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Research Article

An Effective Paradigm for Selecting Channels in 6G Wireless Networks with Improved Quality of Service

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Abstract: Faster transmission of information and improvements to existing spectrum access procedures will define 6G wireless networks. The requirements of communication systems to serve the expanding demands for more services are critical because spectrum resources are quite limited. Due to the vast number of equipment, there is scarcely any spectrum left to offer future technologies. It provides access based on methods that use licensed spectrum to resolve spectrum crowding issues in 6G wireless networks and satisfy the future demands for wireless communications. This results in dynamic access, where licensed access must provide equitable allocation mechanisms that raise quality of service (QoS) while also posing minimum user interference. In this study, a channel selection algorithm for optimizing frequency, power, and penetration rate in a 6G communication system utilizing a technique that allocates frequency dynamically in a multi-user scenario is presented and evaluated. The proposed approach enables secondary users (SUs) to exchange relevant information prior to channel allocation so they can choose the channel with the highest probability of being available. A hybrid approach based on technique for order of preference by similarity to ideal solution (TOPSIS) and analytical hierarchy process (AHP) is used to perform evaluation and validation with the metrics of frequency usage, SU power consumption, and transmitted signal -penetration rate. Simulated outcomes show that the proposed productive channel allocation technique outperforms the traditional channel allocation strategies in terms of minimal frequency utilization, minimal power consumption, and minimal information loss.

Keywords: 6G Wireless Networks, Channel Selection, Dynamic Spectrum Allocation, QoS Optimization.

1. INTRODUCTION

There is no sector that can avoid the utilization of cellular connection and Internet of Things (IoT) as the usage of wireless equipment has reached its peak in recent decades. Anyone having a smartphone or a smart sensor is aware of how crucial wireless connectivity is to modern life. The concept that these equipment and devices are linked to the computer system changes the overall insight of internet as shown in Figure 1. These are capable of communicating with one another without the aid of humans, after all. In the era of developing telecommunications industry trends, one of the important elements in the adoption of the IoT standard is wireless sensor network. Due to the rise in cellular communications and the popularity of the IoT, mobile carriers consistently focus on enhancing the quality of service (QoS). In contrast to earlier cellular generations, 5th generation long term evaluation (5G-LTE) utilizes a significantly higher proportion of the radio frequency (RF) band that enables the 5G system to transfer data much faster with significantly lower latency [1]. The current capabilities of 4G/5G wireless networks allow high-speed transmission. However, none of them are fully equipped to manage the massive volume of data produced by mobile and IoT devices yet.

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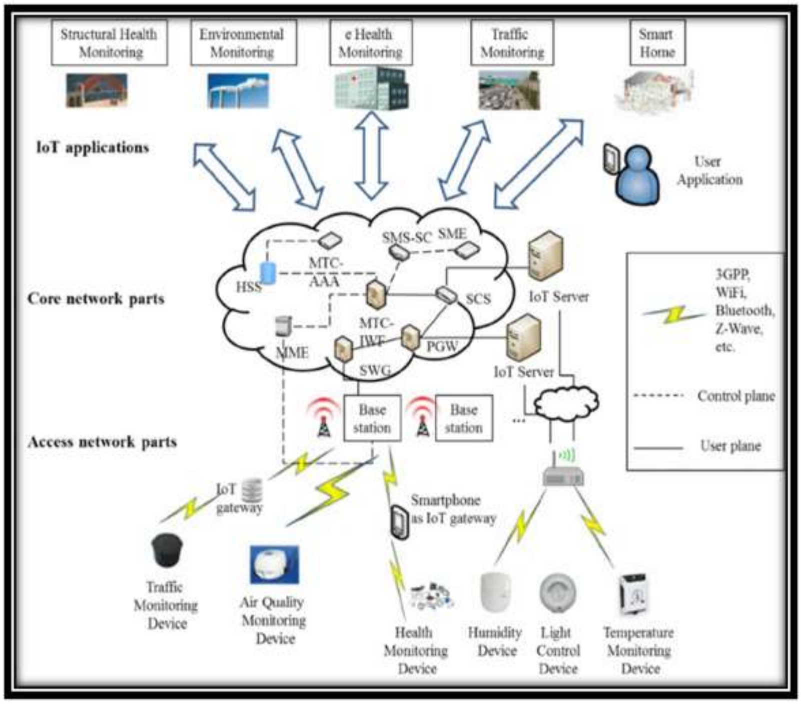

Fig. 1. IoT Architecture.

To address spectrum crowding issues and satisfying the rising needs for wireless technology, licensed frequency access is essential. To achieve dynamic access, the registered users adopt appropriate allocation techniques to improve QoS with the least amount of interference to other users. These characteristics will make cognitive radio (CR) an essential component of upcoming 6G wireless connections. Joseph Mitola [2] was the first who introduced the concept of cognitive radio network (CRN). Later, the CR has emerged as a strategy for resolving shortage difficulties by employing dynamic spectrum allocation. It might be characterized as listening, learning, establishing judgment, and reacting to current network environments. Figure 2 illustrates the CR process. Utilizing all CR Network's features is still challenging due to the limited accuracy of user decisions [3].

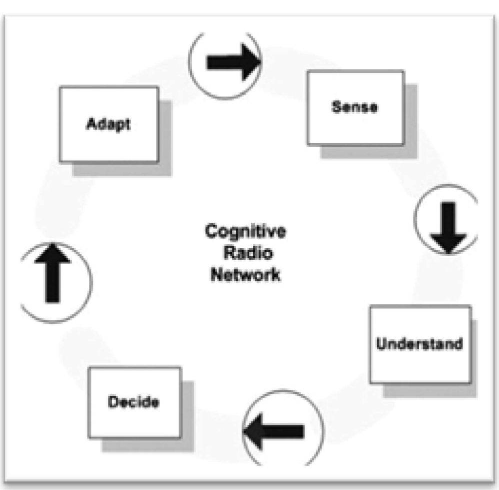

Fig. 2. CR process.

Among the most challenging parts of implementing next-generation systems is radio communication across numerous consumers. Users of CR must be capable of recognizing changes in the surrounding environment in order to collect measurements and expand their partial understanding of the current condition of the system as described in Figure 3. The acquired information can assist to explain the system's indefinite condition and will improve the decision efficiency leading to improve the effectiveness of the system. Each secondary user (SU) must consider channel quality in order to make channel access decisions. Each SU experiences poor performance due to collision among SUs if additional customers access the same frequency band, which is recognized as a negative network externality.

1.1. IoT Enabled CR

The majority of recent research has been towards connection, computation, and communication. The IoT is not considered to be able to handle potentials

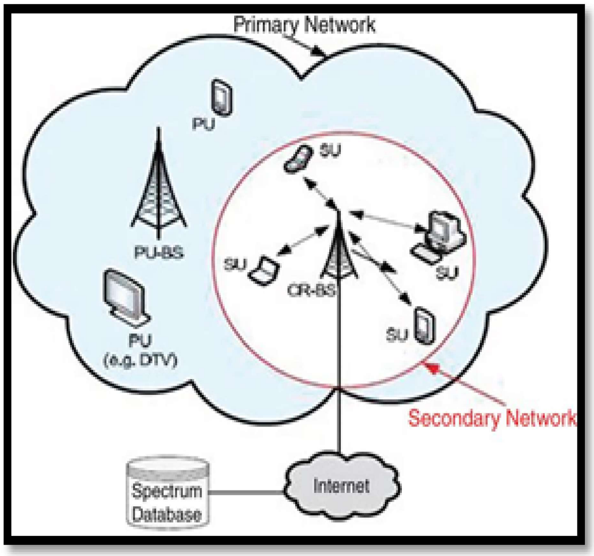

Fig. 3. Radio communication environment.

of growing problems in the absence of complete cognitive capabilities [1]. Therefore, including CR networks into the IoT is essential and the following factors will make it necessary:

- Future sensor communication will rely heavily on wireless technologies such as Bluetooth and Zigbee, etc., and due to its restricted range, the CRN-based IoT framework is to be emerged.
- The scenario will get worse for the enormous number of IoT objects since it would not be able to provide enough bandwidth to all of the devices. Additionally, the price of obtaining bandwidth will be high. This encourages novel solutions and CRNs could be the one.
- Secondary or unlicensed consumers can access the licensed spectrum when not in use by the licensed user or primary users (PUs).
- As more IoT devices are added, interference issues will arise due to their movement from one location to another. The CRN-based IoT devices have the ability to opportunistically seek for interference-free channels to improve transmission.
- In future, there will be expected billions of IoT devices that require constant spectrum operations. Conventional systems will not be able to deal this scenario and hence it would be necessary to change ordinary IoT devices into cognitively connected intelligent devices in order to take advantage of spectrum overcrowding problems.

The contribution of this work is as follows:

i. To increase the effectiveness of radio resource usage by enhancing the decision-making procedure, the dynamic channel selection technique for 6G wireless network is developed.
ii. The proposed hybrid approach efficiently manages the allocation of channels utilized by user equipment.
iii. Next, using the decision-making technique, the best channel is to be chosen based on higher probability of availability.

The overloading problem in 3rd generation partnership project LTE (3GPP-LTE) influencing both machine-to-machine (M2M) and human-to-human (H2H) communications was investigated by Beshley *et al.* [1]. A better priority algorithm design that enables interaction between H2H and M2M traffic and an improved radio resource allocation method was created for LTE and other wireless communications. This approach was based on adaptive channel bandwidth selection taking QoS requirements and priority traffic consolidation into account. An analytical hierarchy process (AHP) based on network interface was introduced by Kim and Kim [4] for interface selection and the suggested approach was expected to have a minimum delay, a high packet reception rate, a long network lifetime, and strong stability. An improved method for channels selection was presented by Thakur *et al.* [5], where access was made using an overlapping mechanism to boost the throughput of CR users. The complexities like random, enhanced, and customized allocation techniques were provided and the results showed the significant performance. A joint channel selection method for mobile CRNs based on link-oriented channel availability and channel-quality was reported by Rahman *et al.* [6]. The link-based probability of channel availability was computed using the distances between PU and CR users in a specific time interval. A useful channel allocation method that utilizes both link-oriented channel availability probability and link-oriented channel quality measurements was also developed to increase the throughput of the network.

The efficient free-channel selection method to enhance the QoS of cooperative CRNs was suggested by Jayakumar and Janakiraman [7]. To determine unused spectrum bands, a combined method employing multi-criteria decision-making approaches including efficient-free AHP called EFAHP and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was also developed by considering several parameters. Moreover, the performance evaluation was tested using calculation time and switching rate with numerous channel sizes, network services, and PU traffic rates. The suggested approach was claimed to outperform the traditional approaches.

An effective technique for channel assignment was developed by Li *et al.* [8] by considering the optimization of system throughput using channel idle probability, channel gain and spectrum access probability of SU. This approach with genetic algorithm could improve system throughput, transmission latency and channel loss for CR users. The probabilistic-based channel allocation strategy was suggested by Salameh *et al.* [9] in order to remove the need for a jamming detection stage or redundant network resources. A constrained method considering the characteristics of the CRN environment and the effects of jamming assaults was incorporated to determine the signal authenticity ratio. The results showed that there was a great enhancement in throughput as compared to conventional channel allocation methods. A novel method for dynamically choosing a realistic free spectrum band was discussed by Khan and Zeeshan [10]. A versatile adaptive modulation method called orthogonal frequency division multiplexing was then applied evaluating various parameters such as retransmission probability, achieved throughput and latency.

An idea of a decentralized system offering a lot of implementation freedom and very little transmission overload was developed by Wang *et al.* [11]. Each pair of SUs competes against the other SUs in a non-cooperative game to maximize their transmission correlation matrix. It is noted that if energy efficiency increases, then multi-user congestion decreases and the effects of erroneous spectrum status information are mitigated by the designed methodology. The work on channel adaptability and dynamic rate in a CRN was reported by Qureshi and Tekin [12] that handles various kinds of applications with changing dynamic spectrum accessibility and rate limitations. It is termed as a Bayesian learning problem by the experts. A volatile constrained Thompson sampling was also proposed which is a cutting-edge learning method that takes each channel-rate pair as a two-dimensional activity. It effectively optimizes action exploration and exploitation while minimizing regrets by taking advantage of the transmission success probabilities monotonicity. In comparison to other methods, it is revealed that volatile constrained Thompson sampling offers substantial improvement in throughput. The solution to the non-convex and dynamic power optimization problem was proposed by Rahimi *et al.* [13] as a hierarchical deep learning-based resource allocation framework. The offered learning automata determines the most effective remedy for the issue by employing a two-time scale-based sophisticated learning automaton. The suggested architecture might provide an improved performance under transmission power limits. Almasri *et al.* [14] independently assessed each channel opportunity without coordination or prior knowledge of the available channels. The priority-based access strategy could be useful both for fixed and dynamic users. However, it is lack of reliance on prior information or user collaboration in contrast to other collaborative methods.

The optimal resource allocation problem is one of the challenges in wireless networks. The traditional mechanisms aim to attain sub-million latency and can support several users but might experience overcrowding in highly populated areas. To address this issue with spectrum allocation in 5G and beyond, several approaches have been investigated to handle resource allocation problem. However, a little effort has been made to address the issue of spectrum overloading in 6G networks. Therefore, 6G innovation needs to be developed for the best spectrum usage. To increase the effectiveness of radio resource usage in 6G wireless networks, this work aims to design a hybrid channel selection mechanism for 6G wireless networks that allocates channels dynamically with a higher probability of availability, low latency, and highly responsive services.

2. PROPOSED RADIO RESOURCE ALLOCATION ALGORITHM TO ENSURE QoS

To satisfy the transmission demands, the base station (BS) first gathers information from the available resources and then examines it as shown in Figure 4.

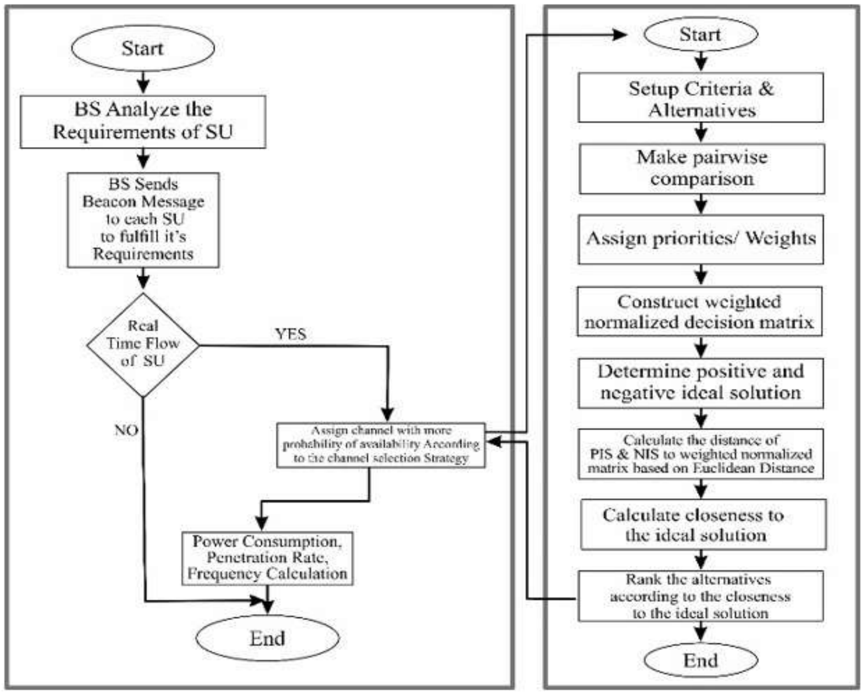

Fig. 4. Block diagram of the proposed strategy.

After analyzing the user's requirements, the BS allocates the smallest available bandwidth to the user. Each SU receives a beacon message from BS in order to fulfill their requirements. This procedure helps to determine the frequency-time constraints and the channel state. To assess whether it is real-time flow or not, the BS monitors the traffic streams. In the case of real-time flow, the BS assigns the channel with the higher chance of availability. On the other hand, if communication is not real-time, the devices are either sorted according to channel selection procedure or will be excluded by the BS. The process of choosing the resource order for mobile users is to be started. In this stage, a buffer is created and cleaned using the resource allocation mechanism and weighting coefficients. The CR users will successfully make use of a channel once find it. After this, frequency, power consumption and penetration rate are computed.

2.1. Hybrid Channel Selection Method based on Multi-Criteria Decision-Making (MCDM)

In this section, a combined channel allocation method is proposed. The weights are assigned using MCDMs to prioritize a number of evaluation parameters. The alternatives are ranked utilizing TOPSIS algorithm, while empty or channels with a greater possibility of being available are weighted with the AHP approach. Its input parameters include penetration rate, power, and frequency. The TOPSIS method uses the normalized vector in order to rank the accessible channels. The best channel will be selected depending upon its availability and SU will have access for data transmission. The final component of MCDM Method is the outcome, which is equivalent to a ranking matrix.

To calculate weights in the proposed hybrid approach, the following expression is used.

$$A = \begin{pmatrix} b_{11} & b_{12} & b_{13} & \cdot\cdots b_{1n} \\ b_{21} & b_{22} & b_{23} & \cdots b_{2n} \\ b_{31} & b_{32} & b_{33} & \cdots b_{nn} \end{pmatrix} \tag{1}$$

where, $b_{ii} = 1$, $b_{ji} = \frac{1}{b_{ij}}$

The decision matrix is normalized as:

$$N_{ij} = \frac{b_{ij}}{\sum_{i=1}^{n} b_{ij}} \tag{2}$$

The weighted decision matrix is calculated using expression given in equation (3). At this stage, the weights sum is also computed. If the sum = 1, the weights are given appropriately, otherwise, the weights are reassigned.

$$Z_i = \frac{\sum_{j=1}^{n} N_{ij}}{n} \quad \text{and} \quad \sum_{j=1}^{n} Z_i = 1 \qquad (3)$$

The all positive ideal and all negative ideal solutions are expressed as:

$$\begin{cases} I^+ = [R_1^{\;+}, \ldots\ldots, R_m^{\;+}] \\ I^- = [R_1^{\;-}, \ldots\ldots, R_m^{\;-}] \end{cases} \qquad (4)$$

Desirable or positive ideal measures are calculated as:

$$\begin{cases} R_i^{\;+} = \max\{w_{ij}\} \\ R_i^{\;-} = \min\{w_{ij}\} \end{cases} \qquad (5)$$

Undesirable or negative ideal measures are calculated as:

$$\begin{cases} R_i^{\;+} = \min\{w_{ij}\} \\ R_i^{\;-} = \max\{w_{ij}\} \end{cases} \qquad (6)$$

The degree of similarity to the ideal solution is computed as:

$$S_j^{\;+} = \sqrt{\sum_{j=1}^{m} \left(R_i^{\;+} - w_{ij}\right)^2} \qquad (7)$$

$$S_j^{\;-} = \sqrt{\sum_{j=1}^{m} \left(w_{ij} - R_i^{\;-}\right)^2} \qquad (8)$$

where, $j = 1, 2, 3, \ldots, n$

The exact closeness to the optimal solution can be determined as:

$$C_j^{\;*} = \frac{S_j^{\;-}}{S_j^{\;+} + S_j^{\;-}}, j = 1, 2, 3, \ldots, n \qquad (9)$$

2.2. Power Consumption

Using control messaging energy (E_m) at the start of each frame, every SU sends its status information to the gateway in t_f time. The pole i used the required amount of power during a control messaging operation is computed as:

$$E_m = P_{max} t_f \qquad (10)$$

Assume that the SU transmits at power P_{max} during the control message interval. After receiving the control message, the gateway shifts SU to allocated channels by utilizing the channel shifting power, E_{sp}. When channel j is assigned, the total energy spent by SU is calculated as:

$$E_{sp} = P_u T_u \qquad (11)$$

Where, P_u represents the energy spent by the SU while switching channels. The amount of power consumed during transmission is calculated as:

$$E_t = P_{max} |G_{i,j}| \tau_t \qquad (12)$$

The energy usage caused by circuit power C_p is as follows:

$$E_u = P_c \tau_t \qquad (13)$$

The total power consumed (E_{tot}) by the SU during data transmission can be calculated by adding equations (10), (11), (12), and (13) as follows:

$$E_{tot} = \left(P_{max} t_f\right) + \left(P_u T_u\right) + \left(P_{max} |G_{i,j}| \tau_t\right) + \left(P_c \tau_t\right) \qquad (14)$$

2.3. Penetration Rate

The penetration rate is expressed as the sum of information loss on all the channels which can be computed as:

$$P_r = \sum_{i=1}^{4} L(C_i) \qquad (15)$$

where, $L(C_1)$, $L(C_2)$, $L(C_3)$, and $L(C_4)$ are the information losses in the channels C_1, C_2, C_3 and C_4, respectively.

3. RESULTS AND DISCUSSION

3.1. Average Frequency

The comparison between AHP, TOPSIS, and proposed hybrid approach is depicted in Figure 5. When compared to TOPSIS and the proposed hybrid approach, the AHP decision-making model is recognized to have 25% and 38% higher frequency utilization, respectively, which results in lowest performance. Additionally, it has been

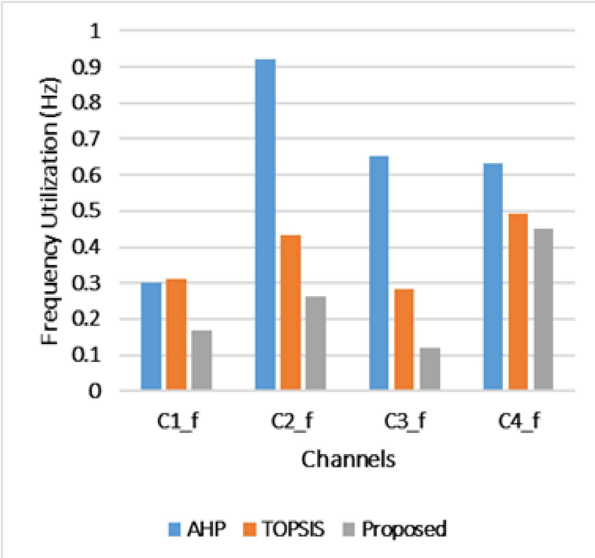

Fig.5. Frequency comparison.

determined that the TOPSIS algorithm performs better than the AHP method but worse when used 13% more frequency than the suggested technique. This indicates that the suggested hybrid technique, which dynamically assigns channels, uses the spectral band's least average to satisfy user equipment.

3.2. Power Comparison

The developed technique is more energy-efficient than AHP and TOPSIS techniques. In case of transmission on the allocated channel, AHP and TOPSIS may cause repeated spectrum handoffs resulting in more power consumption. In comparison to the proposed strategy, the AHP and TOPSIS both use 22% and 8% more power, respectively. The presented method attains a considerable improvement in power consumption and can transfer faster data with less power consumption, because of the dynamic channel allocation mechanism as illustrated in Figure 6.

3.3. Penetration Rate Comparison

The percentage of frame loss, which is determined by dividing the number of lost frames by the overall number of transmitted frames, is used to indicate the penetration rate [15]. The proposed approach offers better transmission with a small percentage of data lost. The penetration rate of the proposed technique is 26% smaller than AHP procedure and 15% lesser than TOPSIS as shown in Figure 7.

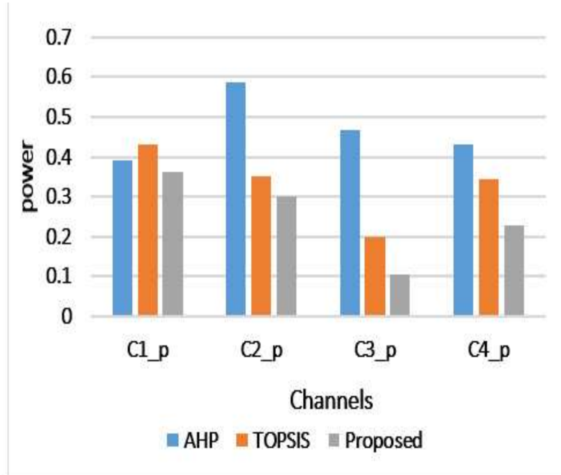

Fig. 6. Power consumption.

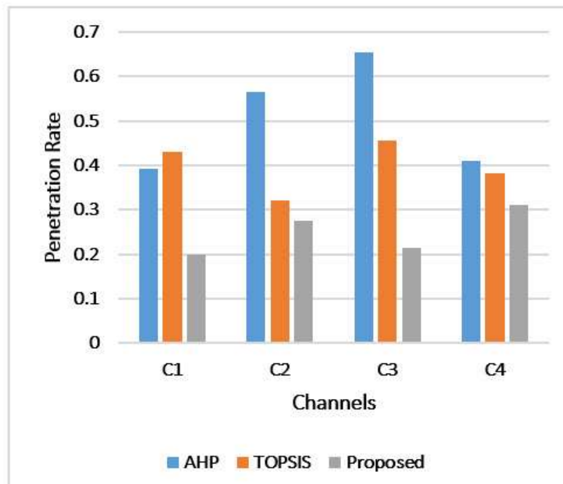

Fig. 7. Penetration rate comparison.

3.4. Discussion

3.4.1. *Parameters selection*

Based on an extensive review of existing 6G network standards and real-world implementation scenarios, the simulation parameters were chosen. By integrating our parameters with these requirements, we make sure that the model's results are appropriate and applicable to real-world network problems. This gives us significant insights about the viability and effectiveness of the suggested solutions.

3.4.2. *Determining real-time data*

We have enabled CR which can sense and adapt traffic according to the network condition. The

CRs examine the entire spectrum frequently in order to identify and assess the type of incoming traffic. It determines whether traffic is real-time or not by evaluating characteristics including data rate, latency requirements, transmission patterns, and the kind of application that is producing the traffic. Services like transferring files or email may be classified as non-real-time, but VoIP and live streaming which have strict latency requirements can be characterized as real-time.

3.4.3. *Scalability of the proposed framework*

By employing a dynamic allocation method that is adaptable to different network sizes and user densities, the proposed model is made to be scalable. Based on real-time network conditions, this approach continuously updates channel availability and optimizes resource allocation, as demonstrated by our experimental results.

4. CONCLUSIONS

This work proposed a channel selection technique that select channel with the probability of their availability. The channel which has more probability of availability or which is free for maximum time duration is selected according to the presented approach. The proposed method allocates channel bandwidth dynamically according to QoS requirements resulting in efficient frequency utilization, less power consumption and reduced information loss in the process of SU data transmission. The feasibilities and use cases of this hybrid channel selection method along with potential implications in real life includes smart cities, IoT, and autonomous vehicles. The proposed method considers only real-time traffic. Future research will concentrate on expanding the proposed strategy to manage different kinds of traffic that go beyond real-time, like bursty and delay-tolerant traffic. We intend to explore the integration of artificial intelligence methodologies to increase the flexibility and capacity for decision-making on channel allocation and selection to improve the methodology. Indeed, our methodology's key concepts can be applied to other cutting-edge technologies like mmWave and Li-Fi.

5. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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