A DISSERTATION

ON

PERFORMANCE ANALYSIS OF SWIPT NOMA

Submitted In Partial Fulfilment of the Requirement for the Award of the Degree in

M.Tech

In

ELECTRONIC CIRCUITS AND SYSTEMS

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DECLARATION

This is to certify that I, Eksha Rastogi (Roll No.: 2101311002), have completed the M.Tech Dissertation work on topic **"Performance Analysis of SWIPT NOMA"** under the supervision of supervisor, Dr. Shailendra Kumar and co-supervisor,Ms. Archana Yadav for the partial fulfillment of the requirement for the Master of Technology in Electronic Circuits and Systems from Department of Electronics and Communication Engineering, Integral University, Lucknow. This is an original piece of work & I have not submitted it earlier elsewhere.

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CERTIFICATE

This is to certify that the dissertation titled **"Performance Analysis of SWIPT NOMA"** has been carried out by Eksha Rastogi (Roll No.: 2101311002), under my supervision and guidance in partial fulfillment of the requirements for the award of degree of "Master of Technology" in Electronic Circuits and Systems at department of Electronics and Communication Engineering, Integral University, Lucknow, India.

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ABSTRACT

Because of its intrinsic capacity to satisfy a wide range of requirements, NOMA is the most promising and appropriate wireless technology for next-generation communication systems. Minimum latency, high dependability, massive connection, and high data rate are the characteristics that distinguish 5G technology from present technology. Using the differential power domain idea, this technology allows access to several clients at the same time and within the same frequency range. The 5G plan was designed to reduce energy usage and enable viable green communication. The proposed study focuses on resource optimization for NOMA that is both energy efficient and cost effective. There are a variety of NOMA methods available, such as powe. HR Operations Manager is a web application that allows the applicants to upload the resumes and allows them to attend the interview once shortlisted. An email will be sent to them on short listing. If the candidate performs well in the interview he/she will be selected. The use of simultaneous wireless information and power transfer (SWIPT) to cooperative non-orthogonal spectrum sharing is investigated in this work (NOMA). A novel cooperative multiple-input single-output (MISO) SWIPT NOMA protocol is developed, in which a user with a good channel condition works as an energy-harvesting (EH) relay by using the power splitting (PS) method to assist a user with a bad channel state. We seek to maximize the data rate of the "strong user" while fulfilling the Application requirements of the "weak user" by optimizing the PS ratio and beamforming vectors together. The semidefinite relaxation (SDR) approach is used to reformulate the original issue and prove rank one optimality in order to solve the stated nonconvex problem. Then, for complexity reduction, an iterative method based on sequential convex approximation (SCA) is developed, which can at least reach its stationary point efficiently. The single-input single-output (SISO) situation is also investigated in light of prospective application scenarios, such as the Internet of Things (IoT). In terms of the PS ratio, the stated issue is shown to be strictly unimodal.

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INTRODUCTION

1.1 Non-Orthogonal Multiple Access (NOMA)

The radio access technique in next generation wireless communications. When compared to orthogonal multiple access technique, NOMA has enhanced spectrum efficiency, reduced latency with high reliability and effective connectivity. NOMA new proposal for encoding technology [1-5].

1.2 Different Types of NOMA

Based on the decoding techniques at the receiver side NOMA is broadly classified to two categories

1. Code division NOMA
2. Power domain NOMA

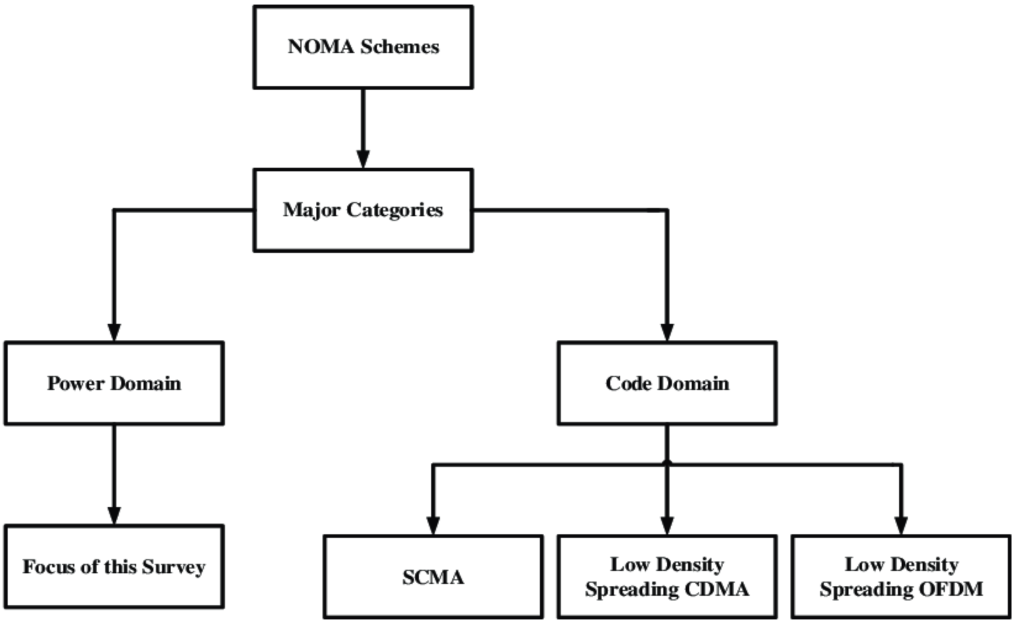

Fig 1.1 Classification of NOMA

The code division NOMA is again classified as low-density spreading NOMA and Sparse code multiple access. There are two special cases in NOMA, Pattern division multiple access and inter-leaver multiple access. In low density spreading multiple access and sparse code multiple access information of single user is spread over multiple subcarriers. The sparse features ensures that same subcarrier is not utilized by large number of users which keeps the complexity of the system manageable. Each user has unique codes to identify at the receiver side for proper decoding. In PD-NOMA multiplexing is performed in power domain. Signals from different users are superposed at the transmitter by allocating optimal power to each user and the subsequent signal, is then transferred using the same subcarriers. For example, the base station provides less power to near user and more power to far user [6-8]. To analyze NOMA schemes, we need a proper understanding on concepts like successive interference cancellation, cooperative communication network and super position coding.

1.3 Principle of NOMA

To understand the working principle of NOMA, consider a two user SISO-NOMA downlink system where the base station serves two users, one is near and other is a far user with powers P_1 and P_2(P_1<P_2) respectively. At the receiver, near user decodes the message considering far user data as noise and far user removes the near user message and decodes his message. In this way both users have full access to whole resource block in which full spectrum efficiency is achieved. Let us consider the data rates of near user and far user be R_1 and R_2 and h_1 and h_2 be the channels used by the near and far user by the base station [9-10].

The data rate of near user given by

$$R_1 = \log\left(\frac{1 + P_1|h_1|^2}{1 + P_2|h_2|^2}\right) \tag{1}$$

The data rate of far user given by

$$R_1 = \log(1 + P_2|h_2|^2) \tag{2}$$

1.4 Existing system

- **ORTHOGONAL MULTIPLE ACCESS TECHNIQUES**

1. **FDMA:**

   The process of dividing a single channel or bandwidth into multiple individual bands, each for use by a single user, is known as FDMA. Each band or channel is large enough to accommodate the signal spectra of the transmissions o be transmitted.

The data to be transmitted is modulated on each subcarrier, which is then linearly mixed together.

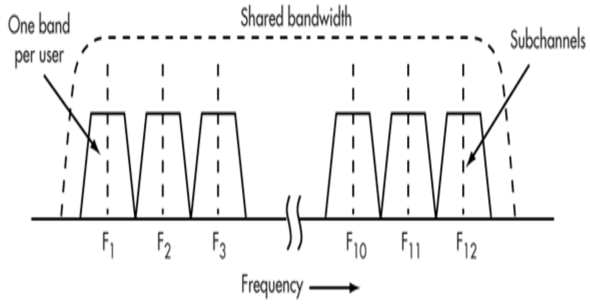

Fig 1.2 FDMA

The original analogue telephone system, which is used a hierarchy of frequency multiplex techniques to put multiple telephone calls on a single line, is one of the older FDMA systems. Analog voice signals ranging from 300 to 3400 Hz were used to modulate subcarriers in 12 channels ranging from 60 to 108 kHz. Modulator/mixers produced single side band (SSB) signals on both the upper and lower sidebands. FDMA was used in early satellite systems to share multiple voice, video, or data signals across individual 36-MHz bandwidth transponders in the 4-GHz to 6-GHz range. TDMA digital techniques are used in all of these applications today.

2. TDMA:

The time division multiple access (TDMA) technique divides a single channel or band into time slots. In the sequential serial data format, each time slot is used to transmit one byte or another digital segment of each signal. This technique is effective with slow voice data signals, but it is also useful with compressed video and other high-speed data.

A good example is the widely used T1 transmission system, which has been used in the telecom industry for many years. T1 lines are capable of carrying up to 24 individual voice telephone calls on a single line. Each voice signal typically spans 300 Hz to 3000 Hz and is digitalized at an 8-kHz rate, which is slightly higher than the minimum Nyquist rate of twice the highest-frequency component required to retain the signal.

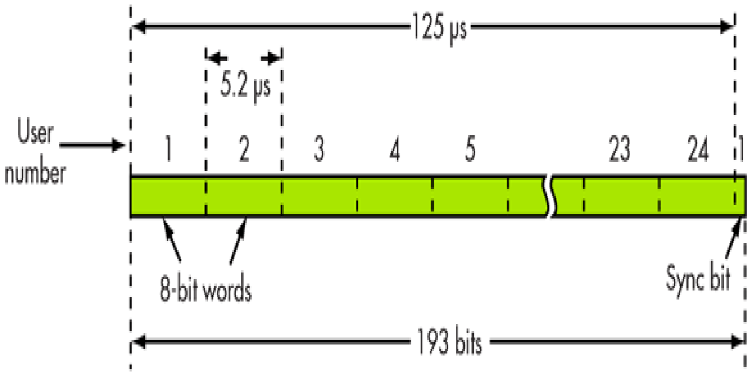

Fig 1.3 TDMA

The GSM (Global System for Mobile Communications) cellular phone system is TDMA-based at its core. It divides the ratio spectrum into 200-kHz bands and then employs time division techniques to combine eight voice calls into a single channel.

1.4.1 Disadvantages of Existing System

1) Multiple Access Techniques are sensitive to cross cell interference.
2) Frame synchronization is usually necessary to maintain orthogonality.
3) TDMA requires synchronization. If the time slot synchronization is lost, the channels may collide with each other.
4) For mobiles and, particularly for handsets, TDMA on the uplink demands high peak power in transmit mode that shortens battery life.
5) Network and spectrum planning are intensive.
6) Dropped calls are possible when users switch in and out of different cells.
7) Higher costs due to greater equipment sophistication.
8) Equalization is required, since transmission rates are generally very high as compared to FDMA channels.
9) Lower spectral efficiency
10) Limited number of users

11) Unfairness for users

1.5 Proposed System

1.5.1 Cooperative Communication network

We know that NOMA involves successive interference cancellation at receiver side, to understand in an effective way let us consider two users, user 1 who is near to the base station and user 2 who is far from the base station and carrying x_1 and x_2 data. In SIC the user 1 decodes user 2 data to retrieve his data, user1 act as a relay and retransmit the user 2 data. This process is known as cooperative communication network. Now that the user 1 has user 2 data he may as well relay the information to the user 2 to aid him. Since the user 2 has poor channel capacity with the transmitting base station, the retransmission of the data by the user1 will provide him diversity. that is, he will receive two different copies of the same message. One from the base station and other from user 1 who is acting like a relay. This is also known as cooperative relaying.

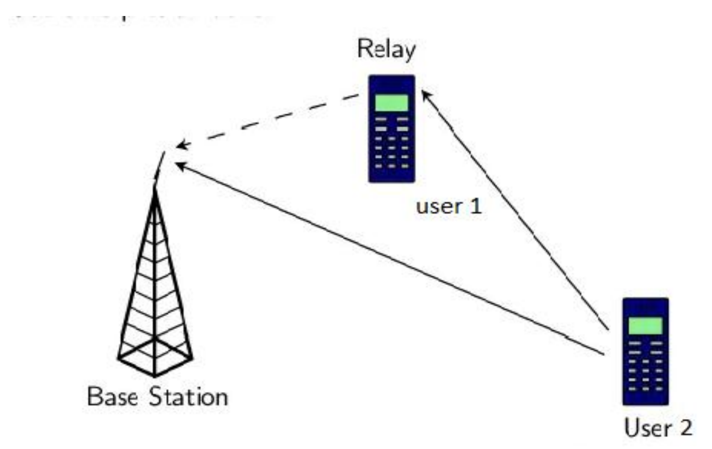

Fig 1.4 Cooperative Communication Network with Two Users

1.5.1.1 Advantages of Cooperative communication

1. Relaying cam virtually extend the coverage area of the base station this gives more channel capacity.
2. We established two links to transmit the same message, even if one of them is in outage chances of the other link is good.

3. We reduce the outage probability and hence diversity gain without the need of additional antennas

Let us design a cooperative Non-Orthogonal Multiple Access (NOMA) network. Consider a downlink transmission where there is a base station and two NOMA users. The two users are near user and far user. The user who is nearer to the base station is called near user and the user who is far to the base station is called far user. Near user has a stronger channel with the base station and a far user has weak channel with the base station. Information source transmits the information data to the users is called data transmission. NOMA is a diverse multiple user access scheme with respect to other established and existing multiple access schemes that is orthogonal multiple access. At the transmitter side, NOMA deliberately introduce intercell interference. Therefore, it can utilize non orthogonal transmission.

Transmission occurs in two time slots. They are

1) Direct Transmission Slot
2) Relaying Transmission Slot
3) Diversity combining

1) Direct Transmission Slot

In direct transmission slot, the base station uses non orthogonal multiple access to transmit data intended for the near user. Let us denote near user as x_n and far user as x_f. The near user does successive interface cancellation (SIC) to decode the far user's data [21]. In direct transmission slot firstly, base station sends information to both far user and near user. Near user has a strong channel because user is very nearer to the base station. So near user receives the information first. Near user decodes both far user and near user's information. Near user has far user's data. Near user does successive interface cancellation to decode the far user information.

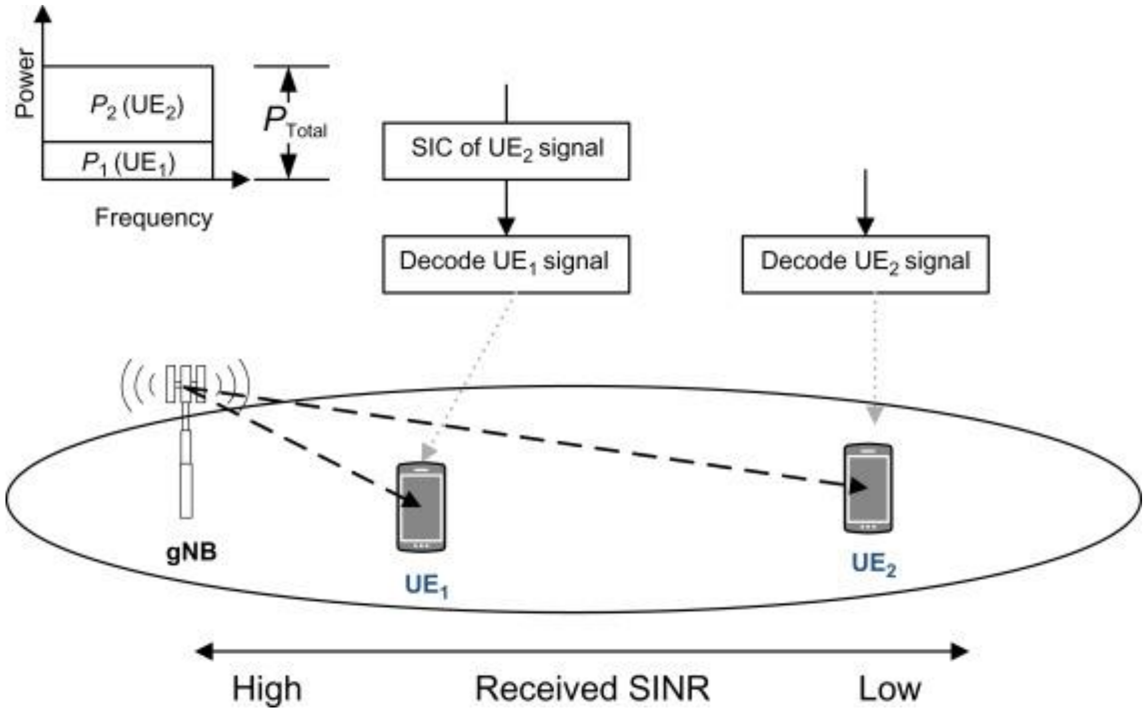

Fig 1.5 Direct Transmission

From figure, GNB is the base station,UE1 is the near user and UE2 is the far user

Near user get the far user's data for this near user should subtract superposition coded signal. And then near user decodes its own data. The far user just performs direct decoding. At the end of direct transmission slot, the achievable data rates at the near user and far user are,

$$S_n = \frac{1}{2}\log_2(1 + \alpha_n \rho |h_n|^2) \tag{3}$$

$$S_{f,1} = \frac{1}{2}\log_2\left(1 + \frac{\alpha_f \rho |h_f|^2}{1 + \alpha_n \rho |h_f|^2}\right) \tag{4}$$

Here,

α_n is power allocation coefficient for near user

α_f is power allocation coefficient for far user

h_n is channel between base station and near user

h_f is channel between base station and far user

ρ is transmit SNR= $\frac{S}{\sigma^2}$ where S is transmitting power and σ^2 is noise variance

As usual, $\alpha_f > \alpha_n$

and $\alpha_f + \alpha_n = 1$

We have this factor of half in front of the achievable rates because we have two time slots of equal distribution and S_n,S_f are the achievable data rates during the direct transmission slot alone.

2) Relaying Slot

Relay transmission has been developed shown to be able to significantly improve the transmission reliability, network coverage, and achievable cellular networks. As a result, the integration of NOMA and cooperative relaying has recently piqued the interest of a growing number of people. Improve future 5G wireless network throughput. A cooperative NOMA transmission scheme was developed [22-25]. In this section we derive analytical expressions for the outage probability and achievable data rates of the proposed relay transmission. Asymptotic high SNR expressions are also presented to provide useful insights into the effects of system and channel parameters on the performance. Finally, our derived result will be compared with existing result. First illustrate the outage probability of the relay assisted cooperative NOMA system. The outage probability is defined as the probability that the instantaneous received SNR falls.

In relaying slot near user act as relay. Near user decode the far user's information and decodes its own information. After getting decoded its own data near user retransmit the far user's information to far user. Here base station transmits the information and also transmit near user. Far user will get two copies of same information. If any one of them fails no problem at all. Far user receive information at least one time. Probability of failing both base station and near user is very less. So, it will not affect the overall performance. The next half of the time slot is called relaying slot. Achievable rate is a key performance for wireless communication systems, so we need to focus on achievable data rates for relaying transmission slot.

The achievable rates are

$$S_{f,2} = \frac{1}{2}\log_2(1 + \rho|h_{nf}|^2) \tag{5}$$

Where,

h_{nf} = the channel between near user and far user.

We already seen that $S_{f,2} > S_{f,1}$ because of two reasons

1) There is no interference from other transmissions
2) There is no fractional power allocation. The whole transmit power is given to the far user.

3) Diversity Combining

Diversity is an effective communication receiver technology that improves wireless links at a reasonable cost. This study establishes a broad framework for future research. A framework for integrating approaches in order to increase to variety wireless communication technology that works in collaboration. This article that serves as an overview of several methods to taking use of the advantages of variety and multi hop relay -based communication, such as a method for extending radio range in mobile and wireless broadband cellular networks. The concept of relaying is given as a way to lower the cost of infrastructure deployment in addition, it is proven that by taking advantage of spatial variety, Multi hop relaying can boost cellular capacity network. While this article concentrates on stationary relays, many of the concepts described may also be applied to systems with moving relays.

Diversity combining is a technique used to reduce the effects of fading by receiving redundancy of the same information-carrying signal over two or more channels. After that, merge these numerous clones via fading channels. To improve the total received SNR at the receiver.

The idea behind this approach is to use the low chance of deep fades overlapping in all of the diversity channels to reduce the likelihood of mistake and outage.

1.5.1.2 Types of diversity combining

At the receiver, there are three fundamental strategies for combining diversity: Selection diversity, equal gain combining, and maximum ratio combining. In the context of selection diversity, the signal with the highest. The received level is fed into the receiver. All incoming signals are combined in equal gain combining. Coherently summed with the same amplitude and phase. A weighted maximum-ratio combination is used. The signal summation is carried out where the amplitudes are proportional to signal-to-noise ratio (SNR) and phase of each signal are preserved equal. The Rayleigh distribution is a statistical time-varying distribution that is widely used to characterize the statistical time charging nature of incoming data. The envelope of a signal multipath component. The Rayleigh distribution of fading has a PDF document in terms of signal received.

1.3.1.3 Super Position Coding:

In NOMA, at the transmitter side we use encoding technique, superposition coding to code the transmitted signal, for simultaneously using the same frequency. way let us consider two users, user 1 who is near to the base station and user 2 who is far from the base station and carrying X_1 and X_2 data carrying 4 bits. Let X_1=1010 and X_2=0110

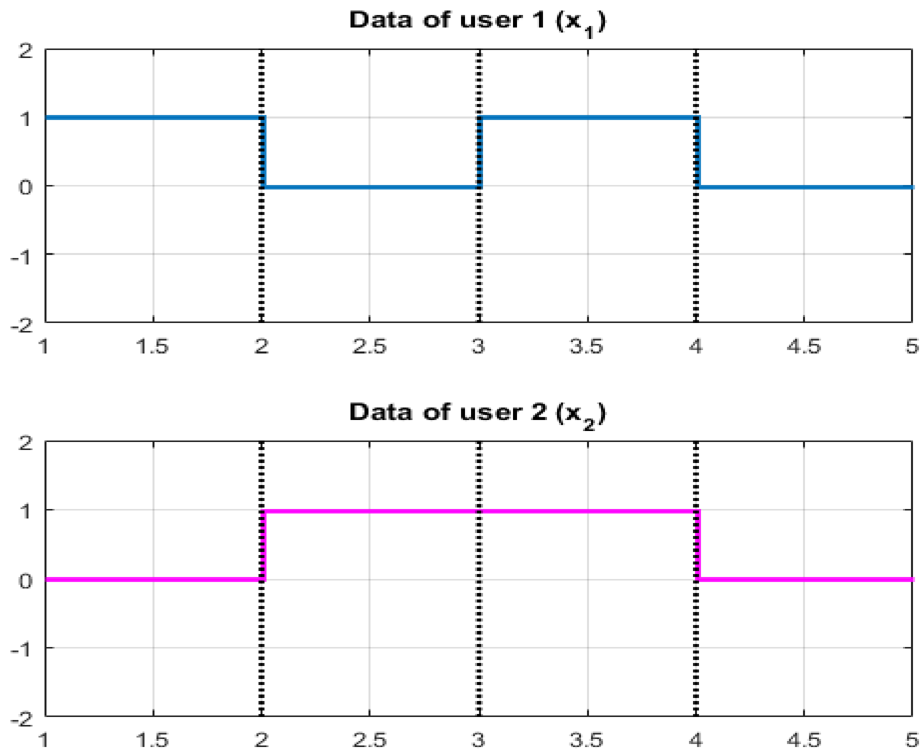

Fig 1.6 The Raw Data Of Near And Far User.

X_1 and X_2 date undergoes digital modulation before transmission like BPSK that transforms 0's to -1 and 1's to +1.

X_1= 1, -1, 1, -1

X_2=-1, +1, +1, -1

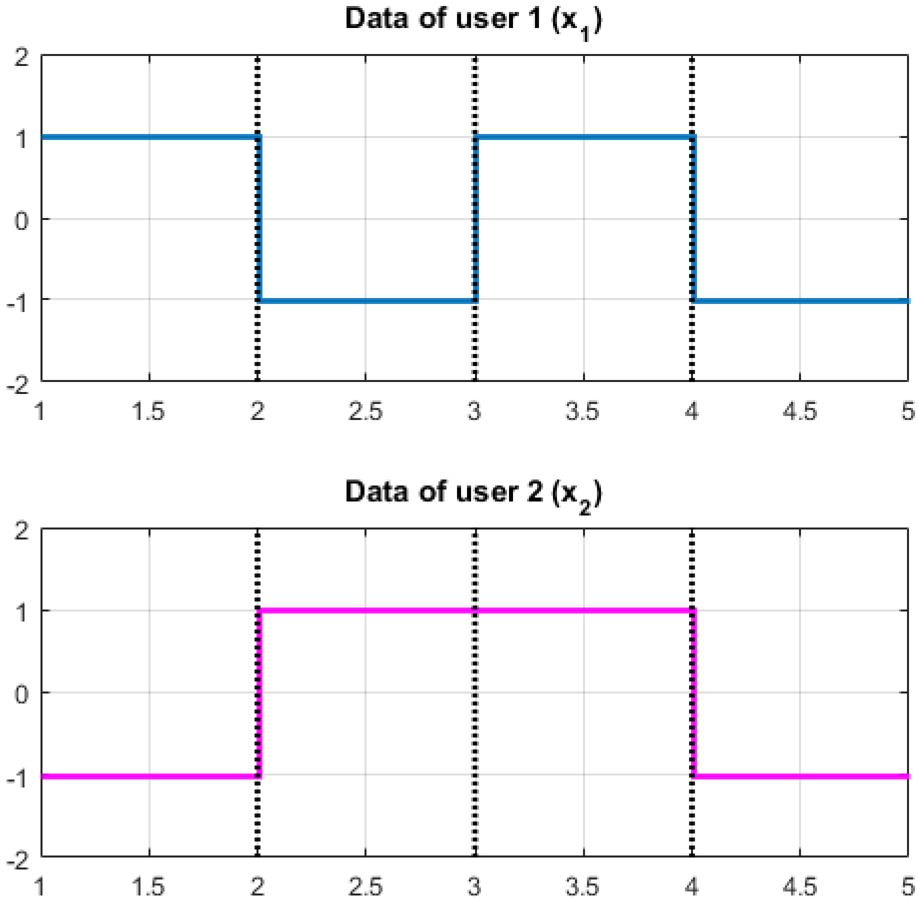

Fig 1.7 The Data Of Near And Far User After QPSK

SPC is a technique for power domain multiplexing. we are adding the data x_1 and x_2, before that the data is converted to BPSK and multiplied by different power levels. The power levels should meet the condition that the sum of power levels should be unity

Let X be the transmitted signal,

$$X = \sqrt{\alpha_1} * x1 + \sqrt{\alpha_2} * x2 \text{ i.e .} \alpha_1^2 + \alpha_2^2 = 1 \quad (6)$$

It looks like a super position principle hence it is known as super position coding technique. Let assume that the power levels is α_1=0.75, α_2=0.25 .The graphs of the superposition coding technique is shown below

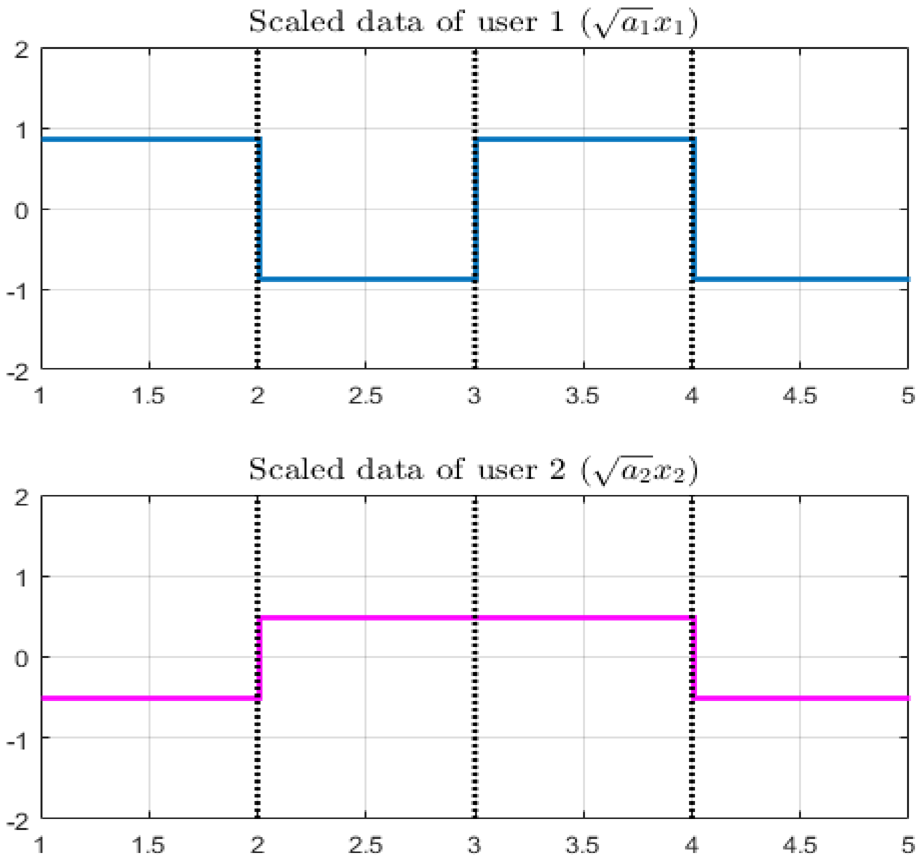

Fig 1.8 Power Level Shifting Of Near User and Far User

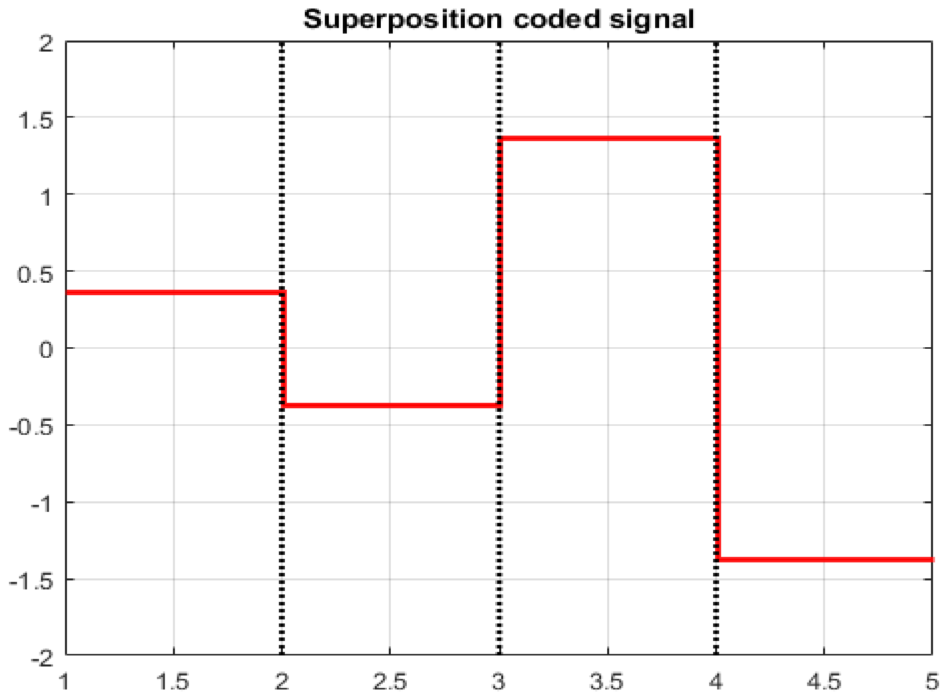

Fig 1.9 Superposition Coded Signal

1.5.1.4 SUCCESSIVE INTERFACE CANCELLATION

NOMA uses power domain multiplexing of users sharing same time and frequency resources. This is accomplished by performing super position coding at transmitter and successive interface coding at receiver. SIC is carried out to decode the super position coded signal at the receiver side. Consider two users in NOMA downlink system. That is user 1 and user 2. User 1 is at near to the base station and user 2 is far to the base station of carrying x_1 and x_2 data. We know that at transmitter side super position coding is done.

The equation of superposition coding is given by

$$X=\sqrt{t_p}\,(\sqrt{\alpha_1}x_1+\sqrt{\alpha_2}x_2) \tag{7}$$

Where, t_p = Transmit power

α_1 and α_2 are the power weights given to x_1 and x_2 respectively.

X is the linear combination of x_1 and x_2.

$a_1^2+a_2^2$ =1 (power levels)

Let h_1 is the channel from base station to near user and h_2 is the channel from base station to the far user. The copy of x is received at user1 through channel h_1.

$$y_1 = h_1 x + w_1 \tag{8}$$

Where, w_1= noise

The copy of x is received at user 2 through channel 2

$$y_2 = h_2 x + w_2 \tag{9}$$

At user1 (far user)

Expanding the received signal at user1

$$y_1 = h_1\sqrt{t_p}(\sqrt{a_1}x_1 + \sqrt{a_2}x_2) + w_1 \tag{10}$$

$$y_1 = h_1\sqrt{t_p}\sqrt{a_1}x_1 + h_1\sqrt{t_p}\sqrt{a_2}x_2 + w_1 \tag{11}$$

Here, w_1= noise

$h_1\sqrt{t_p}\sqrt{a_1}x_1$ = desired and dominating

$h_1\sqrt{t_p}\sqrt{a_2}x_2$= interference and low power

Since $a_1 > a_2$,direct decoding of y_1 would yield x_1. The term containing the x_2 component will be treated as interference. The signal to interference noise ratio for the far user is ,

$$\gamma_1 = \frac{|h_1|^2 t_p}{|h_1|^2 t_p a_2 + s^2} \tag{12}$$

At user 2 (near user)

Expanding the received signal at user 2

$$y_2 = h_2\sqrt{t_p}\sqrt{a_1}x_1 + h_2\sqrt{t_p}\sqrt{a_2}x_2 + w_2 \tag{13}$$

Here,

w_2= noise

$h_2\sqrt{t_p}\sqrt{a_1}x_1$=interference and dominating

$h_2\sqrt{t_p}\sqrt{a_2}x_2$=desired and low power.

User 2 must first perform successive interference cancellation before decoding his own signal.

SIC is carried out as follows:

1) y_2 is directly decoded to obtain$x_1$or rather, an estimate of x_1.
2) $y_2^{'}$=y_2-$\sqrt{a_1}x_1$ is computed.
3) $y_2^{'}$ is decoded to obtain an estimate of x_2.

What happens if SIC is imperfect

As user 2 decodes the message indirectly from user1 that SIC is imperfect means some residues of $x_1$component is still present in y_2

$$y_2^{'}=\sqrt{\mathcal{E}}h_2\sqrt{a_1}t_p+h_2t_p\sqrt{a_2}x_2+w_2 \quad (14)$$

Where Ɛ = fraction of residues of x_1.

1.6 Motivation

As the population of the world is increasing day by day, internet usage has been grown exponentially. In 1940's the population of the world is about 318 million which mobile technologies starts evolving and by the year 2020 it is increased by 43% (1 billion 380 million) population. In olden days there is no use of internet connectivity that number of channels are free and channel capacity is efficient. The problem become complex as number of devices and network usage increases rapidly. To maintain the efficient communication with all the devices many multiple access techniques evolved such as Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), etc., these techniques come under the Orthogonal multiple access technique (OMA) through which orthogonality is achieved by time, space, frequency and code. The main problem with orthogonal multiple access technique is power issue [1-2]. In these techniques battery gets drained and system throughput is very less, another main problem that OMA encounters are successive interference at receiver side. Fading is another problem in orthogonal multiple access technique that the receiver receives delayed and advance copy of same message due to reflection, scattering, refraction etc., this problem is rectified in different multiple access techniques.

The orthogonal multiple access technique supports single input single output (SISO), as well as multiple input and multiple output but the efficient and reliability of these multiple access technique is very less, due to this many connectivity problems occurred in wireless communication. To connect all the devices many techniques are proposed among them one of the most efficient technique is "NON-ORTHOGONAL MULTIPLE ACCESS TECHNIQUE". The common problems encountered in these multiple access techniques is interference, signal to interference ratio(S/I), signal to noise ratio(S/N), fading [4-7]. To avoid these problems many multiple access techniques are proposed. Each of them has their own advantages and disadvantages. The first multiple access technique starts with FDMA and developed to CDMA. In designing the wireless generation networks, multiple access techniques play a vital role, and they are considered very important in describing the efficiency of any communication systems.

We know that IOT devices are increasing day to day and communication with these devices and connectivity between them has become more complex with existing multiple access techniques. To resolve these issues non orthogonal multiple access techniques are used. Before understanding multiple access techniques, we must have a clear idea on SISO and MIMO systems [8-10]. The SISO systems has ability that can process only single input but not the multiple inputs and provide single output at a given time. Whereas MIMO systems produces multiple outputs for the multiple inputs at given time.

We know that the channel capacity is directly proportional to bandwidth, for a SISO system to increase the channel capacity we need to increase the bandwidth of the particular channel. In case of MIMO, increasing the signal power at the transmitter we can achieve more channel capacity without expanding the band width.

1.7 Problem Definition:

In terms of the notion of integrating NOMA with wireless powered networks, NOMA may be implemented with wireless power transfer i.e., the simultaneous wireless information and power transfer (SWIPT) technology was introduced together with a relaying network, and its outage performance was evaluated in. Wireless power transfer is supported in wireless relaying networks to send a signal to far users as a potential technique to extend the lifetime of energy-constrained users. Two well-known policies, namely, time switching (TS) and power splitting (PS) receiver architecture, are introduced as in, as a model of green NOMA, an sometime co-operative NOMA (SWIPT-CNOMA) network is studied as a combination of the NOMA and SWIPT scheme, and such novel approach It is feasible to circumvent the lifespan constraint of the energy-constrained NOMA user who works as a relay and harvests energy from received signals in this topology. The core idea of NOMA is to employ the power domain for several access modes, compared with the time/frequency/code domain used for earlier generations of mobile networks. Take 3GPP-LTE for example the traditional orthogonal multiple-access frequency division (OFDMA) [3-8]. One major problem with this Multiple Access Orthogonal (MAO) method is the low spectral efficiency when certain bandwidth resources are assigned to users with inadequate channel state knowledge, such as subscriber's channels (CSI).In NOMA, several signals can be sent simultaneously at the same frequency on the same spot area. Each user in the cell has different power, thus you may consider that as the technique for power modulation. To separate the multiplexed signals in the NOMA system, special receivers should be utilized. The advantage of NOMA is that capacity and total output are increased. On the other side, the high interference problem should be dealt with. On the other side, NOMA allows all users to access all the sub controller channels, which enables high-CSI users to still use the bandwidth resources that are allocated to poor CSI users, thereby substantially improving spectral efficiency.

1.8 Limitations of thesis

In conventional wireless communication networks, a single antenna is utilised at both the source and the destination, which presents problems in the communication connection due to multipath effects. MISO technology, which uses two or more antennas to transmit multiple signals at the source, can help to alleviate issues caused by multipath wave propagation. MISO has investigated the most optimal transmission method for the best case, in which the two receivers in the communication system concurrently harvest energy and decode information to construct self-sustaining wireless communication networks. It is also worth noting that cross-link signals can help improve receiver EH while limiting the possible sum rate [9]. Following that, two feasible systems based on TDMA are presented, where the receiver executes ID or EH at each time slot, considering the existing limitations of circuit technology.

The transmission period of the second scheme, designated B, is divided into two time slots, as in scheme A, with the exception that in each time slot, one receiver performs ID, and the other receiver does EH concurrently. Simulations were used to investigate the attainable total rate of these suggested TDMA systems A and B under ideal conditions. It was demonstrated that the ideal scheme, which employs ideal receivers, is not always the greatest option in terms of sum rate maximization. In an interference restricted system, TDMA of Scheme A provides a higher sum rate than the optimal scheme. When one of the receivers demands more energy than the other, TDMA of SC is used [9].

CHAPTER 2

LITERATURE SURVEY

The non-orthogonal multiple access (NOMA) technology can serve as many users as possible using the same resources, such as frequency. In recent years, NOMA receives a lot of attention in the literature [10]. To improve the performance of the far user, in cooperative NOMA networks, the near user, which is close to the source, can help the far user, which is far away the source, to enhance its performance [11]. Simultaneous wireless information and power transfer (SWIPT) can supply energy for wireless devices via scavenging energy from the radio frequency (RF) [15]. SWIPT can be integrated with NOMA naturally [12]. In [13], the authors studied the outage performance of the conventional cooperative NOMA (CCN) protocol for the SWIPT based NOMA network. At the near user, the design of the dynamic power splitting (PS) factor only satisfies the requirement of decoding the far user's signal. If the selected target rate pair does not meet the needed condition, the near user will be always in outage. As pointed out in [13], the main purpose of NOMA is serving as many users as possible, in other words, the NOMA based network must ensure the user fairness. To overcome the weakness in [14], at the near user, the power allocation coefficients (PACs) and dynamic PS factor were jointly designed to preferentially decode the far user's and near user's signals. The analysis shows that the scheme in [14] has a much higher throughput than the scheme in [15]. Note that the network in [16] and [17] still adopted a linear energy harvesting model. In fact, due to the non-linearity of the diodes, inductors and capacitors in circuits, the energy harvester actually exhibits a non-linear feature [18]. For the sake of mathematical convenience, instead of the exponential non-linear model [19], the authors in [20] and [21] adopted a piecewise non-linear one, in which the output power of the energy harvester is only split into two segments: the linear and saturated regions. To support more sufficient precision, the piecewise linear model [22] further split the non-saturated region into several linear regions. In cooperative communications, even if the direct link (DL) is strong enough to accomplish the transmission between the source and the destination, the relay node will still participate in the relaying, which wastes the time resource and degrades the performance. At the beginning of each transmission block, with the help of a 1-bit feedback to indicate whether the relaying is needed, the incremental relaying can enhance the system performance [23-24]. In the CCN network with constant power supply, the outage performance of the incremental cooperative NOMA (ICN) protocol was studied in [25]. If the relay node is energy constrained, adopting the SWIPT technology to satisfy the requirement of the relay node is a good choice [26]. To the best of our knowledge, the outage performance of the ICN protocol in the SWIPT based NOMA network has not been studied in the literature. This motivates our work. The tremendous growth of service-demanding smart devices, e.g., global coverage, unprecedented technologies, and intelligent applications accompany the rapid leap in wireless communications. Necessary data transfer with ubiquitous coverage led to revolutionary research efforts. Energy efficiency (EE) and spectral efficiency (SE) are sharp criteria that measure the compatibility of any proposed system [27–31]. Their improvement is essential to meet the stringent requirements of various applications, such as data-hungry and energy-demanding applications, due to 6G increasing demands with its key-enabling technologies. EE is considered a crucial designing metric in wireless communications, particularly in 6G and beyond with their upgraded infrastructures, such as cell-free and ultra-dense heterogeneous networks (UDHNs) with distributed base stations, access points, and relays due to their number of antennas, equipment, and power-consuming electronic (and photonic) elements, connecting billions of devices, i.e., Internet of Everything (IoE) [32-37]. The EE of 6G operations is compulsory for energy savings, green communications, and feasibility in 6G network requirements such as quality of service (QoS) and processing [38]. Terahertz (THz) communication [39] is a cornerstone that will play a pivotal role in the next generations. SE depends mainly on available channel bandwidth (BW) following Shannon's theorem. THz has attracted the great attention of many researchers as the hottest topic in the paradigm shift of 6G due to its unique advantages as the last uninvestigated band of electromagnetic frequencies. It is in the middle of millimeter Wave (mmWave) and infrared bands between (0.1–10) THz and is considered the system's backbone of the next era due to its ability to enable various applications. THz communication has extremely high frequencies, ultrawide BW, superfast data transfer, extensive throughput, extremely low latency, and very good directivity due to its very short wavelength (3–0.03) mm. Locating the boundary between mmWave and optical bands motivated researchers to explore these bands' capability to support THz communications as THz outperforms the two bands at specific points. Electronic, photonic, and plasmonic technologies are expected to evolve the manufacturing of THz transceivers. THz communication is logically complementing mmWave and optical bands by providing alternative signals as a replacement to optical paths in some use cases, such as the connections of backhaul, kiosk to nodes, data center's racks, and intra-device links, in addition to THz integration with fiber networks [40-46]. Hence, the disadvantage of noticeable water vapor absorption and path loss spikes that divide the THz spectrum into several spectral windows, as stated in IEEE Std. 802.15.3d–2017; however, these windows are being extensively explored, considering them to support 6G services with some exemptions where some 6G services will not be compatible with the new frequency bands [47]. The demand for IoE ignites an emergent necessity to connect everything to everything. The current systems have limitations that restrict any upgrades or improvements to meet these requirements. Developing decent techniques to be integrated altogether is mandatory to build a modern communication system in order to satisfy the new requirements such as ultra-massive connectivity, very high SE, very low latency, very high data rate, ultra-high reliability, user fairness, supporting unprecedented applications, EE, and cost-effectiveness. Power domain nonorthogonal multiple access (NOMA) [48] is one of the famous candidates to evolve 6G systems. It can improve the SE of mobile communication systems, outperforming conventional orthogonal multiple access (OMA) schemes in terms of SE, capacity, resource allocation, user fairness, connectivity, and latency. Our research mainly concentrates on single-input single-output (SISO)-NOMA (despite the gains of multiple-input multiple-output (MIMO) systems) because MIMO-NOMA systems are practically complicated to implement. NOMA mechanism allows various users' signals to superimpose at the transmitter (Tx) and then to be distinguished and filtered by using successive interference cancelation (SIC) operation at the receiver (Rx) that effectively enlarges the data transfer capacity that depends mainly on the BW; however, interference is discarded by the SIC implementation, and the noise is filtered. The two operations are conducted at the Rx side. With the NOMA concept, the channel capacity is calculated as $C = BW \times \log_2(1 + S/(N + I))$, where C is the channel capacity, BW is the bandwidth, S is the signal power, N is the noise power, and I is the interference of other users' signals. NOMA multiplexing is performed in the power domain, allocating different power coefficients to the users per their channel conditions (i.e., good or bad). All users' signals are superimposed in Tx. Demultiplexing of NOMA signals is conducted by applying SIC at Rx. Grouping or clustering the served users is essential in THz-NOMA communications to improve SE and mitigate complexity as the line-of-sight (LOS) is the main transmission link. For the NOMA-SISO scheme, BS/users with single antenna equipment rely on the simultaneous channel state information (CSI), where the users are sorted to allow decent SIC decoding at Rx. The larger the channel gain difference, the more sufficient NOMA we gain. User clustering may be impractical with many users; therefore, we aim to develop low complexity solutions to avoid the clustering problem [16,17]. SIC is not only CSI-based but also QoS-based or hybrid-based [16]. CSI acquisition at Tx and Rx is a great challenge for all modulation schemes [49]. Hence, we use simple binary phase-shift keying (BPSK) in our system with its advantages compared with other formats. Research efforts are exploring all the possible means, including NOMA-assisted cooperative systems, to tackle the problems of distance shortages and power losses in THz communications. Cooperative networking with its relaying categories offers multiple advantages such as reliability and capacity with better coverage area, enhancing overall performance. When applied to cooperative networks, the SE of NOMA can be reasonably improved to support extra (blocked, weak, or cell-edge) users in the short-distance THz transmission, significantly when deploying energy harvesting (EH) with NOMA-based cooperative networks [50]. It represents the main topic of our paper in THz communications. Hence, we use decode-and-forward (DF) relaying because NOMA is adopted in our system. Relaying user implies a copy of the far (weak) users' signal (to decode and remove it before decoding the intended strong user's signal in NOMA) included in the superposed signal received by that user. We reasonably utilize that to achieve the objective of relaying as an additional advantage, which is better than using an extra relaying device with extra costly power-consuming complexity. The repetitive use of cooperative networks causes the drainage of the relaying user's battery, leading to system failure because THz-NOMA requires high computational SIC procedures at the Rx. Thus, research efforts aim to overcome the challenge of moving toward green communications [51] by applying the EH technique. Energy and information are sent to other destinations by exploiting the energy of radiofrequency (RF) signals that exist everywhere around most devices. EH enables devices to harvest that energy by using simple RF circuits. We can then utilize that harvested power to use it again with our transmissions to send our signals without applying an extra burden to the relaying user's battery. Relaying user divides the received signal's power into EH and information decoding through EH power splitting, allowing the implementation of energy harvesting and information decoding at the same time, leading to the principle of simultaneous wireless information and power transfer (SWIPT). SWIPT qualifies the near-relaying user to capture power from the transmitted signal from the source and uses that energy to relay information to the far user [52]; this improves the system throughput and outage probability accordingly.

CHAPTER 3

SYSTEM MODEL ANALYSIS

3.1 Introduction

Simultaneous Wireless Information and Power Transfer (SWIPT) is an emerging study field that uses radio waves for both wireless information transfer (WIT) and wireless power transfer (WPT) at the same time (WPT). SWIPT is gaining traction as a technology that can energize and interact with low-power wireless devices, such as Internet-of-Things (IoT) devices, as a result of the rising interest in these devices. MIMO (Multiple-Input-Multiple-Output) systems are a potential way to manage and utilize interference at the same time [27-28]. Multiple antennas at the receiver improve data dependability and boost collected power through geographical variety. Multiple antennas at the transmitter use spatial beamforming to optimize information and power transfer. However, spatial beamforming causes interference isolation, which lowers the collected power. The majority of SWIPT research is focused on small-scale networks. Its use in large-scale networks, on the other hand, has received little attention. Relay-aided and wireless networks are investigated. These studies, on the other hand, focus on single-antenna transmission. Ad hoc networks with multiple-antenna transmitters are investigated in the paper. However, the study does not apply to cellular networks. In addition to legacy and millimeter-wave frequencies, SWIPT cellular networks are studied. Directional antennas are considered in both situations, although MIMO is not. MIMO systems are a promising method that has made its way into a number of contemporary wireless communication networks, with the goal of enhancing system Quality of Service (QoS). As a result, investigating and analyzing the performance of a MIMO system while taking into consideration the influence of various practical difficulties is important. As a result, the combination of MIMO technology with energy harvesting is a fascinating issue[29-30].

3.2 System Design

3.2.1 Bit Error Rate of Non-Orthogonal Multiple Access with QPSK Modulation

In olden days we are analog communication their capacity allocation, carrier power, message signal type it depends on, now the technology become developed and communication transforms to digital communication which involves many new methods and approaches to communicate through wirelessly. One of the key concepts in the communication system that need is end-end performance measurements. Here many concepts like interference, noise, distortion, signal to noise ratio bit synchronization.

- **Bit Error Rate**: The bit error rate is which the reliability of the entire communication systems that number of bits in and number of bits out including signal path, transmitter and receiver side. In an simple way the bit error rate is defined as the ratio of number of errors occurred to the total number of bits in a entire duplex communication.

Bit Error Rate = no. of errors /total no. of bits

3.3 Bit Error System Model

To understand the bit error rate, consider a wireless network consisting of three NOMA users M_1, M_2, M_3.let the respective distances from the base station be h_1, h_2, h_3 such that $h_3<h_2<h_1$. Based on the distances between them the user M_1 is at near to the base station and the user M_2 is moderately and user M_3 is at farthest from the base station. Let assume that r_1, r_2, r_3 denote their corresponding Rayleigh fading coefficients such that $|r_3|^2>|r_2|^2>|r_1|^2$

Let α_1, α_2, α_3 be the respective power allocation coefficients. According to the NOMA Principle the user who is at nearest to the base station is allocated least power and the user who is at the farthest from is allocated the more power by power splitting method. The power allocation coefficients must be ordered as $\alpha_1 > \alpha_2 > \alpha_3$. The power allocation coefficients had a greater impact in the performance of a NOMA network. For simplicity we assume the fixed power allocation is allocated. These are the system parameters assumption that for the system design model.

- **Signal Model for Bit Error Rate**

Let d1, d2, d3 denote the data of user M1, M2, M3 of using the one of the popular modulation technique in digital communication is QPSK The QPSK superposition coded signal transmitted by the BS is given by the equation

$$d = \sqrt{t_p}\left(\sqrt{\alpha_1}D_1 + \sqrt{\alpha_2}D_2 + \sqrt{\alpha_3}D_3\right) \quad (15)$$

The signal in the case of the i^{th} user is given by

$$y_i = h_i\, d + n_i \tag{16}$$

Where n_i denotes AWGN at receiver of M_i

3.4 SC Decoding Procedure

AT User 1

Since M_1 is allocated to the nearest distance to the base station so it is decoded directly by assigning the signal M_2 and M_3 as interference signal

The achievable rate of M_1 is given by

$$R_1 = \log_2\left(1 + \frac{\alpha_1 t_P |h_1|^2}{\alpha_2 t_P |h_1|^2 + \alpha_3 t_P |h_1|^2 + \sigma^2}\right) \tag{17}$$

Which can be further simplified as,

$$R_1 = \log_2\left(1 + \frac{\alpha_1 t_P |h_1|^2}{(\alpha_2 + \alpha_3) t_P |h_1|^2 + \sigma^2}\right) \tag{18}$$

From equation we make one important observation that $\alpha_2 + \alpha_3$ is present at the denominator, now we want α_1 to satisfy $\alpha_1 > (\alpha_2 + \alpha_3)$ if it satisfies the condition M_1's power will dominate in the transmit signal, D and in the received signal, Y_1

AT User 2

The bit error rate equation for M_2, since $\alpha_2 < \alpha_1$ and $\alpha_2 > \alpha_3$,M2 must perform successive interference cancellation to remove M_1's data and treat M_3 as interference. After removing M_1's data the achievable bit error rate is

$$R_2 = \log_2\left(1 + \frac{\alpha_2 t_P |h_2|^2}{\alpha_3 t_P |h_2|^2 + \sigma^2}\right) \tag{19}$$

The condition is should to be meet for interference cancellation is $\alpha_2 > \alpha_3$

AT USER 3

At finally the user who is at far distance from the base station M_3 has to perform signal to interference cancellation two times that to remove m1's data and M_2's data from y_3 as interference, after removing M_1's data.

The achievable data rate of user M_3 is given by

$$R_3 = \log_2\left(1 + \frac{\alpha_3 t_P |h_3|^2}{\sigma^2}\right) \tag{20}$$

The block diagram representation of the three users decoding technique ay the receiver side is given as

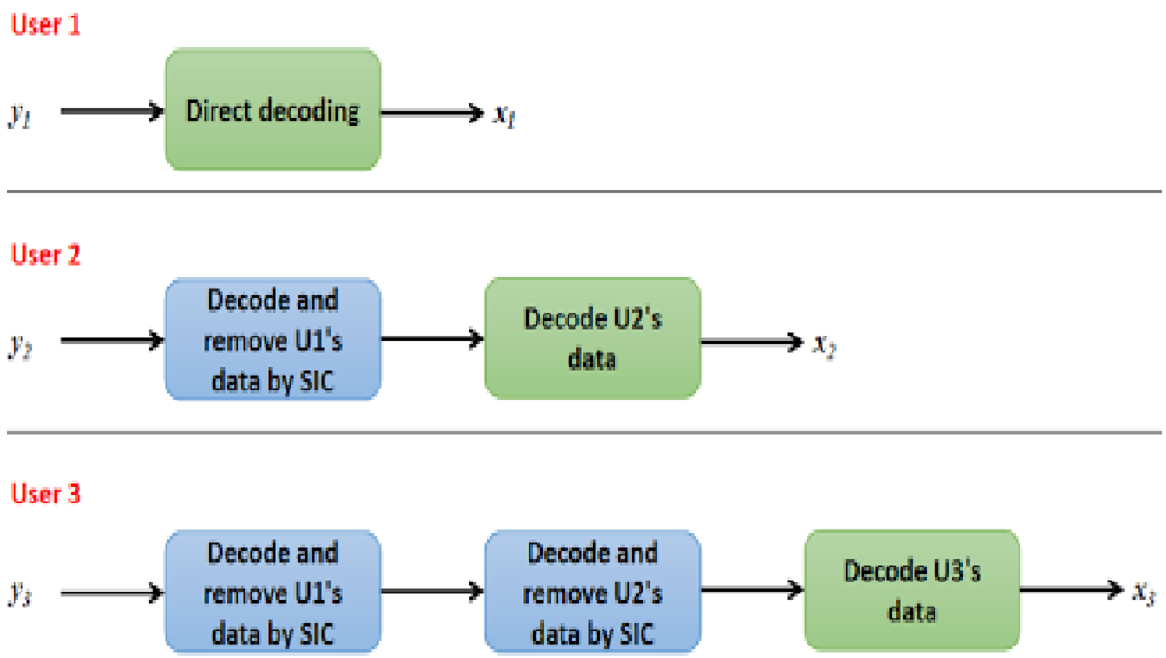

Fig 3.1 Mechanisim of SIC of Three Users

3.5 SWIPT Energy Harvesting

As we are moving towards more and more advanced communication systems, the power consumption of devices becomes an important issue. For example, in a wireless network made up of thousands of IoT sensors, drainage of battery may cause the sensors o die. To address this issue, there is a push towards green communication technologies like RF energy harvesting devices. NOMA involves successive interference cancellation, which is computationally intensive task, this places a burden on the battery life.

When we studied the cooperative NOMA system, we used user cooperation where the near user acted as relay to the far user. This user cooperation was natural because the near user has the data of the far user as well.

There are always electromagnetic signals present everywhere around us due to data transmissions, these signals are no use unless they contain information that is intended for us. They can also carry the power which we harvest using a simple RF circuits, this power is used to transmit the data as a relaying network. To transmit the user 2 data to the by relaying technique we need power to transmit. This can be done in two ways

1) Time Switching

2) Power Splitting

1) Energy Harvesting by Time Switching:

In this process the device operates in a time-slotted fashion, which involve two time slots. In first time slot the energy is harvested from the surroundings, in second time slot the information is transmitted.

2) Energy Harvesting by Power Splitting:

The device splits the received signal power for energy and information decoding, power splitting allows simultaneous implementation of energy harvesting and information decoding, so this method is also called SWIPT (Simultaneous wireless information and power transfer.

CHAPTER 4

COOPERATIVE SWIPT NETWORK

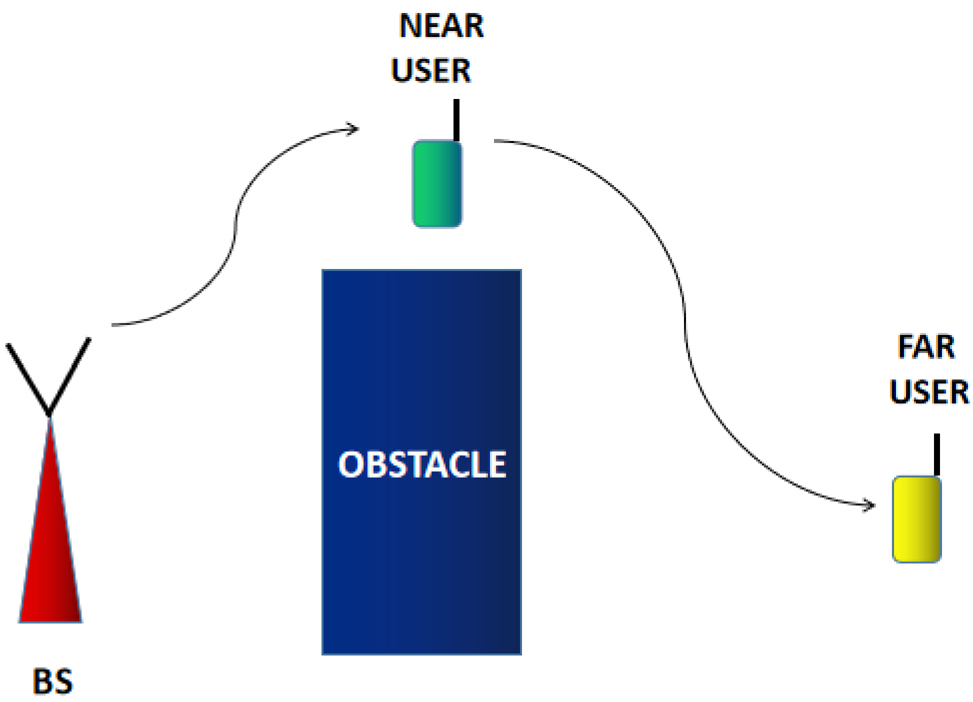

Fig 4.1 Network model of cooperative SWIPT network

We are considering downlink transmission the base station uses NOMA schemes to transmit messages for both near and far users. Unfortunately, there is an obstacle between station and the far user which causes shadowing. But the near user has very good channel with the base station. According to NOMA principles signal interference cancellation is to be done at the near user to decode its own data so the near user has the copy of far user data which can help the far user by acting as decode-and-forward relay. But the problem here is there is no enough power to relay the data of far user. Therefore, the near user decides to perform power splitting method of energy harvesting to obtain the sufficient power to relay the far user data.

4.1 Signal Model of Cooperative SWIPT NOMA

- **Time slot 1**

The NOMA signal transmitted by the base station in the first time slot of the energy harvesting technique is given by

$$d = \sqrt{t_p}\left(\sqrt{\alpha_n}X_n + \sqrt{\alpha_f}X_f\right) \quad (21)$$

Where

d = transmitted superposition coded signal.

t_p = the total power used to transmit the signal.

α_n= the Rayleigh coefficient power allocated to near user.

α_n= the Rayleigh coefficient power allocated to far user.

X_n= the signal used by the near user.

X_f = the signal used by the far user.

Due to the shadowing effect, fading phenomenon the far user cannot receive the signal. The near user received signal is given by

$$d = \sqrt{t_p\left(\sqrt{\alpha_n}X_n + \sqrt{\alpha_f}X_f\right)h_{sn}} + w_n \quad (22)$$

Where,

w_n AWGN with zero mean and variance = σ^2

η path loss component

d_{sn} Rayleigh fading coefficient between the BS and near user with zero mean and

Variance =$d_{sn}^{-\eta}$

d_{sn}distance between Bs and near user

From d_n, the near user harvests a fraction of power and let us denote this fraction by δ. This is also called the energy harvesting coefficient. The $1-\delta$ is the fraction of power available for decoding the information.

The signal available for information decoding, after the energy harvesting is

$$d_D = \left(\sqrt{1-\delta}\right)d_n + w_{eh} = \left(\sqrt{1-\delta}\right)\sqrt{t_p}\left(\sqrt{\alpha_n}X_n + \sqrt{\alpha_f}X_f\right) + \left(\sqrt{1-\delta}\right)w_n + w_{eh} \tag{23}$$

Where,

w_{eh}= thermal noise introduced by the energy harvesting circuit

δ = fraction of power harvested by near user

t_p= total power harvested

α_n= Rayleigh coefficient

Let us assume energy harvested from w_n is neglected leading to the following expression for d_D,

$$d_D = \left(\sqrt{1-\delta}\right)\sqrt{t_p}\left(\sqrt{\alpha_n}X_n + \sqrt{\alpha_f}X_f\right) + w_{eh} \tag{24}$$

From d_D, the near user first performs direct decoding of X_f. The achievable data rate to decode the far user data by the near user is given by

$$S_{nf} = \frac{1}{2}\log_2\left(1 + \frac{(1-\delta)\alpha_f t_P |h_{sn}|^2}{t_P(1-\delta)\alpha_n |h_{sn}|^2 + \sigma^2}\right) \tag{25}$$

Where,

S_{nf} =data rate of near user

After signal to interference cancellation, the achievable data rate for the near user to decode its information is given by,

$$S_n = \frac{1}{2}\log_2\left(1 + \frac{(1-\delta)\alpha_n t_P |h_{sn}|^2}{\sigma^2}\right) \tag{26}$$

Since δ is the power harvested in the first time slot, the amount of power is harvested is given by

$$t_{PH} = t_P |h_{sn}|^2 \delta\xi \quad (27)$$

Where,

ξ= power harvesting efficiency of the circuitry

- **Time slot 2**

In second time slot the near user relays the data to the far user by using power harvested in the time slot 1, t_{PH}.Hence, the transmitted signal by the near user is $\sqrt{t_{PH}} X_f$. The received signal at the far user is given by

$$d_f = \sqrt{t_{PH}} X_f h_{nf} + w_f \quad (28)$$

Where, h_{nf} is the Rayleigh fading channel between the near and far users. Now, the achievable data rate of the far user is given by

$$S_f = \frac{1}{2}\log_2\left(1 + \frac{t_{PH}|h_{sn}|^2}{\sigma^2}\right) \quad (29)$$

4.2 Optimization of Power Splitting Coefficient

In time slot 1 and time slot 2 the power splitting coefficient plays an major role in energy harvesting. The near user decodes the far user data in the first time slot. Then only near user can act as relay for signal to interference cancellation and decode the far user data correctly. To ensure this condition, the achievable data rate of near user should be greater than the far users target data rate. It should be mathematically represented as $S_{nf} > S_f^*$

Where,

S_{nf} = near user achievable data rate

S_f^*= far users target data rate

Let us substitute value of S_{nf} in above condition and solve for δ

$$S_{nf} = \frac{1}{2}\log_2\left(1 + \frac{(1-\delta)\alpha_f t_P |h_{sn}|^2}{t_P(1-\delta)\alpha_n |h_{sn}|^2 + \sigma^2}\right) > S_f^* \quad (30)$$

$$S_{nf} = \log_2\left(1 + \frac{(1-\delta)\alpha_f t_P |h_{sn}|^2}{t_P(1-\delta)\alpha_n |h_{sn}|^2 + \sigma^2}\right) > 2S_f^* \tag{31}$$

$$= \left(1 + \frac{(1-\delta)\alpha_f t_P |h_{sn}|^2}{t_P(1-\delta)\alpha_n |h_{sn}|^2 + \sigma^2}\right) > 2^{2S_f^*} \tag{32}$$

$$= \left(\frac{(1-\delta)\alpha_f t_P |h_{sn}|^2}{t_P(1-\delta)\alpha_n |h_{sn}|^2 + \sigma^2}\right) > 2^{2S_f^*} - 1 \tag{33}$$

Let's assume $2^{2S_f^*} - 1$ by τ_f, and solve for SINR for the far user.

$$\left(\frac{(1-\delta)\alpha_f t_P |h_{sn}|^2}{t_P(1-\delta)\alpha_n |h_{sn}|^2 + \sigma^2}\right) > \tau_f \tag{34}$$

$$(1-\delta)\alpha_f t_P |h_{sn}|^2 > \tau_f (t_P(1-\delta)\alpha_n |h_{sn}|^2 + \sigma^2) \tag{35}$$

$$(1-\delta)\alpha_f t_P |h_{sn}|^2 > \tau_f t_P(1-\delta)\alpha_n |h_{sn}|^2 + \tau_f \sigma^2 \tag{36}$$

$$(1-\delta)\alpha_f t_P |h_{sn}|^2 - \tau_f t_P(1-\delta)\alpha_n |h_{sn}|^2 > \tau_f \sigma^2 \tag{37}$$

$$(1-\delta) t_P |h_{sn}|^2 (\alpha_f - \tau_f \alpha_n) > \tau_f \sigma^2 \tag{38}$$

$$(1-\delta) > \frac{\tau_f \sigma^2}{t_P |h_{sn}|^2 (\alpha_f - \tau_f \alpha_n)} \tag{39}$$

$$\delta < 1 - \frac{\tau_f \sigma^2}{t_P |h_{sn}|^2 (\alpha_f - \tau_f \alpha_n)} \tag{40}$$

From above equation δ is less than 1, and we can modify the equation as given below

$$\delta < 1 - \frac{\tau_f \sigma^2}{t_P |h_{sn}|^2 (\alpha_f - \tau_f \alpha_n)} - \mu \tag{41}$$

Where μ is very small number.

CHAPTER 5

SIMULATION RESULTS

5.1 Cooperative Communication Network

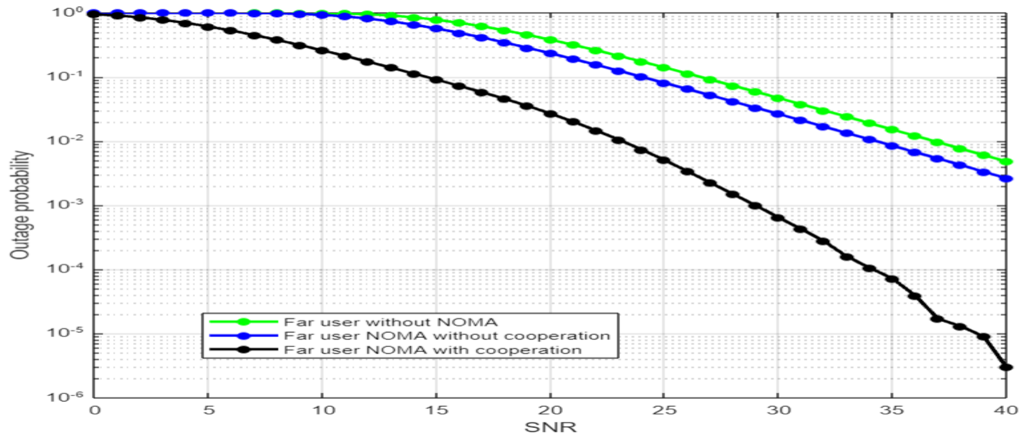

Fig 5.1 Performance Analysis Of Cooperative and Non Cooperative Network

Figure 5.1 shows the graphs of the outage probability for far users vs the SNR over the fading channel using cooperation, without cooperation, and NOMA approaches. By using the different approach, multiple plots of Far users are plotted. The figures demonstrate that NOMA-based cooperative systems have a lower outage probability than conventional cooperative systems and NOMA without cooperative systems.

5.2 Bit Error Rate in NOMA

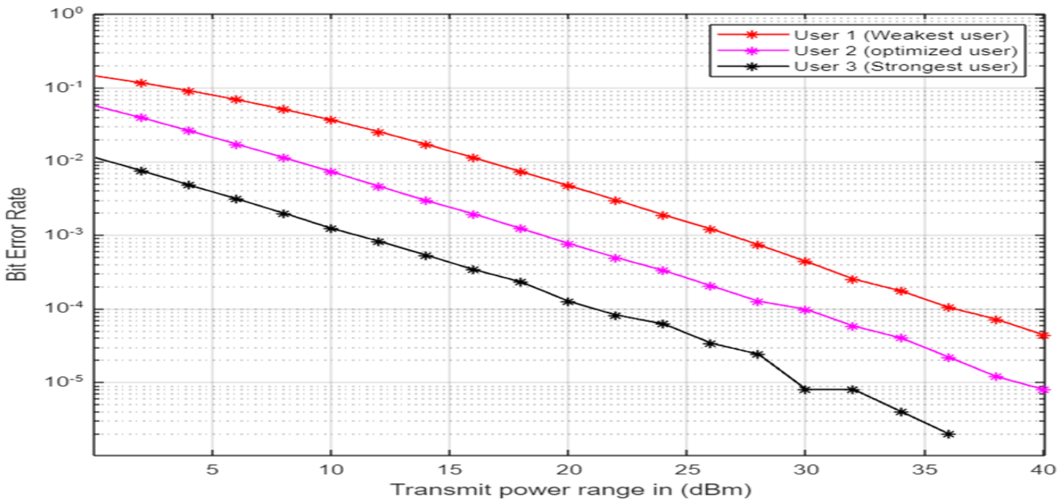

Fig 5.2 Bit error Rate In NOMA Analysis

From the Fig 5.2 shows that the user M_1 (Weak user) has the highest bit rate error among the three users because he suffers the most interference from the user M_2 (optimized user) and M_3(strong user). User M_2 suffers moderate interference due to user M_3. finally, the user M_3 is free from interference and has the lowest BER in the group. The BER performance is strongly affected by the power allocation scheme, more sophisticated power allocation Schemes further improvement in performance.

5.3 SWIPT

Next, let's implement our cooperative SWIPT NOMA network in MATLAB. For this simulation, let's set the target rate for both users as 1 bps/Hz. Also we are considering fixed power allocation with $\alpha_n = 0.2$ and $\alpha_f = 0.8$. As we saw in the post about power allocation, proper choice of target rates and α_n ,α_f values are required to make the fixed power allocation method work. Depending on the network parameters, I have optimized these values by trial and error. Better performance than this can be obtained by dynamic power allocation schemes.

First, let's plot the achievable rates for the near user and far user, given by equations (26) and (29). We will get a graph like this:

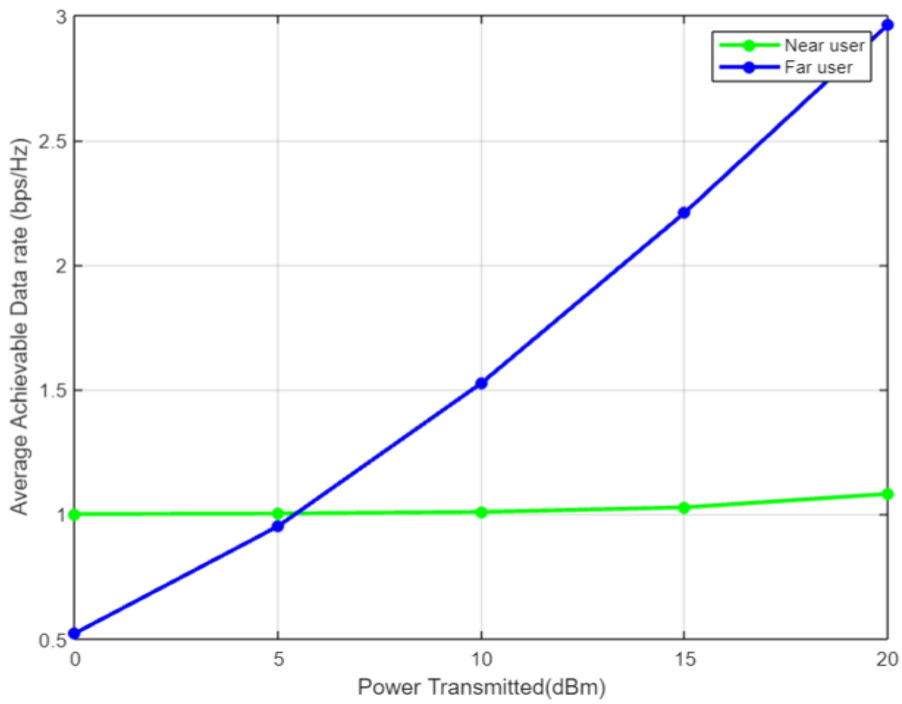

Fig 5.3 Achievable Data Rate of NOMA

As we can observe in Fig 5.3, the near user's rate is saturated at around 1 bps/Hz while the far user's rate increases. This saturation is due to energy harvesting. Once the far user's data rate is met at the near user, all the remaining power is harvested. Even if the transmit power is increased, the achievable rate at the near user is still limited due to the energy harvesting operation. But the upside here is that, the near user's target rate of 1 bps/Hz is not violated. Thus, this saturation in rate does not lead to much outage to the near user.As the transmit power increases, the amount of power harvested [as given by Eq. (27)] increases. Thus the amount of power with which the far user's data is transmitted in the second slot increases. This leads to increase in the far user's achievable rate.

From Fig 5.3, we may come to a conclusion that, since the far user experiences higher average achievable rate, he must have the least outage probability. But when we plot and observe the outage graphs, we see something that is totally opposite to our intuition.

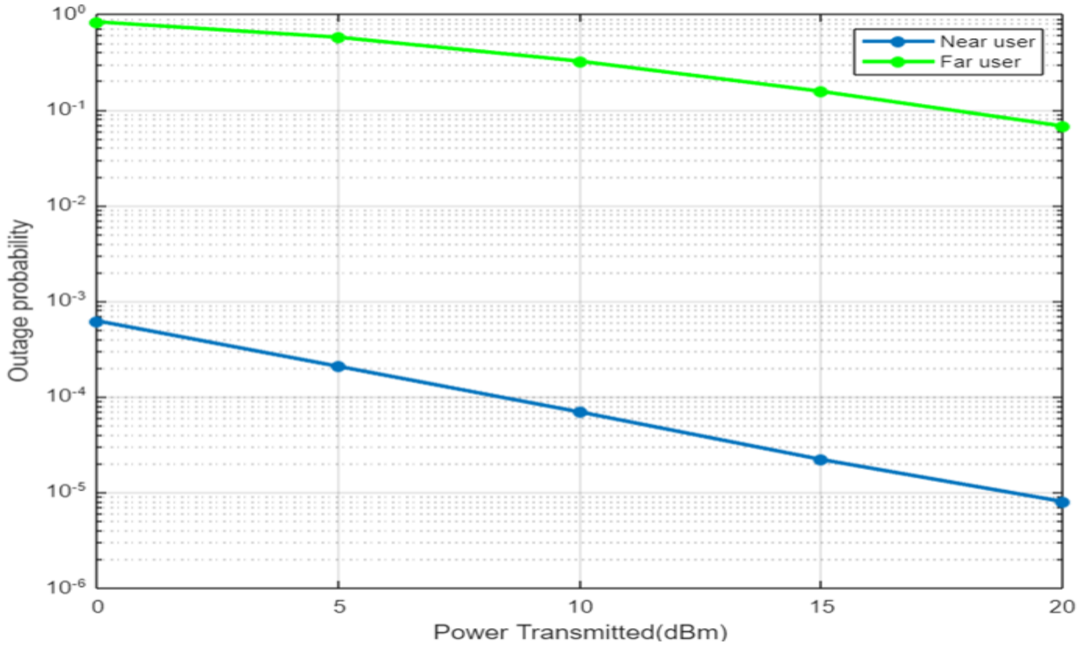

Fig 5.4 Outage Probability of NOMA

From Fig 5.4, we observe that the far user experiences much greater outage than the near user, although he experiences greater achievable rate on average than the near user. Why did this happen? This is because, in Fig 5.3, we are talking about the average performance. If we plot the instantaneous achievable rates of both the users, we will get a graph like this:

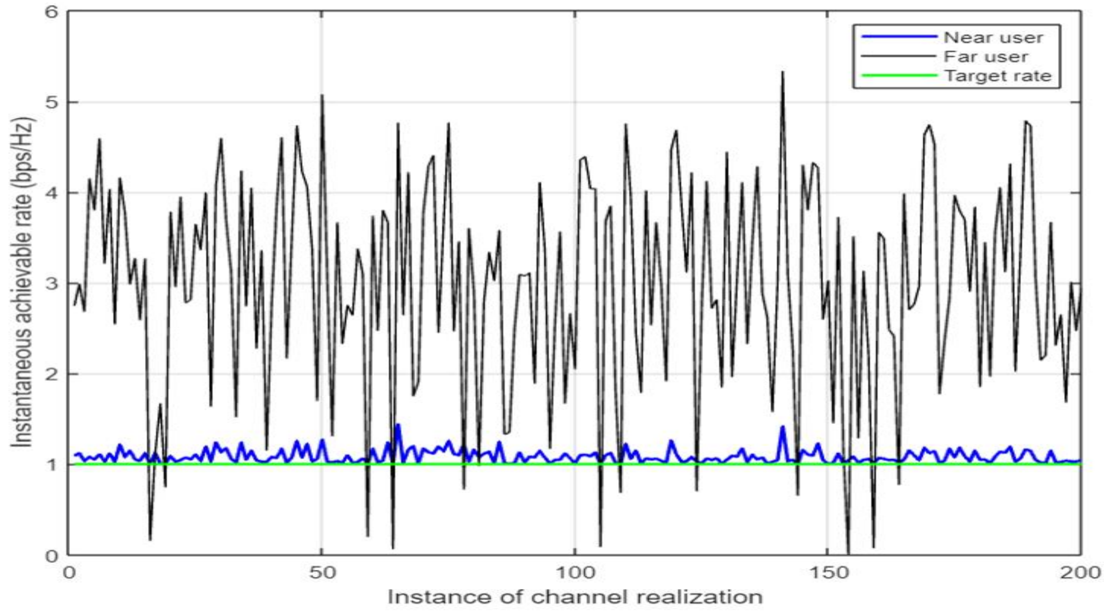

Fig 5.5 Data Rate after SIC analysis

Now we see why the far user has greater outage in spite of having greater achievable rate. Fig 5.5 is plotted for a transmit power of 20 dBm. We can see that the far user's achievable rate is centered around a value of 3 bps/Hz, which is captured in Fig 5.3 at 20 dBm. We can also see that the far user's instantaneous achievable rate falls below the target rate value quite a lot of times. As far as outage calculations are concerned, we don't care how greater the achievable rate is. We only count the number of times the instantaneous rate falls below the target rate. This fall is more frequent for the far user. Thus he has poor outage performance. But for the near user, although he has lesser achievable rate, it is greater than the target rate most of the time. This explains his better outage performance.

CONCLUSION

6.1 Conclusion:

A unique cooperative SWIPT aided NOMA transmission technique has been presented. The cooperative SWIPT NOMA in MISO and SISO instances, as well as the cooperative SWIPT NOMA in MISO and SISO cases, have been studied. The combined design of beamforming and power splitting has been explored in MISO instances. With the SDR approach, we have equivalently changed the stated issue and demonstrated rank-one optimality. Two-dimensional exploratory approach can be used to solve the reformulated issue to its global optimal solution. Due to the complexity of the two-dimensional exhaustive search, a SCA-based method was developed to efficiently generate at least a stationary point. Motivated by the possible applications, the cooperative SWIPT NOMA protocol design in SISO situations has also been studied. A GSS-based approach was provided to achieve the global optimal solution by demonstrating that the optimal value of the stated issue is unimodal with regard to the PS ratio. Furthermore, the best answer may be expressed as a semiclosed-form expression. Furthermore, we discovered that in SISO situations, both methods may converge to the unique global optimum solution. The simulation findings demonstrate that the proposed cooperative SWIPT NOMA method outperforms existing techniques, indicating that it is a potential option for providing IoT scenario capabilities.

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