Performance Analysis Of SWIPT NOMA

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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 power. 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.*

Keywords- NOMA, SWIPT, Energy-Harvesting (EH)

I. INTRODUCTION

Non-Orthogonal Multiple Access (NOMA) is 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 [13-15]. Based on the decoding techniques at the receiver side NOMA is broadly classified to two categories (i) Code division NOMA (ii) Power domain 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 [16-18]. To analyze NOMA schemes, we need a proper understanding on concepts like successive interference cancellation, cooperative communication network and super position coding.

1.1 **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 user2 data to the by relaying technique we need power to transmit. This can be done in two ways

i. 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.

ii. 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

II. SYSTEM MODEL

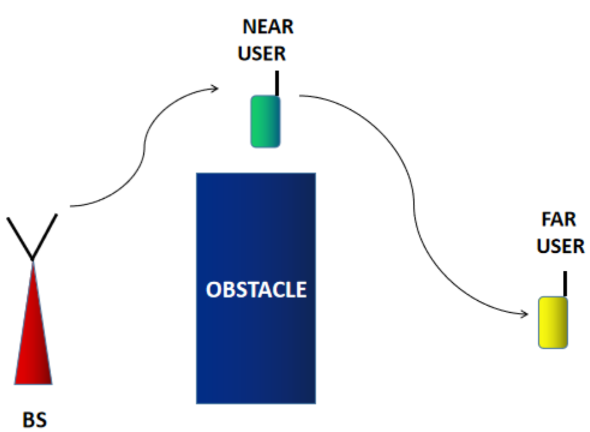

Fig 1: Network model of cooperative SWIPT network

We are considering down link 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.

2.1 Signal Model of Cooperative SWIPT NOMA in first TSL

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

$$d = \sqrt{tp}\left(\sqrt{\alpha_n}X_n + \sqrt{\alpha_f}X_f\right) \qquad (1)$$

Where, d = transmitted super position coded signal, Tp = the total power used to transmit the signal, α_n = the Rayleigh coefficient power allocated to near user, α_f = 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

$$d_n = \sqrt{tp}\left(\sqrt{\alpha_n}X_n + \sqrt{\alpha_f}X_f\right)h_{sn} + w_n \qquad (2)$$

Where, w_n AWGN with zero mean and variance = σ^2, η path loss component , h_{sn} Rayleigh fading coefficient between the BS and near user with zero mean and

Variance = $d^{-\eta}{}_{sn}$, 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

$$d_D = \left(\sqrt{1-\delta}\right)d_n + w_{eh} = \left(\sqrt{1-\delta}\right)\sqrt{tp}\left(\sqrt{\alpha_n}X_n + \sqrt{\alpha_f}X_f\right) + \left(\sqrt{1-\delta}\right)w_n + w_{eh} \qquad (3)$$

Where, w_{eh} = thermal noise introduced by the energy harvesting circuit , δ = fraction of power harvested by near user, tp = 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,

$$d_D = \left(\sqrt{1-\delta}\right)\sqrt{tp}\left(\sqrt{\alpha_n}X_n + \sqrt{\alpha_f}X_f\right) + w_{eh} \qquad (4)$$

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

$$S_{nf} = \frac{1}{2}\log_2\left(1+\frac{tp\left(1-\delta\right)\alpha_f \,|\, h_{sn} \,|^2}{p\left(1-\delta\right)\alpha_n \,|\, h_{sn} \,|^2 + \sigma^2}\right) \tag{5}$$

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,

$$S_n = \frac{1}{2}\log_2\left(1+\frac{tp\left(1-\delta\right)\alpha_n \,|\, h_{sn} \,|^2}{\sigma^2}\right) \tag{6}$$

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

$$tp_H = tp \,|\, h_{sn} \,|\, \delta\zeta \tag{7}$$

Where, ζ = power harvesting efficiency of the circuitry

2.2 Signal Model of Cooperative SWIPT NOMA in second TSL

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

$$d_f = \sqrt{tp_H}X_f h_{nf} + w_f \tag{8}$$

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

$$S_f = \frac{1}{2}\log_2\left(1+\frac{tp_H \,|\, h_{sn} \,|^2}{\sigma^2}\right) \tag{9}$$

2.3 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

$$\frac{1}{2}\log\left(1+\frac{tp\left(1-\partial\right)\alpha f \,|\, h_{sn} \,|^2}{tp\left(1-\partial\right)\alpha_n \,|\, h_{sn} \,|^2 + \sigma^2}\right) > S_f^* \tag{10}$$

$$\log_2\left(1+\frac{tp\left(1-\partial\right)\alpha_f \,|\, h_{sn} \,|^2}{tp\left(1-\partial\right)\alpha_n \,|\, h_{sn} \,|^2 + \sigma^2}\right) > 2S_f^* \tag{11}$$

$$1+\frac{tp\left(1-\partial\right)\alpha_f \,|\, h_{sn} \,|^2}{tp\left(1-\partial\right)\alpha_n \,|\, h_{sn} \,|^2 + \sigma^2} > 2^{2S_f^*} \tag{12}$$

$$\frac{tp\left(1-\partial\right)\alpha_f \,|\, h_{sn} \,|^2}{tp\left(1-\partial\right)\alpha_n \,|\, h_{sn} \,|^2 + \sigma^2} > 2^{2S_f^*} - 1 \tag{13}$$

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

$$\frac{tp\left(1-\delta\right)\alpha_f \,|\, h_{sn} \,|^2}{tp\left(1-\delta\right)\alpha_n \,|\, h_{sn} \,|^2 + \sigma^2} > \tau_f \tag{14}$$

$$tp\left(1-\delta\right)\alpha_f \,|\, h_{sn} \,|^2 > \tau_f\left(tp\left(1-\delta\right)\alpha_n \,|\, h_{sn} \,|^2 + \sigma^2\right) \tag{15}$$

$$tp\left(1-\delta\right)\alpha_f \,|\, h_{sn} \,|^2 - \tau_f tp\left(1-\delta\right)\alpha_n \,|\, h_{sn} \,|^2 > \tau_f\sigma^2 \tag{16}$$

$$tp\left(1-\delta\right)|\, h_{sn} \,|^2 \left(\alpha_f - \tau_f\alpha_n\right) > \tau_f\sigma^2 \tag{17}$$

$$\left(1-\delta\right) > \frac{\tau_f\sigma^2}{tp \,|\, h_{sn} \,|^2 \left(\alpha_f - \tau_f\alpha_n\right)} \tag{18}$$

$$\delta < 1 - \frac{\tau_f \sigma^2}{tp\,|h_{sn}|^2\,(\alpha_f - \tau_f \alpha_n)} \tag{19}$$

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

$$\delta = 1 - \frac{\tau_f \sigma^2}{tp\,|h_{sn}|^2\,(\alpha_f - \tau_f \alpha_n)} - \mu \tag{20}$$

Where μ is very small number.

III. SIMULATION RESULTS

3.1 Cooperative Communication Network

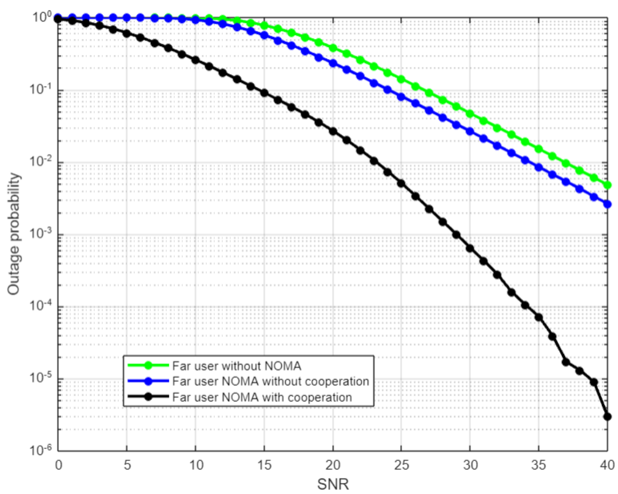

Fig.2 Performance Analysis Of Cooperative And Non Cooperative Network

Fig. 2 shows that the outage probability of cooperative NOMA is lower than the outage probability of user with non-cooperative NOMA and without NOMA.

3.2 Bit Error Rate in NOMA

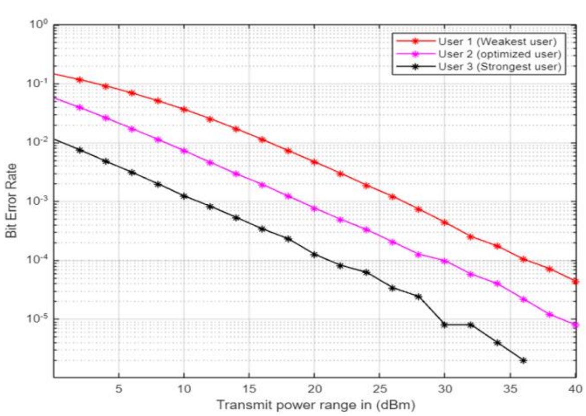

Fig 3 Bit Error Rate In NOMA Analysis

In Fig. 3, the user M_1 has the highest bit rate error among the three users because he suffers the most interference from the user M_2 and M_3. 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.

3.3 SWIPT

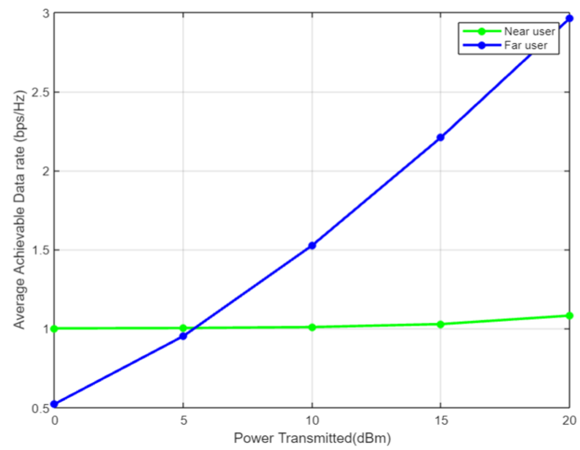

Fig 4Achievable Data Rate of NOMA

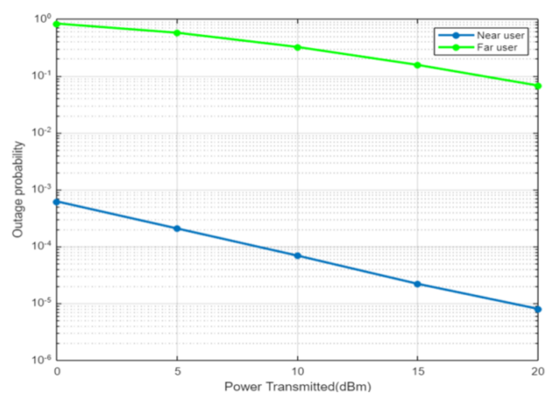

Fig 5 Outage Probability of NOMA

Fig.5 and Fig 6 show the plots of NOMA with SWIPT for achievable data rate and outage probability.

IV. 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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