "Full Interference Cancellation for Two-Path Relay Cooperative Networks," *IEEE Transactions on Vehicular Technology*, vol. 60, no.1, pp. 343-347, 2011.

[21] Lv Y., He Z., and Rong Y., "Two-Way AF MIMO Multi-Relay System Design Using MMSE-DFE Techniques," *IEEE Transactions on Wireless Communications*, vol. 20, no. 1, pp. 389-405, 2021.

[22] Nordio A. and Chiasserini C., "MIMO Full-Duplex Networks with Limited Knowledge of the Relay State," *IEEE Transactions on Wireless Communications*, vol. 20, no. 4, pp. 2516-2529, 2021.

[23] Rankov B. and Wittneben A., "Spectral Efficient Protocols for Half-Duplex Fading Relay Channels," *IEEE Journal on Selected Areas in Communications*, vol. 25, no. 2, pp. 379-389, 2007.

[24] Riihonen T., Werner S., and Wichman R., "Mitigation of Loopback Self-Interference in Full-Duplex MIMO Relays," *IEEE Transactions on Signal Processing*, vol. 59, no.12, pp. 5983-5993, 2011.

[25] Shen H., He Z., Xu W., Gong S., and Zhao C., "Is Full-Duplex Relaying More Energy Efficient Than Half-Duplex Relaying?," *IEEE Wireless Communications Letters*, vol. 8, no. 3, pp. 841-844, 2019.

[26] Singh Y. and Chopra M., "Analysis of Rayleigh, Rician, and Nakagami-m Fading Channel using Matlab Simulation," *International Journal of Engineering Technology and Computer Research (IJETCR)*, vol. 3, no. 4, pp. 105-109, 2015.

[27] Vaezi M., Inaltekin H., Shin W., Vincent P., and Zhang J., "Social-Aware User Cooperation in Full-Duplex and Half- Duplex Multi-Antenna Systems," *IEEE Transactions on Communications*, vol. 66, no.8, pp. 3309-3321, 2018.

[28] Wang D., Wang M., Zhu P., Li J., Wang J., and You X., "Performance of Network-Assisted Full-Duplex for Cell-Free Massive MIMO," *IEEE Transactions on Communications*, vol. 68, no. 3, pp. 1464-1478,2020.

[29] Yun J., "Intra and Inter-Cell Resource Management in Full-Duplex Heterogeneous Cellular Networks," *IEEE Transaction on Mobile Computing*, vol. 15, no. 2, pp. 392-405, 2016.

[30] Zhang Z., Chai X., Long K., Vasilakos A., and Hanzo L., "Full-Duplex Techniques for 5G Networks: Self-Interference Cancellation, Protocol Design, and Relay Selection," *IEEE Communications Magazine*, vol. 53, no. 5, pp. 128-137, 2015.

Daphney Joann received B.E in Computer Science and Engineering from C.S.I Institute of Engineering and Technology, Anna University, Tamilnadu in the year April 2006. Post graduate degree in M.E Computer Science and Engineering from Adhiyamaan College of Engineering, Anna University, Tamilnadu in the year June 2008. She started her carrier in the year 2008 as Lecturer, Currently working as an Assistant Professor in the Department of CSE in Global Institute of Engineering and Technology, Vellore-TamilNadu. She is currently pursuing her Ph.D. in Anna University. Her research interests are in the areas of Web Technology, Wireless Networks and Network Security. She is the life member of ISTE, New Delhi, India and member in IAENG.

Vayanaperumal Rajamani received B.E in Electronics and Communication Engineering from national Engineering College, Madurai Kamaraj University, Madurai, Tamilnadu, India, in the year 1990, Post graduate degree in M.E. Applied Electronics from Govt. College of Technology, Bharathiyar University, Coimbatore, Tamilnadu, India in the year 1995 and Ph.D. degree from the Institute of Technology, Banaras Hindu University (now IIT-BHU), Varanasi, Uttar Pradesh, India in 1999 with a specialization in semiconductor device modeling for optical Communication receivers. He started his academic carrier in the year 1991 as Lecturer. Currently, he is working as a Principal and professor in the department of Electronics and Communication Engineering in the Veltech Multitech Dr. Rangarajan Dr. Sakunthala Engineering College, Avadi, Chennai, Tamilnadu, India. He has published more than 150 papers in the referred national and international journals and conference proceedings. He is the life member of ISTE, New Delhi, India and member in IAENG.