SECURE AND SPECTRUM EFFICIENT FRAMEWORK USING BLOCKCHAIN FOR 5G HETEROGENEOUS SYSTEMS

S.Balamurugan

Director,Albert Einstein Engineering and Research Labs, Tamil Nadu,India. E-mail: sbnbala@gmail.com

Abstract - Mobile technology of the fifth-generation (5G) promises to deliver high-speed network services with dependable quality of service (QoS). Blockchain is a promising way to handle multiple resources such as spectrum usage and subscriber association across multidimensions. This could alleviate the underutilization of the spectrum and can help to increase the implementation of various 5G services. Millions of typical machines will provide widespread and omnipresent information sensing, collecting, and transmission in the future 5G paradigm. Given its traffic patterns and the spectrum constraint of machine-to-machine (M2M) communications, the cost-effective answer is to share an opportunistically little-used human-to-human (H2H) range of users with M2M devices. However, large-scale distribution in heterogeneous 5G networks has several obstacles, including lack of a triggering method, security breach, and vulnerabilities to privacy. This paper proposes a Secure and Spectrum Efficient Framework using Blockchain for 5G Heterogenous Networks (SSEB-HetNets) executed in two phases. First, H2H customers sign a spectrum sharing contract with the base station and earn money depending on their participation. Next, M2M devices are assigned a typical spectrum for maximizing the overall capacity. The intricacies of the operation have been developed for secure ranges, incentives, and effective spectrum distribution. The security and effectiveness of the proposed framework have been demonstrated using utilization value, amount of spectrum sharing, and power efficiency.

Keywords: Spectrum efficiency, Heterogeneous systems, Blockchain, 5G networks, Security.

1 INTRODUCTION

Modern computer and communications systems like 3G, 4G and 5G have been based on progress in microelectronic devices. 5G is the latest technology that enables the Internet of Everything (IoE) and leads its implementations in industry 4.0 and intelligent cities [1]. Industry 4.0 services require industrial standards were newly defined spectrum bands in 5G and current 4G bands are expected to be combined to fulfill growing interest. Moreover, a greater allocation of frequency and conservation of energy have been predicted in this next generation of information and communication technology [2].

5G calls for extra spectrum to create the ultra-low-latency communications systems and the growing need for a wide variety of ultra-high-speed broadband solutions [3]. With the introduction of mmWave in the future 5G technologies, a broader user base has been formed with additional frequency blocks[4]. The development and implementation of this emerging generation of mobile networks nevertheless face inevitable hurdles as wireless devices such as intelligent sensors, cell phones, and haptics evolve continually[5]. Most of these problems include massive volumes of data transmission, latency limitations, and high data rates. In addition, there is also a broad need for different applications. Some applications demand a smaller bandwidth, for example, while others ideally need a greater bandwidth with appropriate transmission and extensive coverage [6]-[7].

Therefore, 5G systems are deployed with a broad, continuous bandwidth, from MHz to GHz. No technology can nevertheless provide the accommodation of ultra-massive User Equipment (UEs) near-infinite frequency blocks [8]. Optimal utilization and distribution of spectrum resources are therefore essential. Diverse techniques have been suggested in recent years for evaluating spectrum capacity and increasing spectra utilization. Techniques such as dynamical spectrum sharing, multi-operator network sharing, random node allocation [9], analytical modeling of the roaming data rates, the connection-oriented density of UEs, and spatial distribution utilization have been employed. However, 5G calls for other mobile management technology (MMT) since it plans to link devices on a considerable scale[10].

The awareness of data on prior generation of cellular installations offers a good starting point for evaluating the need for strategies to improve spectrum use and efficiency [11]-[13]. According to expected figures, worldwide data traffic is projected to rise by 2.75 times and an average cell spectral efficiency by 1.5 times from 2018 to 2023. These estimations anticipate that 5G will have to be provided with substantial radio resources[14]. The generation of spectrum resources should also be considered an expensive element in which maintenance costs, installation, and administration should also be considered. Thus, a compelling and adequately shared, and allotted available spectrum must be used to avoid under-use of the spectrum [15].

The remaining document is organized as follows. Section 2 explores related works on the 5G heterogeneous system. Section 3 includes a comprehensive overview of the proposed Secure and Spectrum Efficient Framework using Blockchain for 5G Heterogeneous Systems (SSEB-HetNets). Section 4 consists of the analysis and findings obtained from the proposed model. The conclusion and possible studies have been outlined in Section 5.

2 RELATED WORKS

Support for high-bandwidth applications from fifth-generation (5G) networks with application scenarios has tremendous promise for a broad spectrum of new applications[16]. The 5G is intended to facilitate significantly unlimited use of artificial intelligence, autonomous driving, IoT, vehicle to everything (V2X), increased and virtual reality interaction, and true multimedia streaming, to mention a few. The 5G is intended to support a variety of applications [17]. The 5G wireless technology is regarded as a new radio (NR) that is a standardized 3GPP (3 GPP) project [18]. However, to achieve consistent speed, dependable and receptive wireless information systems, 5G NR must offer additional frequency bands (3-6 GHz). 5G NR also offers millimeter wave (mmWave), fast syncing over radio access systems (RANs), new over-the-air (OTA) interfaces, updated core and RAN architectures. 5G-NR must be continuously developed to enable ultra-reliability low latency communications (URLLC) [19].

In the non-self-standing mode, 5G-NR is intended to co-occur with other communication networks (e.g., 4G and Wi-Fi). Its carrier infrastructures can use the same non-licensed spectrum and boost network capacities below 6GHz [20]. Focused on URLLC and improved mobile broadband (eMBB) for accelerating speed and enabling OTA interfaces, 5G-NR Release 15 is the most recent physical layer standard for 5G-NR specification. However, the addition of improved mmWave spectrum in 5G-NR version 15 (up to 52.6 GHz) assures a high level of data transmission over OTA interfaces and frequency band of up to 800 MHz. Also, the spectrum is the essential enabler for additional physical layers, providing maximum data speeds for a downlink of up to 20 gigabits per second (Gbps) and uplinks of 10Gbps[21].

Release 15 of the 5G-NR contains specifications for different frequency ranges for various applications and network requirements due to the rapids of mobile and IoT endpoint users, high network coverage in remote and mobile areas, no impact on quality of service (QoS), or overloading of internet backbone capacity [22]. The cellular service providers (CSPs) may either purchase the allocated but expensive frequencies or permit dynamic spectrum sharing in collaboration to satisfy their customers' QoS needs. CSPs have to deal with legislation, centralization, security, stability, and diversity in the course of flexible spectrum sharing, despite cost-effective spectrum sharing solutions[23].

These problems encourage novel solutions for dynamic spectrum sharing. The shocking rise of blockchain environments provided opportunities for integrating distributed ledger technologies publicly accessible through peer-to-peer parallel processing networks [24]–[28]. Similarly, blockchain-based solutions in 5G and beyond networks can facilitate a distributed control of safe and flexible spreading of spectrum over diverse cellular networks [29]. Given the successful blockchain application to deal with everyday challenges, initial studies have suggested blockchain-based distributed solutions to share dynamic spectrums. According to the research carried out, none of the existing systems have applied the spectrum-sharing of CSPs with the permissible and intelligent contract (IC). A two-stage effective and safe spectrum sharing strategy for coexistence with H2H-M2M has been presented for 5G HetNets to resolve these difficulties.

3 SECURE AND SPECTRUM EFFICIENT FRAMEWORK USING BLOCKCHAIN FOR 5G HETEROGENEOUS NETWORKS (SSEB-HETNETS)

A two-stage, secure and efficient blockchain spectrum sharing structure has been suggested in 5G HetNets for H2H-M2M compatibility. The Base Station (BS) provides an incentive mechanism in the initial phase to stimulate H2H users with an under-used spectrum to pool the resources. By employing contract theory, the incentive mechanism under asymmetric information gets maximized. Then the transactions of spectrum sharing between the users of BS and H2H are ensured by using blockchain technology. The two-sided challenge of matching the spectrum allotment between H2H users and M2M devices is developed in the second phase, and both parties take into account their mutual preferences.

3.1 Proposed SSEB-HetNets Model

Figure 1 depicts the proposed model for a Secure and Spectrum Efficient Framework using Blockchain for 5G Heterogenous Networks (SSEB-HetNets). The suggested structure for coexistence between H2H and M2M in 5G HetNets has been seen in Figure 1. To prevent severe interference from the BS uplinks in the FDD scenario has been examined. In conjunction with the uplink data transfer, M2M communication plays a significant role. The proposed method has been extended to the Time-Division Duplex (TDD) paradigm, where the spectrum sharing in the uplink slots is allowed. In spectrum sharing, the prime users (PUs) are the human users, and secondary users (SUs) are mechanical devices.

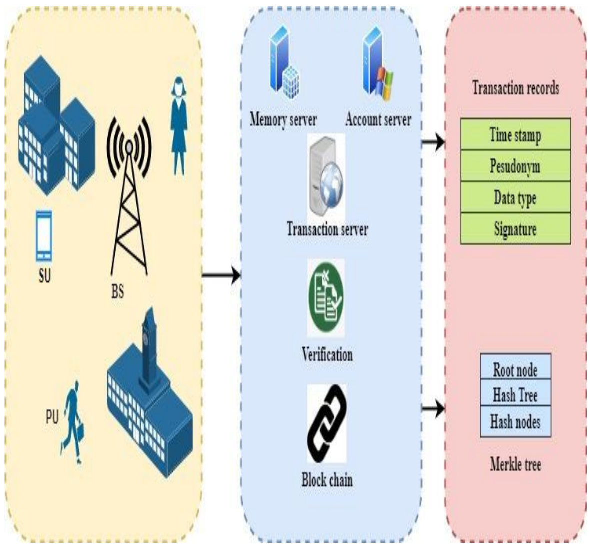


Figure 1 Proposed model for a Secure and Spectrum Efficient Framework using Blockchain for 5G Heterogenous Networks (SSEB-HetNets)

3.2 Achieving Secure Transmission in 5G Hetnets Using Blockchain

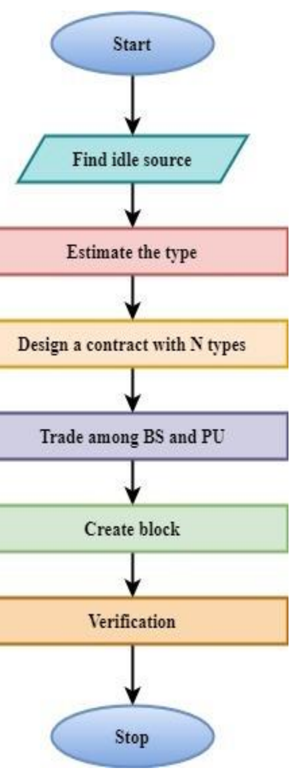
Blockchain is a distributed ledger that saves verifiable and permanent transaction records. In this project, the blockchain consortium is adopted, and the BS can serve as an approved node with solid computing capabilities. The spectrum sharing structure based on Blockchain has been illustrated in Fig. 1. The complete methods for the operation have been discussed below:

Step 1: Exchange of data between BS and PU - At first, both BS and PUs must enroll with competent authorities to get their certificates, public keys, and private keys. A PU utilizes its secret key for interactions and public access to verify their signatures shared with other permitted parties. The BS and PUs hold activity accounts to keep all the data. Electronic assets are held in digital wallets whose real locations are substituted by public keys to maintain anonymity. The BS designs a contract to encourage PUs. The contract includes a range of elements that specify the quantity of available spectrum and the appropriate reward. Each PU picks a contract item and distributes its frequency accordingly.

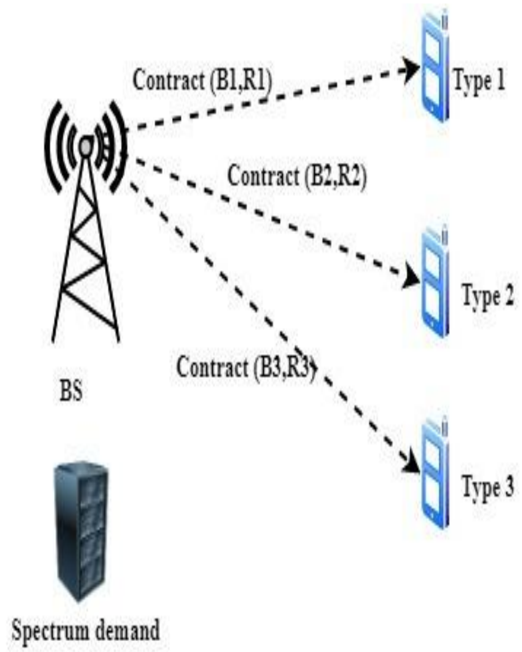
Step 2: Formation of block - A PU who has met the contract will get a spectrum token award from the BS to the address of the PU. Before structuring the transaction into blocks, the validity is confirmed, digitally signed, and encrypted. The BS then operates as the miner and contends using legitimate proof to generate a new block. The procedure involves mapping a hash function that fulfills a given challenge.

Step 3: Block Validation - The miner transmits it to other approved miners for verification when legitimate evidence of work has been mined. When a proportion of miners achieve an agreement, the new block will terminate in the existing Blockchain. The Blockchain is upgraded by appending the Merkle tree hash valves of current transactions, including the whole transaction block dataset, the root hash of the block header, and all branches along the root hash data block. The security of a decentralized consensus is ensured, as every miner independently verifies a new block based on the same criteria. If some fraudulent miners accept an incorrect block, the other honest miners that don't take the block will use their version. Therefore, the legitimate block branch is significantly longer than the illegal branch, and the miners only save the most significant chain and reject the shorter false chains.

3.3 Contract-based Spectrum Sharing



(a) Flowchart for contract-based spectrum sharing



(b) Framework for contract-based spectrum sharing

Figure 2 Contract-based spectrum sharing

Figure 2 shows the flowchart and framework for contract-based spectrum sharing. The theory of contracts provides a robust technique for addressing incentive optimization with asymmetry of knowledge. If the incentive is compatible with the proposed contract, private data should be disclosed. Figures 2a and 2b depict the contract-based incentive system. Given the value J , PUs may be sorted in ascending order into N types. PU types are referred to as $N = \{1,2, \dots. N\}$.

Let B_{min} and B_{max} indicate the lowest and higher limits for all PUs to share the spectrum. The interval $[B_{min}, B_{max}]$ is then divided into N subintervals of the same length, and the n^{th} sub-interval is set to PU type N. Under asymmetry of data, the BS does not know the actual PU type and can only assess its statistical data based on historical knowledge. The N contract items have been created for N types instead of supplying the same contracted item for PUs of different sorts. The projected item for the PU type has been given as (B_N, R_N), in which the spectrum (i.e., the bandwidth) and the reward are denoted by B_N and R_N, respectively.

3.4 Common Spectrum Assignment for Maximizing the Overall Capacity

Figure 3 shows the flowchart for matching-based spectrum sharing to maximize the overall capacity.

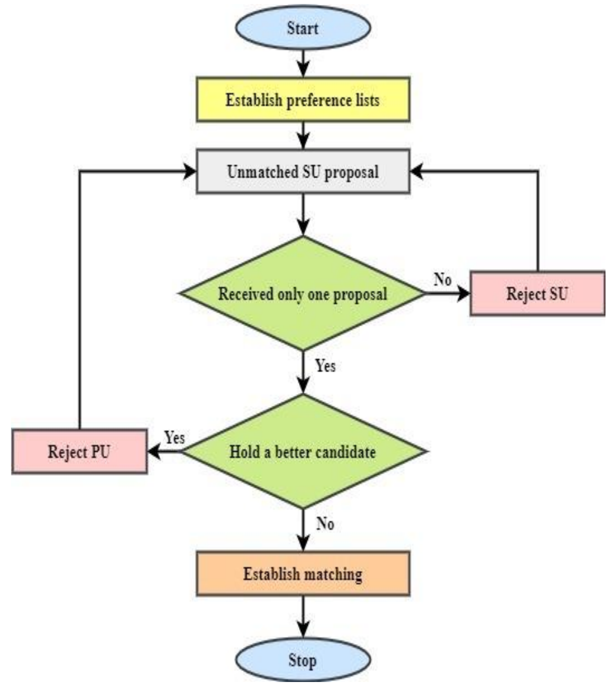


Figure 3 Flowchart for Matching-Based Spectrum Sharing to Maximize the Overall Capacity

The problem of spectrum allocation is that there exists a single one-to-one match involving PUs and SUs in origin. So, a stable matching strategy described resolves this difficulty of one-to-one matching. The following steps are involved in this approach:

Step 1: Establishment of the preferential list: Firstly, it is necessary to construct preference lists of both PUs and SUs. The PU preferences to SUs are determined using interference with the co-channel. SUs with little interference is preferred instinctively. In comparison, the transmission rates represent the preferences of an SU for PUs. Due to the same volume of data, the SU's transmission time is inversely proportionate to the SU's transmission rate. Consequently, the choices for the transmission rate also lead to a reduced delay for SUs. Then, putting all SUs (or PU's) into a decreasing order depending on the choices, a PU preferences list (or SUs) has been obtained.

Step 2: Proposal and rejection of SUs: Each unparalleled SU provides a PU with the highest rating in its preference list in each iteration. The PU compares the current SUs suggested with the SU maintained in the previous versions. The PU maintains just the favorite SU and does not accept the remaining SUs.

Step 3: Preferential Update and matching: After every iteration, the refused SUs are deleted from their preferred lists by the corresponding PUs. The methods in step 2 will then be repeated in the following iteration. This iteration will continue, or certain SUs have been rejected by all PUs until the maximum number of iterations is achieved. Finally, matching between SU and PU will be obtained.

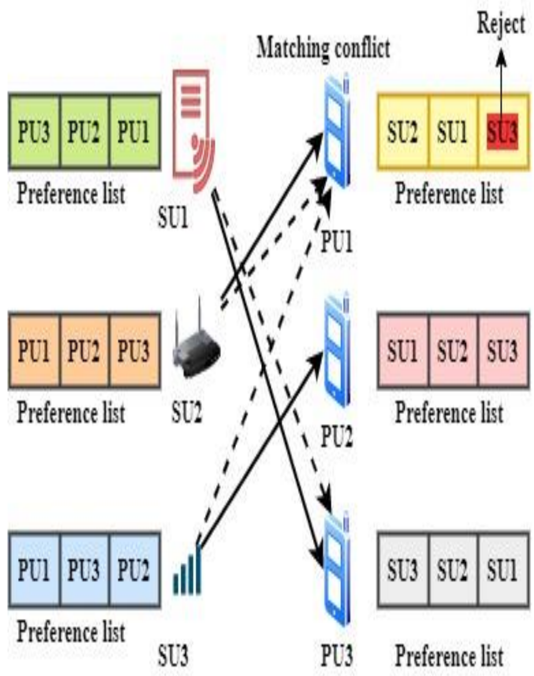


Figure 4 Scenario of the Matching-Based Spectrum Sharing for Maximizing the Overall Capacity

Figure 4 depicts the scenario with 3 PUs and 3 SUs for the matching-based spectrum sharing to maximize the overall capacity. Initially, SU1 offers only to PU3. So, there is a straight matching between SU1 and PU3. PU1 receives an offer from both SU2 and SU3. PU1 accepts the matching response from SU2 and rejects SU3's request after verifying its preference list. As a result, SU3 eliminates PU1 from its list and offers an appeal to PU2, and matching between SU3 and PU2 is established.

4 RESULTS AND DISCUSSION

The amount of spectrum sharing and utilization of PUs and SUs have been analyzed regarding PU type, contract items, and power, respectively. The following parameters have been used for simulation and analysis using Matlab software. Simulation parameters to analyze the performance of the proposed SSEB-HETNETS have been shown in Table 1.

Table 1 Simulation parameters to analyze the performance of the proposed SSEB-HETNETS

Parameters	Values
Number of PUs	30
Number of SUs	10-30
Contract items $\boldsymbol{N}$	20
PU distribution type	Uniform
Minimum bandwidth $\boldsymbol{B_{min}}$	3MHz
Maximum bandwidth $\boldsymbol{B_{max}}$	5MHz
Cell radius	500m
Transmit power	30dBm
Noise power	-110dBm

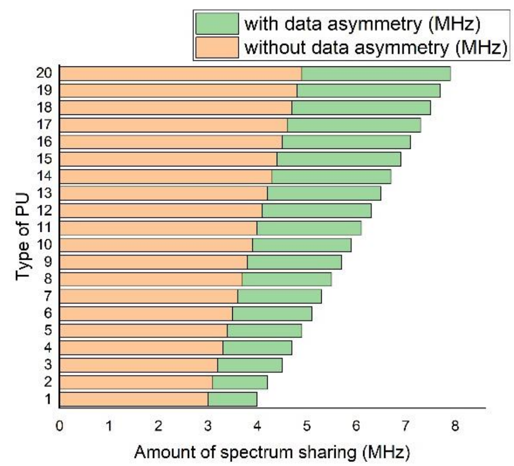


Figure 5 Amount of spectrum sharing against types of PUs using the proposed SSEB-HETNETS

Figure 5 shows the amount of spectrum sharing against types of PUs using the proposed SSEB-HETNETS. Each PU must share all its resources for the ideal contract without asymmetric data. In comparison, data asymmetry has a significantly lower fraction of resources. Thus, asymmetry of information allows more spectrum to the PU's and safeguards them from overuse. In other words, a BS can create a flawless contract without asymmetry to remove all unused spectrum of PUs. It is also noted that the difference between the quantity of asymmetric information with and without PU-type knowledge reduces, which suggests that the suggested system may successfully encourage higher type PUs to split the spectrum under data asymmetry. All PUs with a type below the threshold value will not accept the contract because of the restrictions on spectrum sharing. The underused spectrum of relatively high PUs is therefore not adequately utilized. The total number of pooled resources obtained from the suggested system is 1.801 times better than the random scheme given in [29].

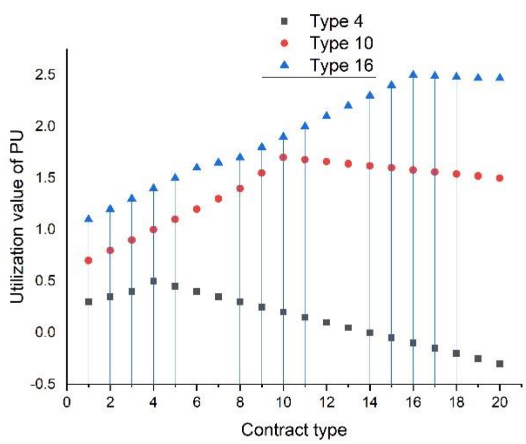


Figure 6 Utilization value of PUs against various contract types using the proposed SSEB-HETNETS

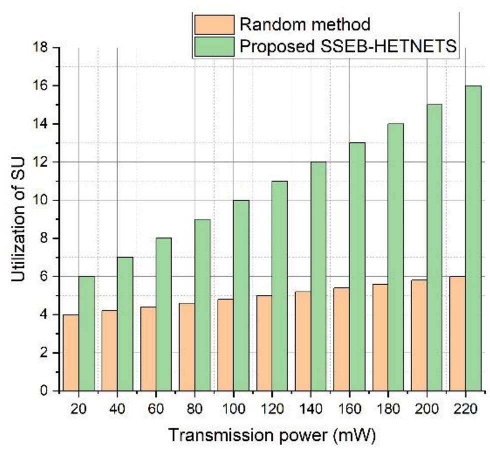


Figure 7 Utilization value of SUs against transmission power using the proposed SSEB-HETNETS

Figure 6 illustrates the type 4, 10, and 16 PU utilities compared with various contract elements. Simulation results show that higher PU utilization is always greater than a smaller PU, given the identical contract element. Moreover, it is noticed that only if the contract element is picked, the PU utilization can be maximized. For example, the type 10 PU achieves the maximum utility when selecting the type 10 contract item. The derivative contract, therefore, provides incentives for PUs and may successfully generate concealed PU information. Due to IC and monotony limitations, the same result applies to other types also.

Figure 7 shows the utilization value of SUs against various contract types using the proposed SSEB-HETNETS. The suggested system is always more helpful than the random matching method given the same transmission power. The power usage of the proposed method is also less than that of the random matching method [29] to attain the same efficiency. This is because the SUs choose a spectrum with better channel gains and fewer interruptions, which means that they need less power consumption, based on Shannon theory, to the same transmission rate.

5 CONCLUSION

This paper proposes a Secure and Spectrum Efficient Framework using Blockchain for 5G Heterogenous Networks (SSEB-HetNets) executed in two phases. First, H2H customers sign a spectrum sharing contract with the base station and earn money depending on their participation. Next, M2M devices are assigned a standard spectrum for maximizing the overall capacity. The intricacies of the operation have been developed for secure ranges, incentives, and effective spectrum distribution. The security and effectiveness of the proposed framework have been demonstrated using utilization value, amount of spectrum sharing, and power efficiency. The pooled resources obtained from the suggested system are 1.801 times better than the random scheme. Simulation results also show that higher PU utilization is always greater than a smaller PU, given the identical contract element. The power usage of the proposed method is also less than that of the random matching method and provides better efficiency.

References

[1] G. Zhang et al., "Spectrum Allocation and Power Control in Full-Duplex Ultra-Dense Heterogeneous Networks," IEEE Trans. Commun., vol. 67, no. 6, pp. 4365–4380, 2019.

[2] M. K. Maheshwari et al., "Directional Discontinuous Reception (DDRX) for MmWave Enabled 5G Communications," IEEE Trans. Mobile Computing, vol. 18, no. 10, pp. 2330–2343, 2019.

[3] O. Semiari et al., "Inter-Operator Resource Management for Millimeter Wave Multi-Hop Backhaul Networks," IEEE Trans. Wireless Commun., vol. 16, no. 8, pp. 5258–5272, 2017.

[4] S. Park et al., "An Evaluation Methodology for Spectrum Usage in LTE-A Networks: Traffic Volume and Resource Utilization Perspective," IEEE Access, vol. 7, pp. 67863–67873, 2019.

[5] Cisco visual networking index: Global mobile data forecast update 2017-2022,Tech. Rep., 2019. Available online: https:// www.cisco.com/c/en/us/ solutions/collateral/serviceprovider/ visual networking-index-vni/white-paper-c11-738429.pdf

[6] D. Wu and N. Ansari, "A Cooperative Computing Strategy for Blockchain secured Fog Computing," IEEE Internet of Things J.,vol.7,no.7, pp. 6603 - 6609, 2020.
[7] S. Aggarwal et al., "Blockchain for Smart Communities: Applications, Challenges and Opportunities," J. Network and Computer Applications, vol. 144, pp. 13–48, 2019.
[8] W. S. H. M. W. Ahmad et al., "5G Technology: Towards Dynamic Spectrum Sharing Using Cognitive Radio Networks," IEEE Access, vol. 8, pp. 14460–14488, 2020.
[9] V. Adat et al., "On Blockchain Enhanced Secure Network Coding for 5G Deployments," Proc. 2018 IEEE Global Commun. Conf. (GLOBECOM), 2018.
[10] G. Praveen et al., "Blockchain for 5G: A Prelude to Future Telecommunication," IEEE Network,vol.34,no.6, pp. 106–113, 2020.
[11] G. Sagirlar et al., "Hybrid-IoT: Hybrid Blockchain Architecture for Internet of Things — Pow Sub-Blockchains," Proc. 2018 IEEE Blockchain Int'l. Conf., pp. 1007–16, 2018.
[12] R. H. Tehrani et al., "Licensed Spectrum Sharing Schemes for Mobile Operators: A Survey and Outlook," IEEE Commun. Surveys Tutorials, vol. 18, no. 4, pp. 2591–2623, 2016.
[13] Ateya, A. A., Muthanna, A., Makolkina, M., & Koucheryavy, A., "Study of 5G services standardization: specifications and requirements", 2018 10th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2018.
[14] J. Sachs et al., "Adaptive 5G Low-Latency Communication for Tactile Internet Services," Proc. IEEE, vol. 107, no. 2, pp. 325–49, 2019.
[15] Liu, Q., Han, T., & Ansari, N.,"Learning-assisted secure end-to-end network slicing for cyber-physical systems", IEEE Network, vol.34,no.3, pp.37-43, 2020.
[16] Nguyen, D. C., Pathirana, P. N., Ding, M., & Seneviratne, A., "Blockchain for 5G and beyond networks: A state of the art survey", Journal of Network and Computer Applications, vol.166,2020.
[17] Alhosani, H., ur Rehman, M. H., Salah, K., Lima, C., & Svetinovic, D. ,"Blockchain-Based Solution for Multiple Operator Spectrum Sharing (MOSS) in 5G Networks", 2020 IEEE Globecom Workshops (GC Wkshps, 2020.
[18] Yang, C., Li, J., Guizani, M., Anpalagan, A., & Elkashlan, M. ,"Advanced spectrum sharing in 5G cognitive heterogeneous networks", IEEE Wireless Communications, vol.23, no.2, pp.94-101, 2016.
[19] Yli-Huumo, J., Ko, D., Choi, S., Park, S., & Smolander, K., "Where is current research on blockchain technology?—a systematic review", PloS one,vol.11, no.10, 2016.
[20] Rehman, M. H., Salah, K., Damiani, E., & Svetinovic, D., "Trust in blockchain cryptocurrency ecosystem", IEEE Transactions on Engineering Management, vol.67,no.4, pp.1196-1212, 2019.
[21] Hakak, S., Khan, W. Z., Gilkar, G. A., Imran, M., & Guizani, N., "Securing smart cities through blockchain technology: Architecture, requirements, and challenges", IEEE Network, vol.34,no.1, pp.8-14, 2020.
[22] S. Hakak, W. Z. Khan, G. A. Gilkar, N. Haider, M. Imran and M. S. Alkatheiri, " Industrial Wastewater Management using Blockchain Technology: Architecture, Requirements, and Future Directions," IEEE Internet of Things Magazine, vol. 3, no. 2, pp. 38-43, 2020.
[23] M. Debe, K. Salah, M. H. Ur Rehman and D. Svetinovic, "Monetization of Services Provided by Public Fog Nodes Using Blockchain and Smart Contracts", IEEE Access, vol. 8, pp. 20118-20128, 2020.
[24] M. Debe, K. Salah, M. H. U. Rehman and D. Svetinovic, "Blockchain Based Decentralized Reverse Bidding in Fog Computing", IEEE Access, vol. 8, pp. 81686-81697, 2020.
[25] A. Chaer, K. Salah, C. Lima, P. P. Ray and T. Sheltami, "Blockchain for 5G: Opportunities and Challenges", 2019 IEEE Globecom Workshops, 2019.
[26] Liang, Y. C., "Blockchain for dynamic spectrum management", Dynamic Spectrum Management, Springer, pp. 121-146, 2020.
[27] B. Mafakheri, T. Subramanya, L. Goratti and R. Riggio, "Blockchain based Infrastructure Sharing in 5G Small Cell Networks", 2018 14th International Conference on Network and Service Management (CNSM), pp. 313-317, 2018.
[28] Z. Zhou, X. Chen, Y. Zhang, and S. Mumtaz, "Blockchain Empowered Secure Spectrum Sharing for 5G Heterogeneous Networks", IEEE Network, vol. 34, no. 1, pp. 24–31, 2020.
[29] Zhang, L., Xiao, M., Wu, G., Alam, M., Liang, Y. C., & Li, S. "A survey of advanced techniques for spectrum sharing in 5G networks", IEEE Wireless Communications, vol.24, no.5, pp.44-51, 2017.