PERFORMANCE EVALUATION OF A MULTI-HOP FULL DUPLEX AMPLIFY-FORWARD & DECODE-FORWARD RELAYING SYSTEM

R.Umamaheswari[1], W.D.Priyadharshini[2], S.Sindhu[3], Vijayalakshmi.k[4]
[1,2,3]UG Scholar, [4]Assistant professor,
Department of ECE, SKP Engineering College, Tiruvannamalai.

ABSTRACT

Multi-hop communications considered to be a useful approach for improving the coverage area with reduced transmit power. Multi-hop relaying has recently attracted significant attention in both academia and industry. Relaying enable efficient utilization of communication resources, by allowing nodes or terminals in a communication network to collaborate with each other in information transmission. This type of communication is used to improve the capacity and diversity. Most common relaying strategies are decode-and-forward (DF) and amplify-and-forward (AF). Full duplex is preferred to overcome the spectral efficiency loss in half duplex. This paper proposes GFDM scheme and AF-DF protocol to find the following parameters such as SNR (Signal to noise ratio) Vs BER (Bit Error Ratio), Outage probability, spectral efficiency.

Keyword: Cooperative systems, multi-hop communication, full duplex, amplify and forward, decode and forward, GFDM.

1.INTRODUCTION:

Multi-hop wireless relaying, in which a source communicates with a destination via multiple intermediate relays, is an important ingredient in ad hoc wireless networks. Compared with direct transmission, multi-hop wireless relaying can save transmitter power, improve the transmission reliability and extend the network coverage. Traditionally, multi-hop wireless relaying operates in a half-duplex mode, where each relay receives and retransmits the signals over orthogonal channels (e.g., time, frequency). Although multi-hop half-duplex relaying (HDR) can simplify the system design and implementation, it incurs significant loss of spectrum efficiency. Recently, encouraged by the advance in antenna design and interference cancellation algorithms, full-duplex relaying (FDR), where the relay node receives and transmits at the same time and over the same frequency band, has been regarded as a promising way to overcome the spectrum efficiency loss of HDR and therefore has drawn significant research interests.

Multi-hop based cooperative communication system is useful for increasing the transmission range (coverage) of a wireless communication system. The max-min selection criterion for the best *path* selection in a *multi*-hop DF cooperative system in Rayleigh fading. The average BER of the considered selection scheme is derived under Rayleigh fading in terms of power series. By using the derived BER expression, the coding gain and diversity order of the path selection scheme are obtained.

Amplify and forward (AF) and decode and forward (DF) relaying are usually used in cooperative systems in order to benefit from spatial diversity without requiring multiple antennas at the transmitter. In the AF relaying protocol, each relay amplifies the received signal from the source and forwards it to the destination. In the DF relaying protocol, only the relays that have decoded correctly regenerate and transmit the original signal to the destination. AF relaying is less complex than DF relaying since decoding is not performed at the relays. AF and DF relaying offer the same diversity order equal to the number of transmitters (the relays and the source). The outage probability of millimetre wave dual-hop systems has been derived in. The optimum placement of radio relays in dual-hop networks has been investigated. Derived the outage performance of DF selection cooperation with maximum ratio combining at the destination in Nakagami-m fading channels. In order to improve the system spectral efficiency, opportunistic AF relaying has been proposed in. In opportunistic AF relaying, only the relay offering the highest instantaneous SNR of the relaying link (source–relay–destination) is activated. In opportunistic DF relaying, the selected relay offers the highest SNR of the relay to destination link among the relays that have decoded correctly. It has been shown that opportunistic AF and DF relaying achieve a full spatial diversity.

The relay first tries to decode the received signal If the decoding succeeds, it transmits the decoded signal as in the DF protocol. If the decoding fails, the relay simply amplifies the received signal. We provide closed form expressions of the SNR outage probability, a tight lower bound of the BEP, and the asymptotic BEP of all participating and opportunistic hybrid AF–DF relaying [2].

Relays or nodes in the network listen to the source, during transmission and re-transmit the received signal to the destination. Relay based cooperative system almost acts like a virtual multiple-input multiple-output (VMIMO) system which overcomes the drawbacks of the conventional MIMO systems [3]. Recently, in many applications such as standardized 3GPP LTE, Wireless LAN, and Sensor networks etc. cooperative communication is used to overcome the problems or limitations of coverage, interference and capacity.

Cellular systems of the fourth generation (4G) have been optimized to provide high data rates and reliable coverage to mobile users. Cellular systems of the next generation will face more diverse application requirements: the demand for higher data rates exceeds 4G capabilities; battery-driven communication sensors need ultra-low power consumption; control applications require very short response times[10]. We envision a unified physical layer waveform, referred to as Generalized Frequency Division Multiplexing (GFDM), to address these requirements. Here we analyze main characteristics of the proposed waveform and highlight relevant features. After introducing the principles of GFDM, this contributes to the following areas: (i)spectral efficiency, (ii) analytical analysis of symbol error performance (v) bit error rate performance. In summary, the flexible nature of GFDM makes this waveform a suitable candidate for future 5G networks.

The rest of the paper is organized as follows. Literature survey regarding multi-hop FDR with AF-DF protocols is presented in section 2. The system model for existing and proposed system is explained in section 3(i) and 3(ii). Applications of GFDM is discussed in section 4. Section 5 describes the simulation results. Finally conclusions in section 6.

2. LITERATURE OVERVIEW:

The performance of multihop DF FDR systems, whose main characteristic is that the relay nodes suffer from both self-interference and interrelay interference. Two cases were considered for the interference at Rm. In case I we considered all the signals at Rm except the desired signal as interference while in case II we subtracted the interference from Rm+1 to RN. We derived the expression for the outage probability, symbol error probability and ergodic capacity, for each case respectively. Yet all the inference was investigated by the author in [1].Here proposed an all-participating hybrid amplify and forward (AF) and decode and forward(DF) relaying protocol in which relays close to the source amplify the received signal whereas the remaining relays transmit only if they have decoded correctly. The proposed protocol offers better performance than AF, APHF, and ADF relaying, and very close performance to DF relaying, while having a lower implementation complexity since close relays do not have to decode the received signal. In order to improve the system spectral efficiency, we have also proposed an opportunistic static hybrid AF and DF relaying protocol in which a single relay is activated among AF relays and the relays that have decoded correctly. The proposed opportunistic hybrid AF and DF relaying protocol offers better performance than opportunistic AF and THS relaying, and close performance to opportunistic DF relaying. The SNR outage probability, and the lower and asymptotic BEP of both all-participating and opportunistic hybrid AF and DF relaying were derived. Yet all the inference was investigated by the author in [2]. The closed form expressions for outage probability, outage capacity, exact and approximate SER for non-coherent and coherent detection under different modulation schemes are derived and analyzed. In addition, the proposed system for different channel parameters by assuming different values for are analyzed. Finally, the analytical results are validated through Monte-Carlo simulations. The closed form expressions are arrived by considering the link between S-R and R-D faded. Since, the analyzed system topology is symmetrical, same expressions hold good, even on interchanging the link between S-R and R-D. Yet all the inference was investigated by the author in [3]. Here considered various cooperative relaying schemes and compared their performance with direct transmission, transmit diversity techniques, and conventional store-and-forward relaying. The common idea of cooperative schemes is that the destination combines the signals transmitted from source and relay, thereby exploiting the diversity of the relay channel and the broadcast nature of wireless propagation. Yet all the inference was investigated by the author in [5]. Cooperative transmission systems with the DF relay is a useful technique but the performance is usually restricted by the link quality of the BS-RS link which absorbs multiuser diversity gain of the RS-user link. Here the two design methods for such the DF based cooperative transmission system by employing multiple receive antennas at the RS to improve the poor BS-RS link. Our proposed schemes can be considered as the network utility function optimization method with the SER constraint. We transformed the original non-convex optimization problem into convex optimization problem by employing the alternative Q-function approximation and primal problem decomposition. Throughout simulations, proposed schemes were shown to enhance the performance of the DF based cooperative transmission scheme significantly. Yet all the inference was investigated by the author in [6]. The performance of multihop FDR was investigated. In particular, expressions for the overall outage probability were derived, given the channel gains of the inter-relay links, as well as the echo-interference of full-duplex relays. In this respect, the optimal number of relays was examined, which for a given distance between the source and destination terminals minimizes the outage probability. When compared with multihop HDR, which serves here as a benchmark, our results showed that there exist cases where multihop FDR leads to a lower outage probability than HDR. The relative performance of FDR and HDR depends on the relative strength of the channels associated with the desired signal in multihop FDR, and the channels bearing the interference signal. Yet all the inference was investigated by the author in [7].With a full range of power consumption sources considered, we have compared the EE gain regions of FD (PSAC), FD(PS) and HD relaying modes in dual-hop OFDM systems at 60 GHz. It is found that FD (PS) can outperform HD in terms of EE, while FD (PSAC) is even more energy efficient than FD(PS) if the transmission power is higher than a threshold in the feasible range. It is proved that EE is strictly quasi-concave or mono-increasing with respect to the transmission power under a maximum transmission power constraint. A low-complexity algorithm is proposed to optimize EE by calculating the gradient of EE with respect to the transmission power. Based on the EE optimization and opportunistic relaying mode selection, the average optimal EE of FD relaying is up to 1.4 Gb/Joule higher than that of HD relaying with given transmission power. It is shown that with the same transmission power, the throughput achieved by FD relaying is 1.3_2 times of that of HD relaying, when the self-interference cancellation amount varies from 40_60 dB (40 dB can be achieved by PS only with relative ease). It is also shown that with low drain efficiency or high static circuit power, FD (PSAC) is preferable over FD (PS) in terms of EE. This work is general and is applicable to a short-range wireless relay system at any frequency band. Yet all the inference was investigated by the author in [8]. Here a framework to analyze the performance of the AF relay schemes in a general class of Gaussian relay networks. We show that compared to the existing methods, the proposed framework not only allows us to characterize the performance of general AF relay networks in a unified manner but it also provides tighter lower bounds. Here AF schemes can be capacity achieving for a large class of wireless relay networks. Yet all the inference was investigated by the author in [9].

3.SYSTEM MODEL:

3(a).EXISTING MODEL:

I. Multi-Hop Full Duplex:

The multi-hop FDR system is depicted in Fig.1. We assume that S and D are equipped with a single antenna, and Rm is equipped with two antennas (one for receiving and one for transmitting). All the antennas are assumed to be omni-directional.

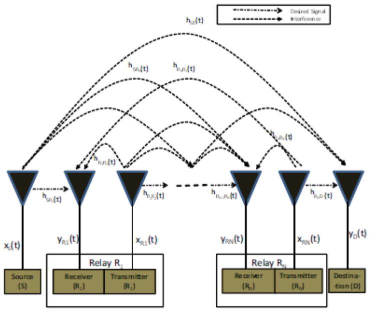

Fig.1 Multi-Hop FDR

The FDR system considered in the Fig.1 employs DF relays and consists of a source node, *S*, *N* relay nodes, *R*1 to *RN*, and a destination node, *D*. The transmission from *S* to *D* is organized as follows. At a given time instance, *S* transmits the information-bearing signal to *R*1. *R*1 decodes the received signal, and transmits a delayed version of to *R*2. The same process continues from *R*1 to *RN*, so that *D* receives the signal incident from *RN*. For notational convenience, in the sequel we will denote *S* and *D* as *R*0 and *RN*+1, respectively. Given that in an FDR system reception and transmission occur at the same time, in addition to the actual information sent from also receives a self-interference component. This type of interference is known as “echo interference” and its magnitude depends on the isolation between the transmit and receive antenna. Moreover, the relay suffers from interference caused by the other relays. The magnitude of the interrelay interference depends on several factors such as the distances between the relays, the level of antenna isolation, and the directivity of the antennas. The small-scale fading in the link between nodes *Ri* and *Rj* is assumed to follow the Rayleigh distribution.

II. Amplify and Forward & Decode and Forward:

In Fig.2 shows the wireless communication system with a source S, a destination D, N AF relays $\{R_i\}N_i=1$ and K DF relays $\{R_i\}N + K_i=N+1$. The AF relaying set is composed by the relays that are close to the source and the DF relaying set contains the remaining relays. In the first phase of the transmission, S broadcasts a symbol x to D and all the relays. The K DF relays estimate the transmitted symbol. In the second phase, and in all participating relaying, the N AF relays and the relays in the DF set that have decoded correctly transmit using orthogonal channels (in time, frequency, or spreading codes). In opportunistic relaying, only the relay offering the highest instantaneous SNR is activated. This relay is chosen among the N AF relays and the relays that have decoded correctly. The destination combines all received signals using a maximum ratio combining (MRC) strategy. Perfect channel estimation is assumed at the different nodes. Here AF-DF is used only in the hybrid system it does not deals with full duplex relay.

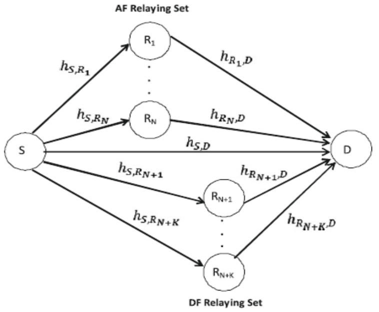

Fig.2 AF and DF Protocol

Amplify-and-forward (AF) relays retransmit the signal without decoding while *decode–and-forward* (DF) relays decode the received signal, encode the signal again, and transmit. Furthermore, relays can operate in *full-duplex* mode. The latter operation requires a spatial separation between transmit and receive antennas to reduce loop-back interference from the transmit antennas to the receive antennas. From signal processing point of view AF relays offer interesting challenges, especially when the AF relay operates in full-duplex mode the effect of interference must be incorporated into analytical performance studies. Spectral shaping of the transmitted signal requires advanced techniques for digital filter design. The research benchmarks AF relays with DF relays taking into account the aforementioned issues. We cooperate with High-frequency and microwave engineering group to gain understanding of the actual propagation environment and loop-back interference with full-duplex relays.

3(b).PROPOSED SYSTEM:

I. Multi-hop routing:

Multi-hop routing is a type of communication in radio networks in which network coverage area is larger than radio range of single nodes. Therefore, to reach some destination a node can use other nodes as relays. Since the transceiver is the major source of power consumption in a radio node and long distance transmission requires high power, in some cases multi-hop routing can be more energy efficient than single-hop routing.

In Fig.3, Relays that receive and retransmit the signals between base stations and mobiles can be used to increase throughput extend coverage of cellular networks. Infrastructure relays do not need wired connection to network thereby offering savings in operators' backhaul costs. Mobile relays can be used to build local area networks between mobile users under the umbrella of the wide area cellular networks. The capacity of the setup below, where the destination is able to hear both source and relay remains unsolved in general case. Several upper and lower bounds have been presented for the general case, and capacity has been solved in relay channel.

In recent years cooperative relay techniques have received a lot of interest. A typical link-level setup is depicted in Fig.3, in which a group of relays help the communication between source and destination. The relays can then use a space-time code or the most reliable relay can be chosen to transmit the signal while the other relays suspend transmission.

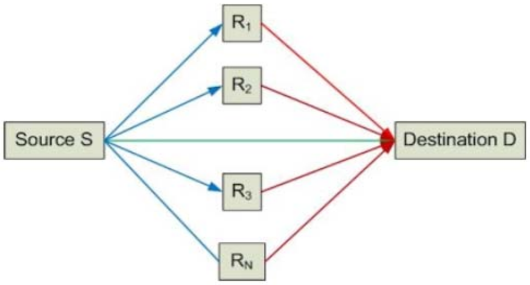

Fig.3 Multi-hop routing

Practical issues of cooperative schemes like signalling between relays and different propagation delays due to different locations of relays are often overlooked. If the difference in time of arrival between the direct path from source to destination and the paths source-relay-destination is constrained then relays must locate inside the ellipsoid as depicted below. Thus, in practice, such a cooperative system should be a narrow band one, or guard interval between transmitted symbols should be used to avoid inter-symbol interference due to relays. Relays are re-ordered according to the descending order of the Signal-to-Noise Ratio (SNR) between *S* and *Q*, i.e., SNRS Q1 >>SNRSQR, where SNRS Or denotes the *r*-th largest SNR between *S* and *Q*.

The multi-hop FDR system, we denote the received signal-to-interference-plus-noise ratio (SINR) at R_m by γ_m, m = 1, 2, · · ·N + 1, which can be written as,

$$\Gamma_{S,R_j,D} = \frac{\Gamma_{S,R_j}\,\Gamma_{R_j,D}}{1+\Gamma_{S,R_j}+\Gamma_{R_j,D}}$$

Since the interference channel also follows Rayleigh distribution, the PDF of i, γ_m is

$$f_{r_{i,m}}(x) = \frac{1}{\gamma_{i,m}}\exp\left(\frac{-x}{\gamma_{i,m}}\right)$$

II.GFDM SCHEME:

GFDM is a promising solution for the 5G PHY layer because its flexibility can address the different requirements. For real-time applications, the signal length must be reduced to fulfill certain latency requirements . Because GFDM is confined in a block structure of MK samples, where K subcarriers carry M sub symbols each, it is possible to design the time-frequency structure to match the time constraints of low latency applications.

Different filter impulse responses can be used to filter the subcarriers and this choice affects the OOB emissions and the SER performance. As will be shown, GFDM allows engineering signals in their frequency and time characteristics. Thus, the scheme retains all main benefits of OFDM at the cost of some additional implementation complexity.

III. BLOCK DIAGRAM:

In Fig. 4 a GFDM block explains about the working of transmission and reception of data. This block consists of a input as binary source, encoder and a decoder, mapper and a demapper, equalizer, cyclic prefix. Encoder and Decoder is used for encoding and decoding process at the transmitter and receiver. Modulation and demodulation is carried out by the modulator and demodulator. Cyclic prefix is used to arrange the LSB and MSB. Equalizer is used to remove the errors.

A data source provides the binary data vector ~b, which is encoded to obtain ~bc. A mapper, e.g. QAM, maps the encoded bits to symbols from a 2μ-valued complex constellation where μ is the modulation order. The resulting vector ~d denotes a data block that contains N elements, which can be decomposed into K subcarriers with M sub symbol .The total number of symbols follows as N = KM. Therein, the individual elements dk, m correspond to the data transmitted on the kth subcarrier and in the math sub symbol of the block.

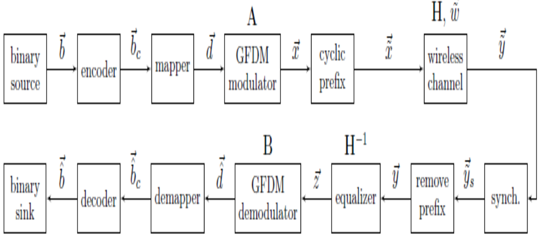

Fig.4 Block diagram of GFDM

4. APPLICATION REQUIREMENTS

New scenarios are being foreseen for 5G networks with requirements that cannot be addressed only with throughput increment. In this section, we present a short description of the most prominent application scenarios and propose sets of GFDM parameters to address the specific requirements. The application scenarios considered in this section are:

1) *Bitpipe communication*: Currently broadcasting services are experiencing a media shift, where television and radio content are being broadcasted through the Internet. People demand their favorite shows anywhere, and smart phones and tablets are commonly used to access the content. With screen resolution on mobile devices beyond high definition, videos and 3D contents will require several tens of Mbps to achieve a good Quality of Experience (Q_oE). Therefore, next generation networks must rely on advanced digital communication techniques, such as MIMO for diversity and multiplexing, highly efficient channel coding, small cell coverage with inter-cell interference management and efficient dynamic spectrum allocation for waveform engineering, low out-of-band emission is a crucial requirement to allow fragmented and opportunistic spectrum allocation with cognitive radios(CR).

2) *Machine Type Communication (MTC)*: Machines, devices and even objects are becoming intelligent and equipped with sensors, which increasingly allow them to operate autonomously and to communicate without human interaction. While today's MTC is mainly based on short-range wireless technologies, such as Bluetooth and Zigbee, it is expected that cellular systems providing wide area coverage will gain a significant market share. There are two major markets foreseen for MTC. The first considers machines as complete systems with only an interface that allows for controlling it over the Internet. The other considers machines as sensors and actuators where all the control system is to be moved to a cloud infrastructure. Although the first approach can be implemented shortly, the second one is regarded as the most interesting because the connected sensors will provide accurate information for Big Data processing , allowing for data analytics to uncover patterns and correlations, and offer new or better services.

3) *Tactile Internet*: This new application scenario is first envisioned, where the 5G network is used for real-time control applications with at most 1ms round-trip latency requirements. The low latency requirement is determined by the typical interaction latency for tactile steering and control of real and virtual objects. In fact, most of today's mobile devices use a touch screen as input interface and future devices will integrate various interfaces for haptic, visual and auditory input and feedback. These new interface devices are also going to be used to interact with the online environment for virtual and augmented reality, health monitoring, smart house controlling, gaming and many different applications.

4) *WRAN*: Despite the fact that reasonable Internet access is available in cities, sparsely populated areas suffer from low data rate and unreliable solutions. Wired technologies have limited coverage and require large investments. Today's wireless networks have relatively small cell size and operate in licensed frequencies, which makes them economical unfeasible in low populated areas. CR technology addresses this problem by dynamically and opportunistically accessing vacant UHF TV bands.

5. RESULTS AND DISSCUSSIONS:

The evaluation of SNR Vs BER of AF, DF and AF-DF for BPSK, QPSK and GFDM; Outage probability of AF-DF; Spectral efficiency of full duplex and half duplex were done with the help of MATLAB software.

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that have been altered due to noise, interference, distortion or bit synchronization errors. The bit error rate (BER) is the number of bit errors per unit time. The bit error ratio (also BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. Bit error ratio is a unitless performance measure, often expressed as a percentage.

In analog and digital communications, signal-to-noise ratio, often written S/N or SNR, is a measure of signal strength relative to background noise. The ratio is usually measured in decibels (dB) using a signal-to-noise ratio formula. If the incoming signal strength in micro volts is Vs, and the noise level, also in microvolts, is Vn, then the signal-to-noise ratio, S/N, in decibels is given by the formula: S/N = 20 log10(Vs/Vn).

The following graph explain the performance of signal to noise ratio and bit error rate in various protocols such as Amplify and forward , Decode and forward, Amlpify and forward & Decode and forward.The following graph explain the performace of signal to noise ratio and bit error rate in various protocols such as Amplify and forward , Decode and forward, Amlpify and forward & Decode and forward.

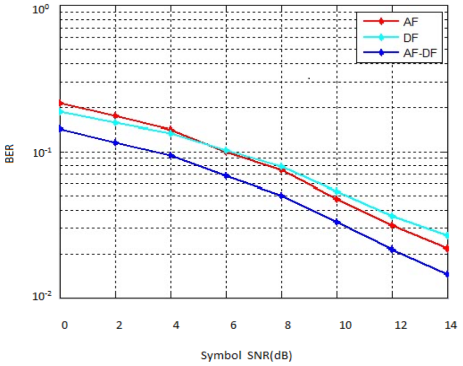

Fig.5 SNR Vs BER for multi-hop FDR for N=2.BPSK is used.

In Fig.5 BPSK modulation, when SNR is at 8dB the BER for AF falls at 0.07, DF at 0.02 and AF-DF at 0.05. For AF-DF, when BER is 10^$^{-1}$, SNR increased to 2 dB.

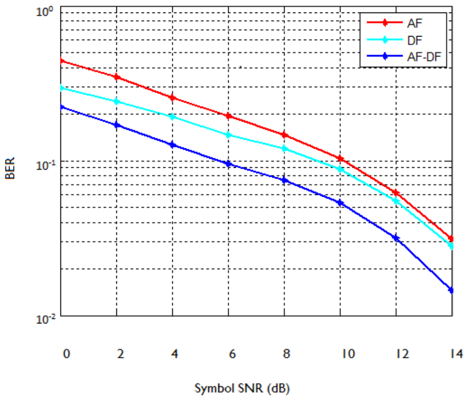

Fig 6. SNR Vs BER for multi-hop FDR for N=2.QPSK is used.

In Fig.6 for QPSK modulation, when SNR is at 8dB the BER for AF falls at 0.3, DF at 0.2 and AF-DF at 0.07. For AF-DF, when BER is 0.06, SNR increased to 10 dB.

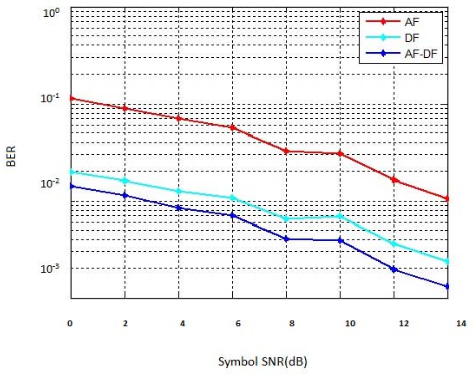

Fig.7 SNR Vs BER for multi-hop FDR for N=2.GFDM is used.

In Fig.7 For GFDM modulation, when SNR is at 8dB the BER for AF falls at 0.1, DF at 0.02 and AF-DF at 0.01. For AF-DF, when BER is 010^$^{-3}$, SNR increased to 12 dB.

The above graph clearly explains that the bit error rate decreases as the SNR increases. when SNR is 8dB, AF-DF provides a better BER in all three modulation schemes. Thus it is proved that the performance of AF-DF is good compared to others.

Outage probability of AF-DF is given based on the SNR value for number of relays such as N=1,2,3. The below graph Fig.8 explains the outage probability Vs SNR for three relays.

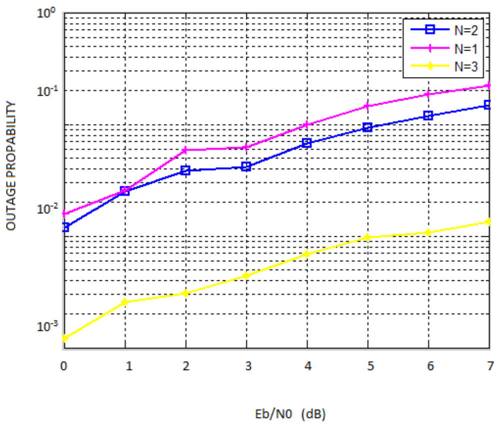

Fig.8 Outage probability of AF-DF for relays N=1,2,3.

Spectral efficiency refers to the information rate that can be transmitted over a given bandwidth in a specific communication system. Here, Spectral efficiency of half duplex and full duplex were compared.

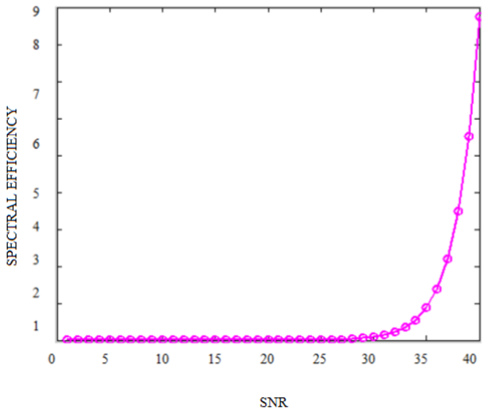

Fig.9 Spectral efficiency of half duplex

In Fig.9, when channel interval is at 30 the efficiency starts to increase. For half duplex, the information rate is increased between 2 to 9 for the channel interval from 30 to 40.

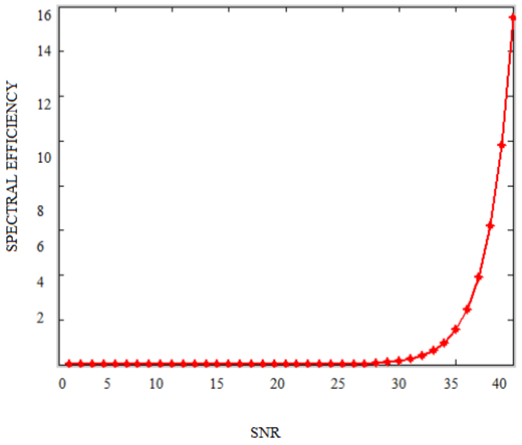

Fig.10 Spectral efficiency of full duplex

In Fig.10, when channel interval is at 30 the efficiency starts to increase. For full duplex, the information rate is increased between 2 to 16 for the channel interval from 30 to 40.

By comparing the spectral efficiency of half duplex and full duplex, Full duplex possess better efficiency than half duplex. Hence information rate is high in full duplex.

6. CONCLUSION:

In this paper, we investigated the performance of multi-hop AF-DF FDR systems which improves the spectral efficiency compared with HDR. Multi-hop routing is a type of communication in radio networks in which network coverage area is larger than radio range of single nodes. Therefore, to reach destination a node can use other nodes as relays.

Relaying system plays an major role in improving the communication. Generalized frequency division multiplexing (GFDM) is a new concept used in 5G cellular system which provides the better performance than OFDM. The scheme is based on the filtered multi-carrier approach which offers an increased flexibility. Hence GFDM offers a higher data rate, Ultra-low power consumption very short response time.

Output parameter such as BER Vs SNR was compared with various protocol such as AF , DF, AF-DF. when SNR is 8dB, AF-DF provides a better BER in all three modulation schemes. Thus it the analysed that the performance of AF-DF is good compared to others. Outage probability of AF-DF for N=1,2,3 are determined. Spectral efficiency of full duplex and half duplex were compared which shows full duplex provides higher data rate.

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