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Security Aware Resource Allocation, Scheduling for Cognitive-NOMA Network

Shyleshchandra Gudihatti K. N., Tanuja R., S. H. Manjula, Venugopal K. R.

Abstract: The demand of real-time wireless communication is increasing drastically where users demand for better Quality of Service (QoS) for various applications. In order to satisfy the communication requirement, communication spectrum must be utilized efficiently and all the available resource must be allocated appropriately. Recently, the cognitive radio network has gained attraction in this field of communication due to its efficient nature of spectrum sensing and sharing. However, the interference between primary and secondary user is a tedious task which can degrade the performance. Hence, multiple-access schemes are introduced and Non-Orthogonal Multiple Access (NOMA) is considered as most promising technique. Several models have been introduced based on the combined model of CR (Cognitive Radio) and NOMA but dynamic resource allocation, channel state information and eavesdropping are the most challenging task in this field. Moreover, user scheduling is also an important parameter which improves the resource utilization. In this work, we have focused on downlink communication for CR-NOMA network and presented a new approach for resource allocation and user scheduling by presenting an optimization strategy. In order to address the eavesdropping attack, the secrecy transmission rate and secrecy capacity are introduced. Finally, simulation study is carried out and the performance of proposed approach is compared with the existing techniques which shows that the proposed approach achieves higher throughput and improve outage probability.

Keywords : Cognitive Radio, NOMA, Resource Allocation, Scheduling, Security.

I. INTRODUCTION

During last two decades, a tremendous growth of mobile devices and wireless communication has been noticed. Due to this growth, promising wireless communication techniques are introduced such as third Generation Partnership Project (3GPP), fourth generation (4G) networks, and the fifth generation (5G). According to 3GPP, the 5G networks are required to achieve higher capacity, higher spectral efficiency and higher connectivity [1]. Thus, 5G mobile communication technology has considered as a promising technique to enable the efficient communication system.

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* Correspondence Author
Shyleshchandra Gudihatti K. N.*, Department of CSE, University Visvesvaraya College of Engg, Bangalore University, Bangalore, India. Email: shyleshchandra444@gmail.com
Tanuja R., Department of CSE, University Visvesvaraya College of Engg, Bangalore University, Bangalore, India.
S. H. Manjula, Department of CSE, University Visvesvaraya College of Engg, Bangalore University, Bangalore, India. Email: shmanjula@gmail.com
Venugopal K. R., Vice Chancellor, Bangalore University, Bangalore, India. Email: venugopalkr@gmail.com

Moreover, system capacity is considered as a challenging task in these models which is caused due to the limited spectrum availability and underutilization of resources. On the other hand, the power, bandwidth and interference are also known as the parameters which limits the performance of these systems. Recently, multiple-access techniques are introduced widely to improve the wireless communication. In this field, Non-orthogonal multiple access (NOMA) has been envisioned as a promising technique to provide the improved system capacity and communication performance of the future wireless communication. However, NOMA systems are also included in 3GPP and Long Term Evolution (LTE) systems [2]. The main task of NOMA is to ask users for resource sharing such as frequency, spreading code and time slots. According to the working principle of NOMA, it utilizes power domain for multiple access which helps to serve numerous types of wireless users at different level of power [3]. Moreover, NOMA users employ successive interference cancellation scheme to mitigate the interference. The resource utilization is a tedious task which has a significant impact on these networks. A report by the Federal Communications Commission revealed that only 30% of the available licensed spectrum is utilized in United States [4]. Hence, a new technique is required which can help to improve the communication by addressing the following issues such as spectrum availability, spectral efficiency, network connectivity and bandwidth. Based on the aforementioned requirement and challenges, the Cognitive Radio (CR) technology has gained huge attraction in various fields like research community, industries and academia due to its nature to provide higher spectral efficiency and connectivity. According to the working of cognitive radio networks, it allows Secondary Users (SUs)/ unlicensed users to access the available licensed bands where adaptive transmission schemes can be incorporated to achieve the desired Quality-of-Service (QoS) without affecting the performance of Primary Users. However, the performance of CR can be degraded due to the co-channel interference which is generated by secondary user network. However, several studies have been carried out in this field such as cooperative scheme where secondary user is considered as relay which assists the signal transmission and also helps secondary users to access the licensed band. Zhao et al., [5] presented interference alignment based scheme for CR, similarly, cooperative spectrum sensing is also discussed in [6]. Authors in [7] presented overlay spectrum access mechanism, energy harvesting scheme is discussed in [8]. However, the primary and secondary networks are always operated in the same frequency band hence there exists the mutual interference between these two networks which affects the performance.

Based on the advantage of NOMA and CR, these two technologies can be combined together to gain the solution for improving the performance of the future wireless communication system. Several approaches have been introduced based on the combination of NOMA and CR. In [9], authors considered the NOMA for CR networks where outage probability is used for performance enhancement. Wang et al., [4] presented multi-objective solution for resource allocation using energy harvesting models in CRs. Moreover, cooperative schemes are also incorporated in the NOMA based CRs which shows a significant improvement in the network performance. In general, the NOMA based networks can be categorized as power allocation, joint power, scheduling and resource allocation. Zeng et al., [10] focused on power allocation and presented a new scheme for power allocation in CRNs using NOMA. A downlink and uplink power management protocol is also presented in [11]. Several works have focused on resource management such as Song et al., [12] employed NOMA for resource management in 5G systems. Energy consumption during resource allocation is also considered as a challenging task, hence Zhang et al., [13] presented energy aware resource allocation for NOMA based networks.

Efficient spectrum allocation is a promising model which can help to improve the resource utilization in wireless cellular networks. As discussed before, the cognitive radio technology is one of the most promising scheme which neglects overlay or underlay channel interferences and selects the efficient channels dynamically. Similarly, NOMA also improves the network performance by providing the multiple access scheme to the cognitive users. Several studies have been presented for optimal and secure transmission in cognitive radios. Li et al., [14] presented combined study for MIMO and CRNs where authors analyzed the spectrum efficiency and secrecy capacity maximization based on the cooperative jamming schemes. In [15] authors introduced a cooperative scheme for secure communication for four-node CRN scenario and presented a model to achieve the desired rate of communication for secondary users. In another study presented in [16] authors assumed that SU is not causing any interference to the PU and developed a cooperative transmission scheme for the considered PU and SUs.

Background and Motivation

As discussed before that the demand of wireless communication is increasing rapidly. In order to satisfy the increased demand of cellular/wireless communication Cognitive radio and NOMA has gained attraction from research community due to their nature of intelligently sensing the spectrum and utilization. NOMA is classified as power domain and code-domain. In the code domain NOMA, the sparse spreading sequence is used to mitigate the interference whereas the power domain NOMA take the advantage of successive interference cancellation and identifies the power of different receivers which allows users to share the same non-orthogonal resources.

According to the concept of CRNs, secondary users are allowed to utilize the free spectrum of primary user to improve the QoS. Similarly, in overlay communication strategy, secondary user cooperates with the primary user and relay node which helps to exchange the information, also support cooperative and sharing scheme. The data of secondary user is superposed on the primary users signal, further it performs amplify and forward to communicate among different users. However, recently the ubiquitous connectivity is increasing which demand for privacy and secrecy to the radio space. In this case, the security becomes the prime concern while designing the communication system. Moreover, the broadcast nature of these networks is also vulnerable to the eavesdropper attacks.

Contribution of the Work

In this paper, we also consider the NOMA based network and present a new approach for resource allocation and scheduling to minimize the overall delay of the communication system. The main contributions of this work are as follows:

- we present a new solution for resource allocation and user scheduling along with the data packet scheduling.
- A new solution is introduced for secrecy rate problem.
- A dynamic resource allocation model is presented without considering the channel state information of the users.

Organization:

Rest of the article is organized as follows: section II presents a brief discussion about recent technique of resource allocation, scheduling and other methods of improving the performance of NOMA- CR networks. Section III presents the proposed solution for NOMA-CR. Section IV presents a comparative simulation analysis where performance of proposed approach is compared with the existing techniques Finally, section V presents concluding remarks about this work.

II. LITERATURE SURVEY

In this section, we present a brief discussion about recent trends and techniques in the field of cognitive radio network, NOMA and combined cognitive NOMA networks. Several techniques have been introduced to improve the resource allocation and scheduling in the cognitive radio based networks. In conventional CR based wireless communication systems, the cognitive radio networks suffer from interference caused due to primary and secondary users. On the other hand, multiple access also gained attraction due to its nature to mitigate the interference and improving the performance for wireless communication systems. Recently, combined NOMA and cognitive radio network is considered as a promising technique to reduce the interference and improves the system performance. Resource allocation is a challenging task which affects the performance.

Liu et al., [17] presented a novel approach of resource allocation in NOMA based wireless networks. In this field of wireless communication, the interference cancellation schemes play important role. In this work, authors focused on improving the spectral efficiency and energy aware resource allocation. The complete work is divided into four phases where all successive interference cancellation scheme is analyzed.

In the next phase, the mutual interference between IoT and users are analyzed and a stepwise resource allocation model is presented.

The resource allocation task is modeled in an optimization process and the optimization problem is solved using deep recurrent neural network. Finally, experimental study is carried out in terms of spectral efficiency, connectivity, power and energy consumption.

Sun et al., [18] focused on the MultiCarrier Non-Orthogonal Multiple Access (MC-NOMA) and developed cooperative relaying scheme for resource allocation. According to the working concept of cognitive radio, the secondary users relay nodes to assist the communication between primary and secondary users. In this work, the main aim is to develop efficient approach for resource allocation which aim on the maximizing the system throughput by optimizing the power and subcarrier allocation for all primary and secondary users of the network. Also, this work focuses on the maintaining the QoS of the primary users.

Xu et al., [19] presented a combined model for sensing duration adaption, power allocation for cognitive Orthogonal Frequency Division Multiplexing (OFDM)-NOMA. This model integrates NOMA with the cognitive radio based Orthogonal Frequency-Division Multiplexing (OFDM) systems. The main aim of this model is to present a novel approach to boost the system capacity. In this work, authors modeled the capacity maximization problem as half-duplex problem for the CR based OFDM-NOMA network. In this network, each subcarrier is assigned two users for communication. Furthermore, the system capacity maximization problem is partitioned into three smaller sub-problems as: (a) power allocation, (b) sensing duration and (c) user scheduling. These problems are solved using optimization strategies.

On other hand, security is also considered as a prime component which affects the system performance. In these types of network various attacks can be detected but eavesdropping attack is the most common attack which can lead towards an inappropriate communication. Chen et al., [20] focused on the security issues of NOMA model and presented a physical layer security model for cognitive NOMA. In order to obtain this, the authors presented network coding based schemes where both type of techniques are considered as amplify-and-forward and decode-and-forward. Along with the network coding, the secrecy transmission rate is also presented to improve the security in the considered communication model and derived two metrics Secrecy Outage Probability (SOP) and Strictly Positive Secrecy Capacity (SPSC).

Nandan et al., [21] presented the advantages of combined cognitive radio network and NOMA models in the 5G communication. This work shows that the physical layer security is a challenging task in these models. In order to address the security related issues a beamforming scheme is developed which is known as Zero-Forcing-BeamForming (ZFBF) for two-cell based MIMO NOMA based cognitive radio networks. The main aim of this technique is to protect the information from eavesdroppers in current and adjacent cells. Moreover, this technique helps to analyze the number of transmitter using signal alignment for ZFBF scheme. Zhao et al., [22] studied about Maximal Ratio Combining (MRC) scheme for MIMO based cognitive radio networks. The main aim of MRC scheme is to improve the secrecy outage by selecting the transmit antenna. According to the secondary user, the antennas equipped by SU uses transmit antenna selection to establish the communication to another SU for transmitting the secret information whereas the receiver side, the MRC scheme is applied to process the multiple received signal at the receiver end. Zhang et al., [23] presented a study to improve the energy efficiency performance for NOMA based multiuser downlink communication system. First of all, an existing cognitive radio model is generalized with the help of NOMA where multiple antennas are introduced and also the number of PU and SU is also increased. Later, energy optimization is considered as main task for this generalized CR based NOMA to improve the QoS of each user. This problem is formulated as non-convex fractional programming problem which is solved using Sequential Convex Approximation (SCA) method.

Sun et al., [24] studied about the Multiple Input Multiple Output (MIMO)-NOMA based cognitive radio networks and identified that the power consumption is a serious issues in this field. Hence, in this work, authors have adopted power splitting architecture for each secondary user to minimize the power consumption. Moreover, identification of Channel State Inforamtion (CSI) is also a challenging task hence Gaussian CSI error model is also included to obtain the CSI uncertainity model. In this work, authors have mainly focused on two optimzation problems which are minimizing the transmission power and maximizing the energy harvesting. These issues are addressed by using beamforming and power splitting techniques. shylesh et al., [25] analyzed the review on spectrum management techniques, energy detection, energy efficient routing approaches and security techniques for Cognitive Radio Network.

The NOMA based cognitive radio networks are widely used in 5G communication technology. However, the resource allocation and optimization is a challenging task in this field. In order to overcome this issue, Liu et al., [26] presented a novel approach. According to the study presented in [26] authors show that the conventional cognitive radio systems have poor performance for resource allocation. To overcome this issue, PU-First-Decoding Mode (PFDM) and SU-First-Decoding Mode (SFDM) schemes are introduced to decode the NOMA signal at the receiver end.

III. PROPOSED SOLUTION FOR RESOURCE ALLOCATION AND SCHEDULING

In this section, we present a new approach to address the challenging issues present in the NOMA and Cognitive Radio Networks. In this work, we have adopted the NOMA based CR model as mentioned in [3]. The network model is presented as follows.

Network Model

In this work, we have considered two networks known as primary network where primary base stations and primary users are present. similarly, the secondary network is also considered which is based on the NOMA technology. The secondary network contains secondary users, secondary base station and also some eavesdropper. A network architecture is presented in Figure 1.

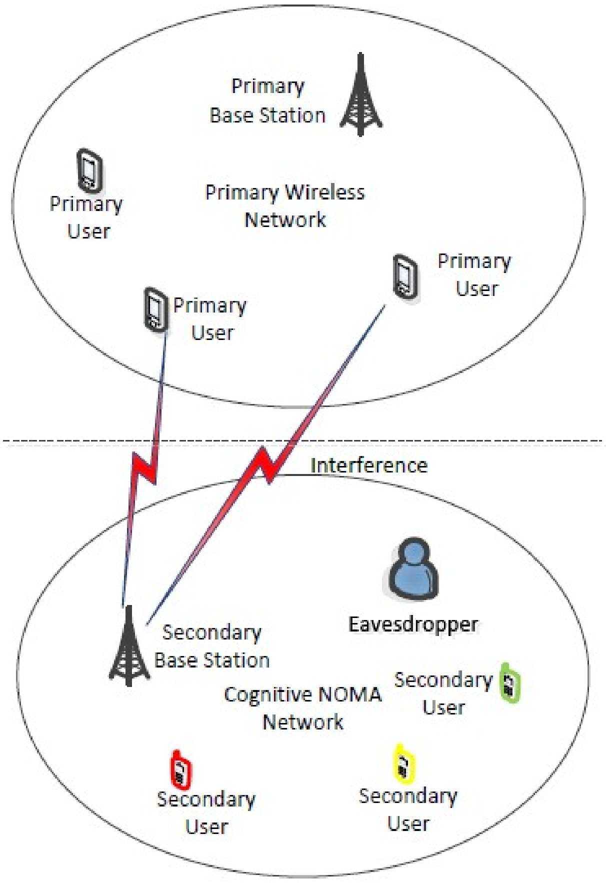

Fig. 1: NOMA and CR network architecture.

According to the Figure 1, where primary network has one primary base station and three primary users, also cognitive NOMA network is presented where a secondary base station, three secondary users and an eavesdropper are present in the network. These two networks are operated in the same frequency band hence there exists a mutual interference which degrades the network performance. According to the network model presented in [3], the available bandwidth is divided as orthogonal sub-channels at the physical layer of the deployed network and NOMA scheme is adopted for each orthogonal sub-channels. The Cognitive NOMA network has one eavesdropper which monitors and listens the transmitted signal. In this network, the wireless channel state information is perfectly known for transmission. Let us consider that the primary network has a group of various primary users which are denoted as $PU = 1, 2, ...N_{PU}$, likewise, the secondary users are also grouped as $SU = 1, 2, ...M_{SU}$. Due to the multiple access nature of NOMA, the secondary users are capable to access the available subs channels in an opportunistic manner.

The process of opportunistic sub-channel access helps to improve the resource utilization. The sub-channels in primary NOMA network are presented as to allocate the power in NOMA based CR, the secondary user which is near to the secondary base station by assigning less power and the secondary user which is located far from base station of secondary network, is allocated more power to establish and participate in the communication. It is also assumed that the secondary users have normalized channel gain and interference cancellation capacity. The communication time T is partitioned into equal partitions as t where the power gain of the current channel remains same in one time slot and varies in the next time slot. According to [3], the resource allocation process, resources are allocated in same way where allocated resources remains same in one time slot and vary in the next time slot. Let us consider that the total number of active secondary users S_k are present at the K^{th} sub-channel. Due to spectrum sharing nature of CR networks, the secondary users can share q_u sub-channel in the given time slot while performing the communication. Here, the secondary users are present in the same channel hence a small amount of interference is generated which affects the receiving signal, due to the interference, the receiving signal of m^{th} users at K^{th} sub channel can be expressed as

$$y_m^k = g_m^k \sum n_m^k + \sqrt{P^k_{M_{su}}}\, X_m^k \tag{1}$$

Where n_m^k denotes the additive white Gaussian noise present in the k^{th} sub-channel for m^{th} user, X_m^k denotes the symbols to be transmitted for m^{th} secondary user in the current sub-channel, g_m^k denotes the power gain of the current channel and $P^k_{M_{SU}}$ denotes the allocated power for m^{th} secondary user.

Each sub-channel is assigned with a bandwidth which is denoted as B_w . The current channel contains spectrum and the bandwidth of the channel spectrum is given as $\omega_s + (j-1)B_w$ to $\omega_s + jB_w$. During the communication between secondary Base station and secondary users, the interference is caused to the j^{th} sub-channel for n^{th} primary user, this interference is expressed as:

$$I_{mn}^{kj} = \int_{(j-1)B_w-(k-0.5)B_w}^{(j)B_w-(k-0.5)B_w} h_n^k \gamma(\omega) d\omega \tag{2}$$

where power gain of the channel is expressed by h_n^k for K^{th} channel during communication between the n^{th} primary user and secondary base station, ω denotes the NOMA signal and $\gamma(\omega)$ represents the power spectrum density (PSD) for each NOMA signal ω which can be expressed as:

$$\gamma(\omega) = T(\sin \pi\omega T / \pi\omega T)^2 \tag{3}$$

As discussed before, the cognitive NOMA network contains eavesdroppers which can affect the security of the network. In order to deal with these issue, we adopt the concept of Secrecy Transmission Rate Model to avoid the effects of Eavesdroppers. This approach is adopted from [3] however the method discussed in [3] does not consider the SNR criteria for the main channel and Eavesdroppers.

Hence, in this work we present SNR computation for both types of channels i.e. Eavesdroppers and main channel. This can be expressed as:

$$X_M = max_{t=1..M} P_{avg}/N_0 [h_{B_t}]^2$$ and

$$X_E = max_{s=1..M} P_{avg}/N_0 [h_{E_s}]^2 \quad (4)$$

Where X_M denotes the SNR for main channel and X_E denote the SNR for Eavesdropper channels. The secrecy rate in this network can be defined as:

$$S_c = \begin{cases} M_c - E_e = \log_2\left(\frac{1+\chi_M}{1+\chi_E}\right) if\ \chi_M > \chi_E \\ 0\ if\ \chi_M \leq \chi_E \end{cases} \quad (5)$$

Where M_c represents the channel capacity between user and Eavesdropper computed as $M_c = \log_2(1+X_M)$ similarly channel capacity of Eavesdropper is computed as $E_e = \log_2(1+X_E)$ Based on these assumptions the secrecy rate can be given as:

$$S_c = \log_2((1+X_M)/(1+X_E)) \quad (6)$$

Algorithm 1 Secrecy Rate algorithm

Input: Set of PU, Set of SU, sub-channels K^v, communication time slots, sub-channel sharing coefficient q_u

1: Begin

2:Deploy the network N □ (E, V) where N_{PU} primary users and M_{SU} secondary users are present

3:Let us consider a scenario of K^{th} sub-channel where S_k number of active users are present.

4:SU causes interference hence q the received signal is given as $y_m^k = g_m^k \sum n_m^k + \sqrt{P_{M_{su}}^k} X_m^k$

5:Each sub-channel has a bandwidth B w based on this bandwidth the channel spectrum can be given as $\omega_s + (j-1)B_w$ to $\omega_s + jB_w$

6:Compute the power gain Q and power spectrum density (PSD) as $\gamma(\omega) = T(\sin \pi\omega T/\pi\omega T)^2$

7:Measure the sub-channel interference for primary user as I_{mn}^{kj} using power gain and PSD.

8:SNR based channel representation for main channel and eavesdropper channels as: X_M , X_E for main channel and eavesdropper channel respectively.

9:Find the secrecy rate as S c which can be expressed as $S_c = \log_2((1+X_M)/(1+X_E))$

10:End

Problem Formulation for Resource Allocation

In this sub-section, we present the problem formulation for resource allocation and also secondary user scheduling is also presented for the NOMA based cognitive radio. In order to perform the scheduling, we introduce a scheduling variable given as $X_m^{fl_f}$ which indicates the packet scheduling to the secondary user. According to the proposed approach, if $X_m^{fl_f}$ is obtained as 1 that means the data packet l_f of the current data sequence, is assigned to the secondary user else if the value of $X_m^{fl_f}$ is 0 then the current data packet is not allocated to the secondary user mSU . Similarly for the data packet scheduling model, we also introduce a new variable for scheduling the secondary users of the Cognitive NOMA network. This variable is expressed as mk, should satisfy the condition as given in (9) for better scheduling. This condition is written as follows:

$$\sum \zeta_m^k \leq q_u \quad \zeta_m^k \square [0,1], \forall \square K^v \quad (7)$$

Moreover, according to the proposed solution, the maximum consumed energy by secondary users must satisfy the following energy constraint given as:

$$P_M^T \leq \frac{EB_m}{OT_m}, \forall \square M \quad (8)$$

where EB_m denotes the total available energy budget for secondary user and OT_m denotes the operation time for secondary user. This network shows that the primary base station causes interference which should not go beyond the threshold of the interference. This can be measured as follows

$$\sum \sum \zeta_m^k P_m^k I_m^k \leq I_{Threshold} \quad (9)$$

Now, this rate of packet scheduling must satisfy the transmission rate capacity of secondary users. This relationship can be expressed as:

$$\sum \sum X_m^{lf} r(l_f) \leq \sum R_m^k, \forall_m \square M \quad (10)$$

In wireless communication, the quality of the system depends on the quality of data received which can be characterized by the distortion of the data during transmission. It can be given as:

$$O_m = \sum \sum v_f^{fl_f} X_m^{fl_f} \quad (11)$$

Based on this assumption, the packet distortion problem can be presented as optimization problem which is expressed as follows:

$$\max_{\zeta_m^k P_m^k X_m^{fl_f}} \min(O_m)$$

where $s.t\ P_m^k \geq 0$ (12)

According to equation (12), we focus on minimizing the distortion of received data to improve the QoS along with the maximizing the user scheduling to improve the energy consumption performance.

The above mentioned problem is considered as a MINLP problem which contains power allocation, sub-channel allocation, user and packet scheduling variables.

Algorithm 2

Input: consider the deployed network from previous algorithm 1, and other parameters such as secrecy rate, channel conditions and interference rates.

1:Begin

2:Let us consider that we have a data packet l_f

3:To schedule the secondary user a scheduling variable is introduced as $X_m^{fl_f}$

4:The scheduling of the packet is obtained as f (x) then it represents that the packet is assigned to the secondary user or else packet is not assigned to the secondary user.

5:Similarly, secondary user is scheduled as $\sum \zeta_m^k \leq q_u$ where $\zeta_m^k \in [0,1], \forall \in K^v$

6:Scheduling is done based on the following energy constraints $P_M^T \leq \frac{EB_m}{OT_m}, \forall \in M$

7:Compare the signal interference with the interference threshold $\sum\sum \zeta_m^k P_m^k I_m^k \leq I_{Threshold}$

8:Establish the relation between packet scheduling and transmission rate capacity as $\sum\sum X_m^{lf} r(l_f) \leq \sum R_m^k, \forall_m \in M$

9:Find the packet distortion during communication as $O_m = \sum\sum v_f^{fl_f} X_m^{fl_f}$

10:Formulate the optimization problem to minimize the distortion and power consumption as $\max_{\zeta_m^k P_m^k X_m^{fl_f}} \min(O_m)$ where $s.t \; P_m^k \geq 0$

11:End

Packet and user scheduling

The proposed scheduling algorithm helps to allow multiple users to participate in communication for transmitting the data packets to the base station. Generally, a secrecy rate is predefined as R_s , if the secrecy capacity falls below to the predefined rate, secrecy outage occurs. During transmission of signal to the base station, the outage probability of the considered eavesdroppers can be computed as follows:

$$P_{out,i} = P_r(C_i^{sec} < R_s) \tag{13}$$

Based on the obtained secrecy from (6) the outage probability can be given as:

$$P_{out} = P_r\left(\max_{e_j \in E}(h^2) > \frac{h_{ib}}{2^{R_s}} - (2^{R_s} - 1)\frac{N}{2^{R_s} P_i}\right) \tag{14}$$

With the help of exponential random distribution and binomial theorem it can be expressed as:

$$P_{out,i} = 1 - \sum_{n=0}^{2^N - 1} \frac{(-1)_n^{\delta}}{1 + \frac{\sum_{e_j \in \delta_n} \sigma_{ib}^2}{2^{R_s}\sigma_{ie_j}^2}} \tag{15}$$

where β computed as $(2^{R_s} - 1)\frac{N_0}{P_i}, N_0$ denotes the the total eavesdroppers in the cognitive NOMA network. δ_n denotes n^{th} non-empty collection of δ, σ_b and σ_e denotes the channel gain of h_b and h_e (i.e. main channel and eavesdroppers channel). In this scheme, total M number of users participate to transmit to the BS hence the secrecy outage probability is computed by taking the mean of M users secrecy outage probability which can be computed as:

$$P_{out} = \frac{1}{M_{SU}} \sum_{i=1}^{M_{SU}} P_{out,i} \tag{16}$$

Later, we present the scheduling model where channel state information of M users is known and the CSI of N eavesdroppers is not known. Generally, the nature of eavesdroppers is passive in the network hence it is difficult to obtain the CSI of eavesdroppers. In this scenario, let us consider that the CSI of user-to-base station is known and the user which is having the highest channel gain is selected for transmission to BS, the scheduling for the user can be expressed as:

$$U_{schedule} = \arg_{i \in U}(h_{ib}{}^2) \tag{17}$$

where U is the number of users present in the current network, Eq. (15) shows that only main channels are considered for scheduling the users present in the network and also the CSI of eavesdroppers is not considered for allocation i.e. the CSI is not known. Let us denote the scheduled user by s. Thus, we can achieve the secrecy capacity of the scheduled users in the presence of total N number of eavesdroppers in the network can be computed as:

$$C_s^{secrecy} = C_{sb} - \max_{j \in E} C_{se_i} \tag{18}$$

C_{sb} represents the capacity of scheduled user to base station and C_{se} represents the capacity of scheduled user and eavesdropper. The C_{sb} and C_{se} can be computed as follows:

$$C_{sb} = \log_2\left(1 + (h_{sb}{}^2)\frac{P_i}{N_0}\right)$$

$$C_{se} = \log_2\left(1 + (h_{se}{}^2)\frac{P_i}{N_0}\right) \tag{19}$$

h_{sb} and h_{se} denote the channel fading coefficients for scheduled user to base station and scheduled user to eavesdropper, respectively.

With the help of (19) the secrecy outage probability for multi-user scheduling can be obtained as:

$$P_r\left(max_{e_j \in E}\left(h_{ie_j}^2\right) \succ \frac{\left(h_{ib}^2\right) - \beta}{2^{R_s}}\right) \quad (20)$$

By using total probability model, it can be rewritten as:

$$P_{out,new} = \sum P_r\left(max_{e_j \in E}\left(h_{ie_j}^2\right) \succ \frac{\left(h_{ib}^2\right) - \beta}{2^{R_s}}, s = i\right) \quad (21)$$

The above given equation is used for computing the new probability for secrecy outage probability. According to this, we consider the fading coefficient of the scheduled eavesdropper and secrecy outage probability of the base station. This probability is computed for varied number of eavesdropper. Hence, we achieve the optimal solution for the secrecy outage probability and also a multi-user scheduling algorithm is also developed to ensure the reliable packet delivery by avoiding the effects of eavesdroppers.

Algorithm 3

INPUT: CONSIDER THE PARAMETERS AND PROBLEM FORMULATED IN ALGORITHM 1 AND ALGORITHM 2.

1:Begin

2: Measure the current secrecy rate

3:Compare the secrecy rate with channel secrecy rate to find out the outage probability of eavesdropper as $P_{out,i} = P_r\left(C_i^{sec} < R_s\right)$

4:Compute the outage probability based on the secrecy rate and outage probability as given in Eq. (15)

5:Achieve the total outage probability for all users: $P_{out} = \frac{1}{M_{SU}} \sum_{i=1}^{M_{SU}} P_{out,i}$

6:Measure the secrecy rate for scheduling the users as $C_s^{secrecy} = C_{sb} - maxe_j \in EC_{se_i}$

$$C_{sb} = \log_2\left(1 + \left(h_{sb}^2\right)\frac{P_i}{N_0}\right), \quad C_{se} = \log_2\left(1 + \left(h_{se}^2\right)\frac{P_i}{N_0}\right)$$

7:The new secrecy rate for the user scheduling as $P_r\left(max_{e_j \in E}\left(h_{ie_j}^2\right) \succ \frac{\left(h_{ib}^2\right) - \beta}{2^{R_s}}\right)$ which considers eavesdropper and main channel.

8:End

IV. RESULTS AND DISCUSSION

In this section, we present a complete simulation analysis using proposed approach and compared the performance with existing techniques. The complete simulation parameters are adopted from [3]. The simulation parameters are presented in a given table 1. According to the given network configurations, we deploy a NOMA cognitive radio network which has 200 m radius. In this network, initially, we deploy 2 primary and 2 secondary users. The distance of primary user from primary base station is 300 m and the distance from secondary base station is 600 m. In the considered network, the path loss factor is 4 and that an Eavesdropper is present in the Cognitive NOMA network which is located 900 m away from the secondary base station. Total number of sub-channels are 32 and the length of the packet is assumed as 1024 bits. The interference power threshold between primary and secondary users is considered as 1×10^{-9} *W*.

Table 1: Simulation Setup Parameters

Parameter of the Cognitive NOMA	Considered Value Value
Network Area	200 m radius
Path Loss Factor	2
Number of Primary Users	4
Distance from primary BS	300 m
Distance from secondary BS	600 m
Number of Eavesdropper	1
Distance from secondary	900 m

The performance of proposed approach is measured in terms of secrecy throughput for varied interference power threshold, varied number of secondary users, and varied number of sub-channels. In this section, we present a comparative simulation analysis by varying the interference threshold power. In order to carry out this study, we consider 5 number of secondary users present in the secondary network with total 32 sub-channels. In this case, we have $P^{total} = 1$ and $P^{total} = 1.5$ to measure the performance, as given in [3]. The obtained performance is presented in figure 2. The above given figure shows the comparative performance in terms of network throughput for varied interference threshold power. As the interference threshold power increases the network throughput also increases but in the NOMA *P* = 1 and NOMA *P* = 1.5, the throughput remains unchanged when it reaches to its optimal power whereas proposed approach achieves better performance. The average performance of NOMA *P* = 1 is obtained as 2.53, NOMA *P* = 1.5 achieves the average throughput as 2.64 and proposed model achieves 2.80 as the average throughput performance.

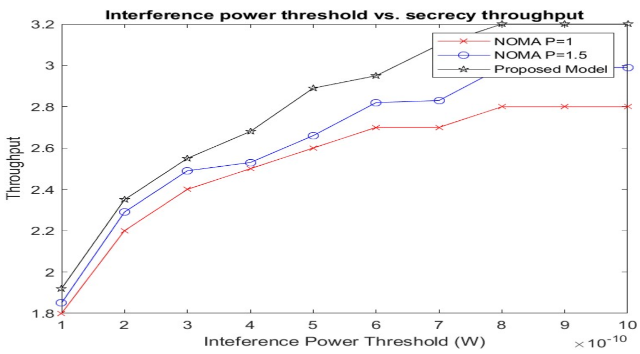

Fig 2 Interference power threshold vs. secrecy throughput

In the next phase, we have considered the sub-channel bandwidth as 20M Hz, total number of sub-channels are 32 and power for secondary user is 2.5W . the interference threshold power is considered as 3×10^{-9} . Based on these parameters we have conducted simulation and the obtained performance is compared with the existing technique [3].
The above given figure 3 shows a comparative performance in terms of throughput for varied number of secondary users in the Cognitive NOMA network. This study shows

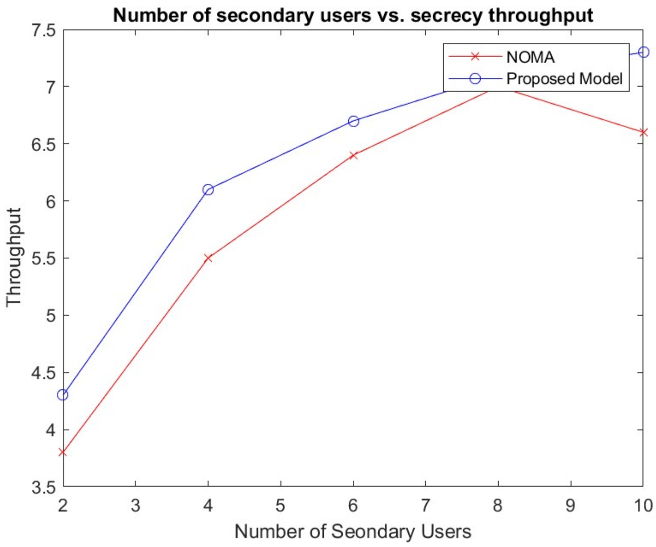

Fig.3 Number of secondary Users and throughput performance.

that as the number of secondary users increases the throughput also increases but due to the interference and delay in packet arrival leads to performance degradation in the network throughput whereas proposed approach able to handle this issue due to appropriate scheduling of the users. The average throughput is obtained using NOMA as 5.8 whereas proposed approach achieves the average throughput as 6.3. Similarly, we consider the performance measurement scenario for 4 number of secondary users where varied number of sub channels are considered for performance measurement. In this case, we have considered the interference power threshold as 2×10^{-9} . The obtained performance is depicted in Figure 4.

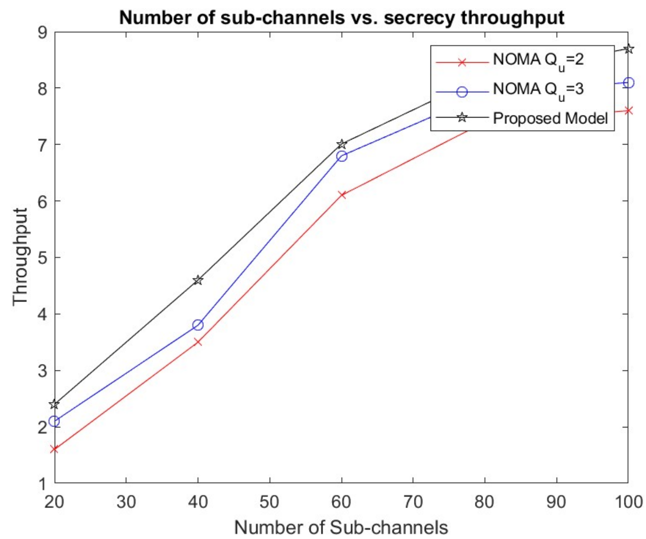

Fig.4 Number of sub-channels vs. secrecy throughput performance

The above given figure shows comparative study for varied sub-channels which shows that as the number of sub-channels are increasing, the throughput performance also increases. This simulation result shows that the average throughput performance using NOMA $Q_u = 2$ is obtained as 5.24 and proposed model achieves the average throughput performance as 6.18.

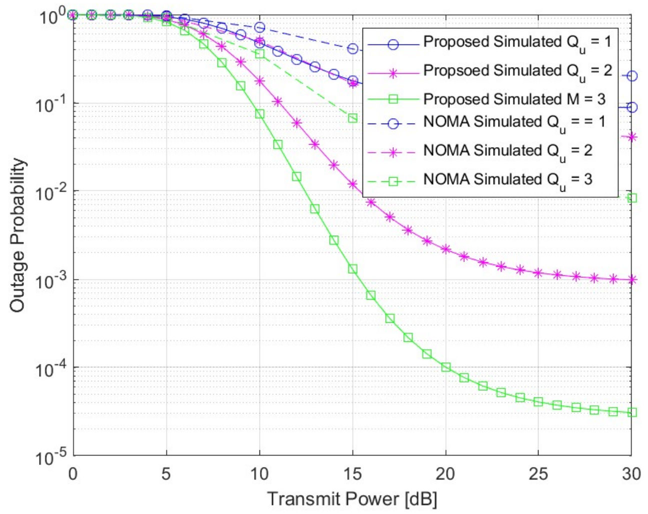

Fig.5 Outage probability for varied transmit power

On the other hand, we have evaluated the performance of proposed approach in terms of outage probability which helps to satisfy the security requirement of the system. In order to obtain this performance, we have considered 5 PU and *SU* with varied q_u transmit power. The obtained performance is depicted in figure 5 where performance of proposed model is compared with the existing NOMA model.
Based on the varied rate of channel sharing capacity, we evaluate the system performance in terms of SER vs. Transmit power.
The obtained performance is depicted in figure 6. In order to achieve this performance, we have considered power variations from 0 dB to 30 dB and channel sharing is also varied as from 1 to 3. The simulation study shows that the average symbol error rate is obtained as 0.5 for $q^u = 1$, 0.42 for $q_u = 2$ and 0.09 for $q_u = 3$.

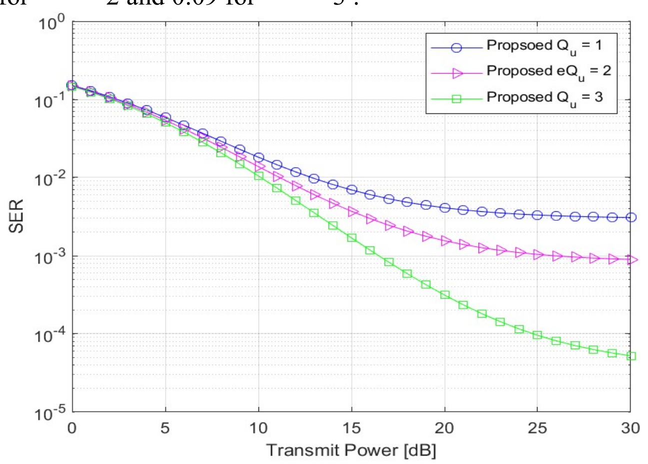

Fig.6 Symbol error rate vs. Transmit Power

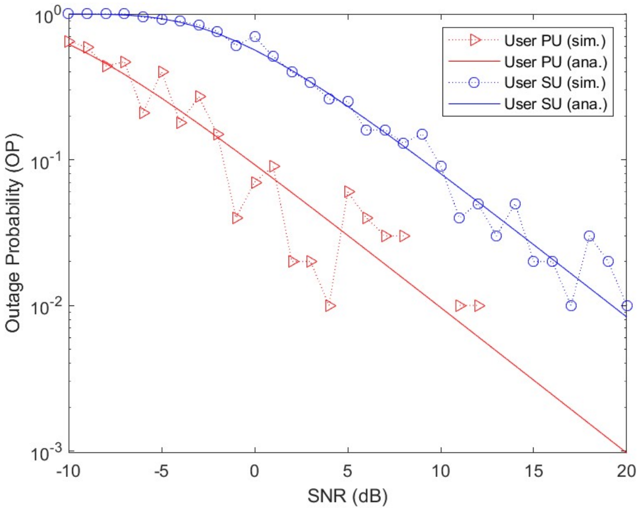

Fig.7 SNR vs. Outage probability

Based on this study, we conclude that the transmit power and channel sharing capacity are increasing, the symbol error rate decreases due to the efficient packet delivery between communicating users.

In the next phase, we compute the performance for varied number of SNR values and measured the outage probability for both primary and secondary users is depicted in Figure 7. In this simulation study, we have considered SNR values as -10 dB to 20dB. The obtained performance is measured in terms of simulated outage probability and analytical outage probability.

This study shows that the average simulated outage probability is 0.119 whereas the analytical average outage probability is obtained as 0.12 which shows that the proposed model achieves better outage probability for the considered primary users. Similarly, we have measured the performance for secondary users. The simulation study shows that the average outage probability of secondary user is obtained as 0.38 using analytical model whereas the simulation model achieves the outage probability as 0.40. The complete study shows a significant improvement in the outage probability of the system.

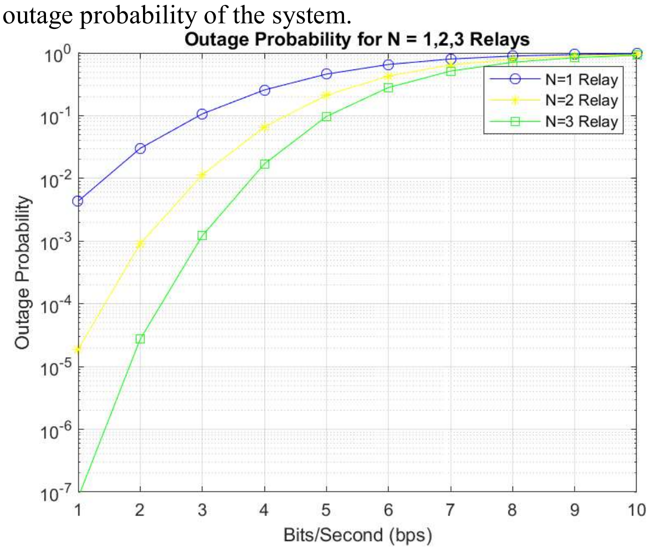

Fig.8 Outage probability performance

Finally, we present the outage probability performance of the network by considering different rates of data transmission with three relay node scenario. The obtained performance is depicted in figure 8. In this simulation, we have considered different rate of data packet transmission ranging from 1 to 10 bits/second. The comparative performance shows that the less number of relay node increases the outage probability of the NOMA-Cognitive radio networks. The average outage probability is obtained as 0.51, 0.39, and 0.33 for relay 1, 2 and 3 scenario.

V. CONCLUSIONS

In this work we have focused on the cognitive radio and NOMA based approach to improve the communication performance. CRN technology is widely adopted for spectrum sensing, sharing and allocation which improves the resource utilization, similarly, NOMA is adopted for interference cancellation. According to the proposed approach, resource allocation optimization problem is formulated along with the user scheduling. These optimization problems are examined and solved using the proposed scheduling algorithm. Moreover, in this work we have included an improved model of secrecy transmission rate which helps to mitigate the eavesdropping attack from the network. An extensive comparative simulation result analysis is conducted which shows that the proposed approach achieves better performance in terms of outage probability, throughput and symbol error rate (SER).

In future, meta heuristic approaches can be incorporated to achieve the best secrecy rate and outage probability along with the maximizing the energy efficiency and reduced complexity.

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AUTHORS PROFILE

Shyleshchandra Gudihatti K. N., is a full time Research Scholar in the Department of Computer Science and Engineering at University Visvesvaraya College of Engineering, Bangalore, India. He obtained Bachelor of Engineering in Computer Science \& Engineering from Mysore University. He obtained Masters degree in Computer Science & Engineering in B M S College, Bangalore from Visvesvaraya Technological University. His research interests are in the field of Cognitive Radio Network, Internet of Thing and Computer Network.

Tanuja R. is currently Assistant Professor in Dept. of Computer Science and Engineering at UVCE Bangalore University. She was awarded Ph.D in Computer Science from Bangalore University. Her research interests are in the field of Computer Networks and Security.

S. H. Manjula is currently Professor , Department of Computer Science & Engineering. University Visvesvaraya College of Engineering, Bangalore University, Bengaluru. She obtained B.E., M.Tech., Ph.D in Computer Science & Engineering Chennai. Her research interests are in the field of wireless sensor Network, Data Mining and Computer Network.

Venugopal K. R., is currently the Vice Chancellor, Bangalore University, Bangalore. He obtained his Bachelor of Engineering from University Visvesvaraya College of Engineering. He received his Masters degree in Computer Science and Automation from Indian Institute of Science Bangalore. He was awarded Ph.D in Economics from Bangalore University and Ph.D in Computer Science from Indian Institute of Technology, Madras. He has a distinguished academic career and has degrees in Electronics, Economics, Law, Business Finance, Public Relations, Communications,Industrial Relations, Computer Science and Journalism. He has authored and edited 64 books on Computer Science and Economics, which include Petrodollar and the World Economy, C Aptitude, Mastering C, Microprocessor Programming, Mastering C++ and Digital Circuits and Systems etc., He has filed 101 patents. During his three decades of service at UVCE he has over 640 research papers to his credit. His research interests include Computer Networks, Wireless Sensor Networks, Parallel and Distributed Systems, Digital Signal Processing and Data Mining. He is a Fellow of IEEE and ACM Distinguished Educator.