

V2X Spectrum Allocation for Emergency Communication using Cognitive Radio Transmission

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ABSTRACT

Cognitive radio and complex spectrum connectivity are two other phenomena that influence the world of wireless networking. We have developed an experimental cognitive radio simulation system to research the role of information representation and reasoning technologies. A traditional radio often follows the same protocol when working in a certain contact mode and is effective or failing at a specified task. GPS has become a popular vehicular technology with an adaptation of 4G and 5G infrastructure. The GPS includes details on the current location and positioning of every vehicle. Some plans require the use of local wireless networks close to computer networking. Other recommendations include taking advantage of existing wireless networks to exchange this info. The transmitted system relies on the frequency spectrum to be used. The paper aims to construct and first available allocation spectrum for transmission of emergency messages between vehicles and vehicles to infrastructure environments.

Keyword: Cognitive Radio, Cooperative Communication, Spectrum Whitespace, V2X, 5G.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2022); DOI: 10.18090/samriddhi.v14i01.13

INTRODUCTION

Cognitive radio strategies that allow spectrum sharing in the non-time scenario are essential applications for intelligent, cooperative communication between Vehicle-to-vehicle communication.^[1,2] Several applications were seen as most promising: multimedia smartphone communication (for example, the download to portable players of music/video files),^[3] requiring modest data speeds, and almost universal coverage.^[4] Emergency response systems involve a modest data rate and localized reach (e.g., video transmission).^[5] Wireless internet networking (for instance, through nomadic laptops) demands high data rates but can accommodate consumers with regional hot spot networks. Multimedia wireless networking systems require high data speeds (e.g., audio/video sharing inside and out of the homes).^[2] The critical advantage of full cognitive radio is that it allows applications to maximize access and use of spectrum by leveraging their spectrum sensing capability. From a regulator point of view, Cognitive Radio's complex spectrum access strategies could minimize the strain of spectrum management and optimize spectrum performance.^[6] Wireless connectivity in an automotive network is an IEEE effort to establish a wireless networking standard for vehicles. Just one tier of dedicated shorter-range networking protocols is WAVE or IEEE 802.11p.^[7] The contact with V2V must be almost instantaneous, and there is a need for fast transmission of

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How to cite this article: Nyati, S.U., Suralkar, S.R., & Bhadade, U.S. (2022). V2X Spectrum Allocation for Emergency Communication using Cognitive Radio Transmission. *SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology*, 14(1), 79-85.

Source of support: Nil

Conflict of interest: None

the message.^[8] The paper's objective is to experimentally develop a first allocation method for identifying the open spectrum white space for message allocation during the broadcast of the emergency message.

BACKGROUND

Vehicle to Vehicle communications can be categorized into three specific means; vehicle to vehicle connectivity, infrastructure to vehicles communication, and vehicle to infrastructure communication. The approaches considered in this paper are of the vehicle to vehicle and vehicle to the interface have been developed for spectral allocation. A literature survey is a way to obtain insight details on wireless networking for automotive networks and context information about what developments operate,

what approaches, and how the industry implements this developmental technology. Figure 1 (a & b) below illustrates these broadcasting methods in a pictorial illustration.

Communications between vehicles, or V2V, allow the car to become autonomous. There is an inclusion of relay infrastructure. For a variety of factors, this is significant to have a mediatory vehicle to act like a rely upon between the source and destination. First of all, the high costs of constructing an infrastructure that will help the vehicles exchange information are tough to achieve shortly. Strict V2V connectivity depends heavily on ad hoc multi-hop routing.^[9] The vehicles need to build their questions and strive to acquire or pass on information to other vehicles. This information is then transmitted to hope that all drivers in the area can be aware of the data provided by the driver to the vehicle. Message transmission rates, broadcast-quality, and stability are important items to remember in such a network.^[10]

The transmission of messages refers to how rapidly communication is exchanged between network nodes. This is necessary since a protocol for broadcasting information would have to be developed if the protocol does not allow for correspondence at a pace sufficiently quickly to hold the information up to fast-moving traffic. The quality of broadcasting relates to the success of broadcasts. This is a calculation of the frequency at which the broadcasts are received or a vehicle no longer within reach of the call. Finally, since the system is not managed and supported by the external network, this network must be secure.^[11] If external sources can easily abuse it. It is unreliable and can create even more difficulties in delivering safety information. The two other solutions are vehicle-to-infrastructure and infrastructure-to-vehicle networks. In most cases, these two networks will operate together. It will be impossible to make a good network without including interface infrastructure.

These networks potentially do include some V2V communications, as seen in Figure 1, but most of the technological capabilities are carried out by infrastructure. A few technologies that utilize cellular networks include mobile phones, car radios, and machine wireless access points. The purpose of V2V communication is to create an alert system of accidents, traffic congestions, ambulance arrival, and fire brigade, among others, which occur outside of a driver's sightline almost definitely preclude a frequency requiring direct sight communication equipment.^[12] This approach is helpful when applying short-range technologies, including

lane-keeping and crash avoidance when the driver cannot respond as quickly as possible. However, if an incident occurs at the corner, a good warning contact is expected.^[13] A broadcast method is required to transfer the information from a vehicle to a vehicle. Whatever the system is, it should be connected to the car system. This ensures that the radio that transmits the message must calculate the spectrum.^[14,15]

Inter-vehicle communication performance lags. The goal rates and power allocation variables influence these measures for assessing SN performance, especially when CSI imperfection and PN interference are present. Also, an ideal power allocation factor for vehicle outage performance may be shown. Monte Carlo simulations were used to verify the performance above assessments.^[16] A system using DF forwarding, RSU selection, and energy harvesting. This article developed closed-form formulations of outage probability, allowing for comparisons of two vehicles' outage probabilities.

Moreover, we discovered that more RSUs and more collected power led to higher performance in many system metrics.^[17] The coexistence of VUs and CUs in 5G wireless networks. The power and subchannel distribution of the VUs depend on their channel gain and interference with the CUs. There are several constraints on the goal function. We present an MBINP optimum power allocation approach. The suggested resource allocation technique may better protect CU channel capacity while sustaining VU QoS than PM and RM algorithms.^[18]

V2I allows information to be sent from a vehicle to infrastructure through a roadside device (RSU). The RSU is a fixed transceiver. When the RSU receives the broadcast, it forwards it to one or more V2V supporting units or vehicles. Deploying RSU takes time and money. V2P allows pedestrians to communicate with cars. Drivers and pedestrians can transmit and receive notifications even when not in the line of sight. Due to antenna and battery differences, pedestrians may be less sensitive than automobiles.^[19] V2N helps mobile carriers communicate with RSU, reducing time, costs, and complexity. V2N might use cellular networks like 4G or 5G to connect vehicles and servers. The future connected car network will need to provide connectivity between devices with varied modes of operation using two communication technologies: DSRC and cellular networks.^[20]

Vehicles connecting with other entities brought up new mobility possibilities. This type of wireless communication involves vehicles, infrastructure, pedestrians, and networks called V2X. According to a study, cellular networks may eventually serve the same role as a communication link. The hybrid technique has also improved vehicle safety for extended range and more reliable usage scenarios [16]. Globally, automotive and telecoms industry participants have recognized V2X's influence on ITS. Given its considerable concentration, it is unlikely to become universal within the next decade. To identify communication technologies, platforms, deployed goods, and deployment issues, this

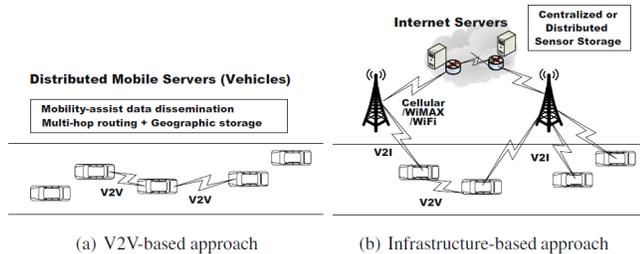


Figure 1 a and b: Cognitive Radio V2V and V2I architecture



study uses V2X technology.^[17] The paper further discusses the 5G architecture and the spectrum allocation.

5G ARCHITECTURE

Wireless technology 5G (fifth generation) is still being studied and needs further studies. The analysis explores numerous architectures to suggest core principles of this new technology. Software-Defined Networks has been suggested as a promising strategy for these networks, a key factor in developing 5G wireless networks. The 5G would be built on a user-centered concept like 3G or operation center as seen with 4G instead of being operator-centric. There is also a mixture of several incomings from various technologies at mobile stages.^[21-23]

This latest generation 5G cellular broadband network would provide trillions of new users with less predictable fundamental infrastructure traffic patterns to the network.^[24,25] To be competitive with this new technology, message transmission is critical to a successful rollout and a powerful future of wireless technologies.^[26-33]

COGNITIVE RADIO

Cognitive radios are the result of a multidisciplinary collaboration including specialists in cellular networks, digital networking, device architecture, artificial intelligence, and other areas, using Software Driven Radio (SDR) technology.^[2,34] As a result of these practices, it is hoped that these programs simultaneously respect the interests of the license holder while offering greater stability and spectrum access. Given the need for increased bandwidth and under-utilized spectrum, DSA networks with intelligent radios will revolutionize the telecommunication market, radically improve the way we use spectrum tools, and design

wireless systems and services.^[6,10,35] For this purpose, we have attempted to mimic the fundamental elements of cognitive radio technology to sensitize electrical and electronic engineers to the complexity and implementations of this enormous new technology. There are very few experimental simulation techniques in cognitive radios, so we plan to create a simplified and more successful MATLAB simulation process using ten users and allocating two new users with the noise of 3dB at 30% attenuation.

SPECTRUM SYSTEM MODEL

When an emergency vehicle has to send a request over the chain of vehicles to communicate a traffic signal to be reset, a procedure must be followed to choose a broadcast frequency. As the frequency range used is the digital spectrum, each radio must know which frequencies a licensed frequency holder uses. The radio must detect when an event is transmitted and the frequency of the transmission. Moreover, this device must not interfere with pre-occupied vehicles' transmission in the field. Figure 3 indicates where broadcasting is appropriate.

A signal composed of several identical sub-carriers would have a constant Power Spectrum Density (PSD) over their spectrum, and the overall signal power will then be found as $P=PSD$. Consider an $X(t)X(t)$ random Spectrum White Space process with the $R_X(\tau)R_X(\mu)$ autocorrelation feature. We defined $X(t)X(t)$ Power Spectral Density (PSD) as the Fourier $R_X(\mu)R_X(\mu)$. The $X(t)X(t)$ PSD is seen by $S_X(f)S_X(f)$. Which is written as.^[37,38]

$$S_x(f) = F\{R_x(\tau)\} = \int_{-\infty}^{\infty} R_x(\tau) e^{-2j\pi f\tau} d\tau,$$

Where $j = \sqrt{-1}$

Eq. 1: Power Spectral Density Estimation

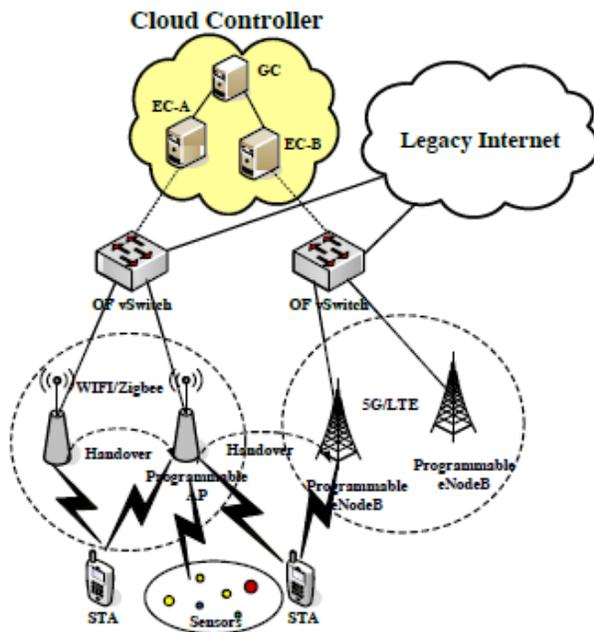


Figure 2: 5G Architecture with Software Defined Network^[2]

PROPOSED METHOD

There has been extensive and long research in message broadcasting in the 5G network using Cognitive Radio. So,

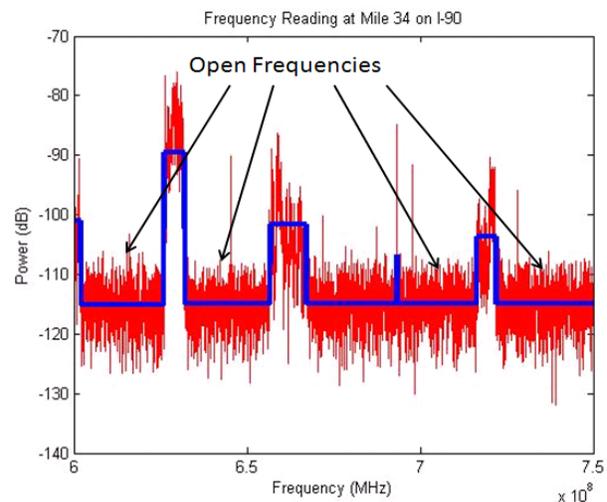


Figure 3: Broadcast Frequencies those acceptable^[36]

what exactly is this information being transmitted? There are infinite options. However, before the niceties are applied to a framework, some necessities must be discussed. Three fields of broadcast knowledge are effectively present: traffic patterns and warnings, positioning networks, and station directories.^[1] Traffic conditions and warnings are the most critical of the three. There may be several warning notices or messages. An alert may be that multiple vehicles are blocking the road. An emergency warning may be a traffic congestion notification or emergency message from the Ambulance, police vehicle, and fire brigade. Location-aware facilities consist of road conditions; if a transmitting infrastructure transmits the information to vehicles approaching a zone, roadworks could be ahead, among other alerts.

The paper discusses the cognitive radio system and cooperative communication system simulation to reuse unused vehicle bandwidth to boost the overall system capability. We attempted to construct a cognitive distribution of radio spectrum for the first free spectrum available. The previously available stimulatory methods have only simulated such aspects of cognitive radio technology, such as inter-system handover testbeds, spectral performance, scanning by wavelength, SDN, MIMO, interference with cognitive radio systems, etc. Using MATLAB, we simulated the fundamentals of a simple cognitive radio device to allocate unused spectral space between vehicles. The experimental analysis is achieved by a simulation of ten vehicles where two emergency vehicles broadcast the emergency message over a set of vehicles moving along the source vehicles.

Figure 4 illustrates the scenario where an ambulance (A1) and police vehicle (P1) is the source who is trying to broadcast an emergency message to control the signal system. The scenario exhibits vehicle-to-interface communication over a set of vehicles where the forward going vehicles termed as protentional carrier vehicles (FCn) are also called relays. All the vehicles are given a range of frequencies to simulate a spectral power density plot. Vehicles 1 and 4 and 5 are the empty spectra, and vehicles 2 and 9 are the sources while all other's spectrums are allocated or engaged for new communications.

Our system experimented with ten separate frequency channels, and a specific frequency band is allocated to each

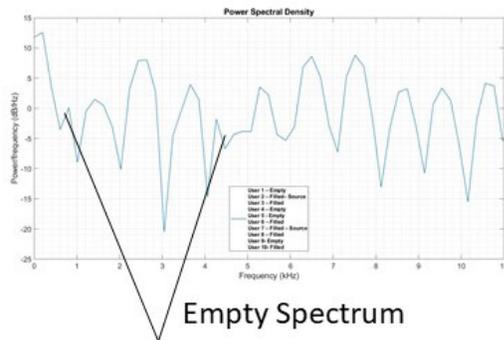


Figure 5: Spectral density with empty slots

user. When there is a need for any vehicle to disseminate an emergency message, the user is added newly, and the user is given a special band in ascending order. Figure 5 shows the empty spectrum among the other allocated spectrums.

Figures 6 and 7 above illustrate the possibility of an open spectrum for vehicles with spectrum white space that allows

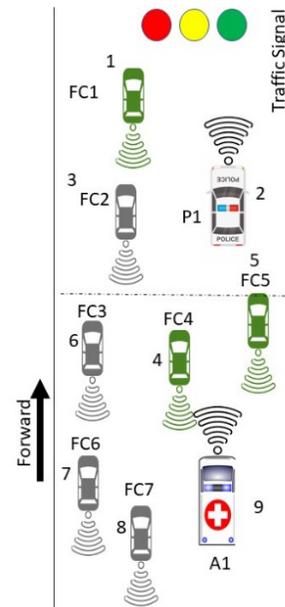


Figure 4: Emergency vehicles on road to message dissemination

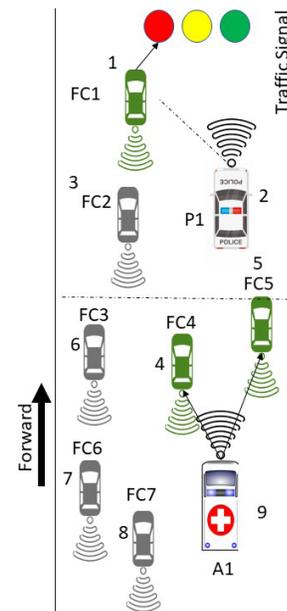


Figure 6: Possibilities of free spectrum white space

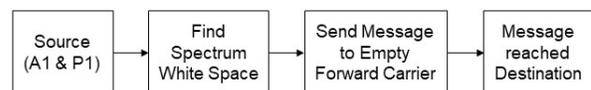


Figure 7: Flow chart of the message dissemination



message transmission. A possible communication channel can be established in the scenario where we discuss empty vehicles.

Figures 8-11 show the allocation of the first space availability to reduce the time for randomly broadcasting the message and waiting for an acknowledgment. The Spectral empty spaces are allocated in an idle case scenario, but to keep it more real close to the practical approach, we include in Figure 12 a noise of 3dB and Attenuation of 30%. The comparisons are illustrated below, showing frequency changes.

Allocation of unused spectrum indirect vehicle to vehicle communication was executed, but when there is a need for the vehicle to interface, communication is to be established. The Source vehicle, in this case, the Ambulance (A1) and Police Van (P1), act as the source (S), and the traffic signal here is the interface (I). The vehicles passing by the adjacent act a relay. In the case of Ambulance, the forward car (FC4) acts as a relay (R1) for the source vehicle (A1). Then, with

forward messaging, the routing of the first available vehicle spectrum allocation, the vehicle (FC2) receives the message that forward allocates to the first available vehicle (FC1). Then, the FC1 relay transmits to Traffic Signal, which is the destination (Figure 13).

We simulated the fundamentals of a cognitive radio device that enables complex access to the spectrum in time.

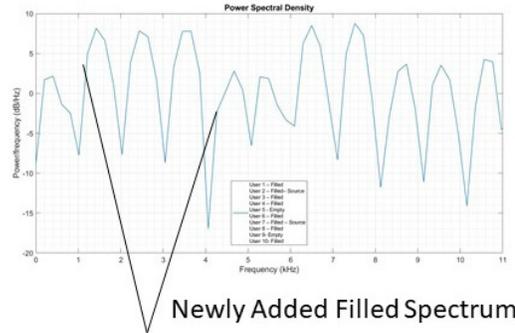


Figure 10: Newly added empty spectrums

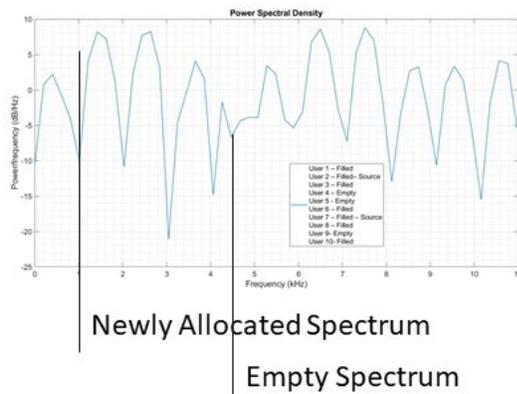


Figure 8: One new user added and one empty space

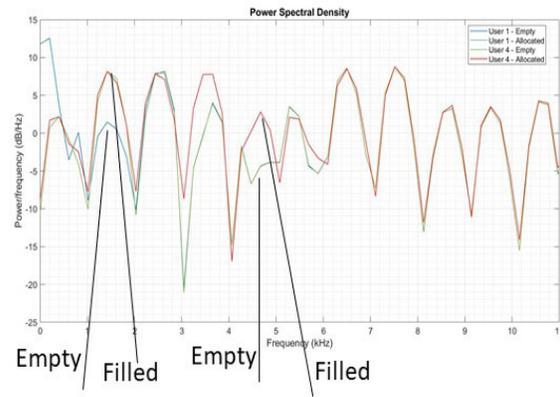


Figure 11: Comparison of empty vs. Filled spectral white spaces

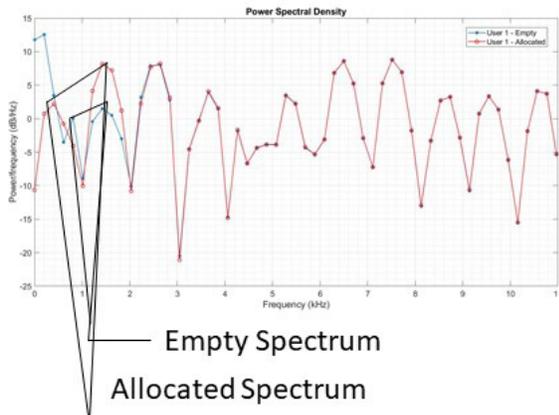


Figure 9: Frequency comparison when and not allocated

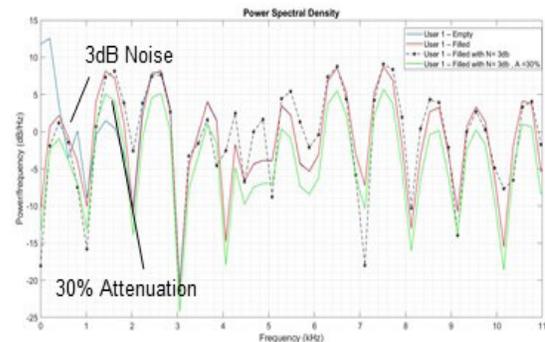


Figure 12: Frequency noise and attenuation

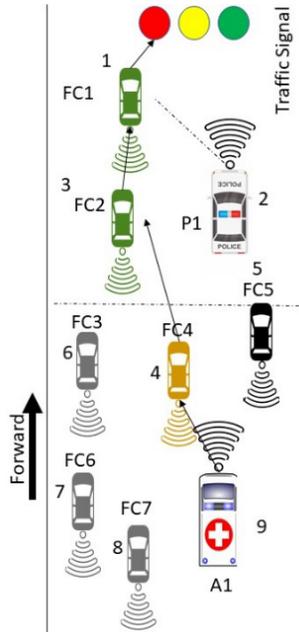


Figure 13: Relay message transmission system

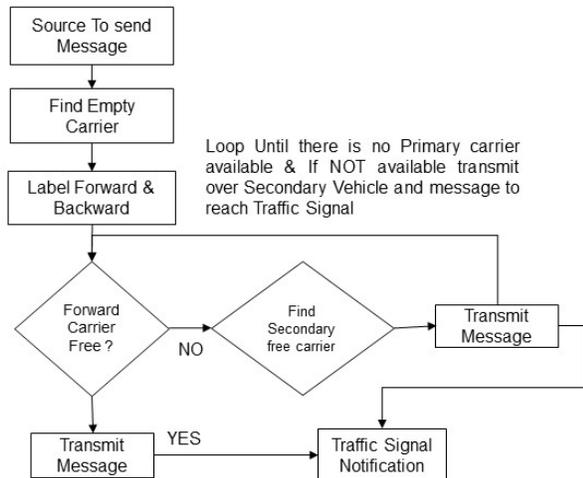


Figure 14: Flow chart of multi-hop message transmission

Mobile multimedia or text emergency communications systems, cellular internet networking, hot spot services, and others can be used with the current 5G network; Cognitive radio system implementations are the strongest. Cognitive radios are also in research pipelines at an early age as cognitive science. We created a simplified and more effective simulation methodology using MATLAB to allocate the first available free spectrum rather than pooling around for a strong, trusted, or efficient node. The results depend on the spectral power density of the channel that can be used cognitively to define the white space that is open to new incoming users, thereby increasing the overall canal performance. Finally, the implementation using MATLAB for ten user scenarios in both idle case and noise insertion was

achieved as expected and still work to develop the code for better and more intelligent presentable results (Figure 14).

CONCLUSION

Cognitive radios can hop in and out of unused spectrum gaps to improve spectrum efficiency and deliver broadcast messaging services. The simulation of a cognitive radio device was demonstrated using MATLAB, where optimum frequency consumption and reliability were ensured, and the noisy signal was also attenuated. The future scope of the paper is to achieve the present first allocation method with an approach of Artificial Intelligence and Machine Learning, enabling data-driven networks using cognitive radio for cooperative communication.

REFERENCES

- [1] Ahmadi, S. (2019). 5G network architecture. 5G NR, 1-194. <https://doi.org/10.1016/b978-0-08-102267-2.00001-4>
- [2] Balakrishnan, P., Selvi, S. T., & Britto, G. R. (2008). GSMA based automated negotiation model for grid scheduling. 2008 IEEE International Conference on Services Computing. <https://doi.org/10.1109/sc.2008.59>
- [3] Boukerche, A., Coutinho, R. W., & Loureiro, A. A. (2019). Information-centric cognitive radio networks for content distribution in smart cities. IEEE Network, 33(3), 146-151. <https://doi.org/10.1109/mnet.2019.1800044>
- [4] Cheng, N., Lyu, F., Chen, J., Xu, W., Zhou, H., Zhang, S., & Shen, X. (2018). Big data driven vehicular networks. IEEE Network, 32(6), 160-167. <https://doi.org/10.1109/mnet.2018.1700460>
- [5] Dahlman, E., Parkvall, S., & Sköld, J. (2018). LTE/NR interworking and coexistence. 5G NR: the Next Generation Wireless Access Technology, 335-343. <https://doi.org/10.1016/b978-0-12-814323-0.00017-x>
- [6] Dikaiakos, M., Florides, A., Nadeem, T., & Iftode, L. (2007). Location-aware services over vehicular ad-hoc networks using car-to-car communication. IEEE Journal on Selected Areas in Communications, 25(8), 1590-1602. <https://doi.org/10.1109/jsac.2007.071008>
- [7] Do, D., Anh Le, T., Nguyen, T. N., Li, X., & Rabie, K. M. (2020). Joint impacts of imperfect CSI and imperfect SIC in cognitive radio-assisted NOMA-V2X communications. IEEE Access, 8, 128629-128645. <https://doi.org/10.1109/access.2020.3008788>
- [8] Do, D., Le, A., Hoang, T., & Lee, B. M. (2020). Cognitive radio-assisted NOMA broadcasting for 5G cellular V2X communications: Model of roadside unit selection and SWIPT. Sensors, 20(6), 1786. <https://doi.org/10.3390/s20061786>
- [9] Dung, L., & Choi, S. (2019). Connectivity analysis of cognitive radio ad-hoc networks with multi-pair primary networks. Sensors, 19(3), 565. <https://doi.org/10.3390/s19030565>
- [10] Dung, L., Nguyen, B., & Hoang, T. (2019). A simulation analysis of the connectivity of multi-hop path between two arbitrary nodes in cognitive radio ad hoc networks. EAI Endorsed Transactions on Industrial Networks and Intelligent Systems, 6(21), 160984. <https://doi.org/10.4108/eai.24-10-2019.160984>
- [11] Durech, J., Franekova, M., & Holecko, P. (2015). VANET throughput model scenarios for authorized V2V communication. 2015 IEEE 19th International Conference on Intelligent Engineering Systems (INES). <https://doi.org/10.1109/ines.2015.7329652>
- [12] Gao, Y., Zhang, X., & Ma, Y. (2017). Hybrid Sub-Nyquist spectrum



- sensing with geo-location database in M2M communications. 2017 IEEE 86th Vehicular Technology Conference (VTC-Fall). <https://doi.org/10.1109/vtcfall.2017.8287975>
- [13] Gonzalez, S., & Ramos, V. (2016). Preset delay broadcast: A protocol for fast information dissemination in vehicular ad hoc networks (VANETs). *EURASIP Journal on Wireless Communications and Networking*, 2016(1). <https://doi.org/10.1186/s13638-016-0614-4>
- [14] Hsin-Hung Cho, Chin-Feng Lai, Shih, T. K., & Han-Chieh Chao. (2014). Integration of SDR and SDN for 5G. *IEEE Access*, 2, 1196-1204. <https://doi.org/10.1109/access.2014.2357435>
- [15] Huang, T., Yin, X., & Cao, Q. (2020). A new algorithm for considering green communication and excellent sensing performance in cognitive radio networks. *International Journal of Distributed Sensor Networks*, 16(6), 155014772093313. <https://doi.org/10.1177/1550147720933131>
- [16] Jiang, D., & Delgrossi, L. (2008). IEEE 802.11p: Towards an international standard for wireless access in vehicular environments. *VTC Spring 2008 - IEEE Vehicular Technology Conference*. <https://doi.org/10.1109/vetecs.2008.458>
- [17] Kaippallimalil, J., & Xiang, A. (2019). 5G system architecture. *5G System Design*, 273-298. https://doi.org/10.1007/978-3-030-22236-9_4
- [18] LO, G. S., Niang, A. B., & Okereke, L. C. (2020). A course of elementary probability course. <https://doi.org/10.16929/sts/2020.001>
- [19] Long, C., Du, X., Wang, D., & Liu, W. (2020). Research on integrated security management and control technology of big data information platform in the intelligent community based on 5G. *2020 IEEE International Conference on Advances in Electrical Engineering and Computer Applications (AEECA)*. <https://doi.org/10.1109/aeeca49918.2020.9213635>
- [20] Luo, G., Yuan, Q., Zhou, H., Cheng, N., Liu, Z., Yang, F., & Shen, X. S. (2018). Cooperative vehicular content distribution in edge computing assisted 5G-VANET. *China Communications*, 15(7), 1-17. <https://doi.org/10.1109/cc.2018.8424578>
- [21] Luo, J., & Hubaux, J. (n.d.). A survey of research in inter-vehicle communications. *Embedded Security in Cars*, 111-122. https://doi.org/10.1007/3-540-28428-1_7
- [22] Mademann, F. (2018). The 5G system architecture. *Journal of ICT Standardization*, 6(1), 77-86. <https://doi.org/10.13052/jicts2245-800x.615>
- [23] Mahmoodi, T. (2015). 5G and software-defined networking (SDN). *5G Radio Technology Seminar. Exploring Technical Challenges in the Emerging 5G Ecosystem*. <https://doi.org/10.1049/ic.2015.0034>
- [24] Mozaffari, M., Kasgari, A. T., Saad, W., Bennis, M., & Debbah, M. (2018). 3D cellular network architecture with drones for beyond 5G. *2018 IEEE Global Communications Conference (GLOBECOM)*. <https://doi.org/10.1109/glocom.2018.8647225>
- [25] Mumtaz, S., Saidul Huq, K. M., Ashraf, M. I., Rodriguez, J., Monteiro, V., & Politis, C. (2015). Cognitive vehicular communication for 5G. *IEEE Communications Magazine*, 53(7), 109-117. <https://doi.org/10.1109/mcom.2015.7158273>
- [26] Ojanpera, T., Makela, J., Mammela, O., Majanen, M., & Martikainen, O. (2018). Use cases and communications architecture for 5G-Enabled road safety services. *2018 European Conference on Networks and Communications (EuCNC)*. <https://doi.org/10.1109/eucnc.2018.8443193>
- [27] Rahmati, A., He, X., Guvenc, I., & Dai, H. (2019). Dynamic mobility-aware interference avoidance for aerial base stations in cognitive radio networks. *IEEE INFOCOM 2019 - IEEE Conference on Computer Communications*. <https://doi.org/10.1109/infocom.2019.8737472>
- [28] Saily, M., Estevan, C. B., Gimenez, J. J., Tesema, F., Guo, W., Gomez-Barquero, D., & Mi, D. (2020). 5G radio access network architecture for terrestrial broadcast services. *IEEE Transactions on Broadcasting*, 66(2), 404-415. <https://doi.org/10.1109/tbc.2020.2985906>
- [29] Sarfaraz, A., & Hammainen, H. (2017). 5G transformation: How mobile network operators are preparing for transformation to 5G? *2017 Internet of Things Business Models, Users, and Networks*. <https://doi.org/10.1109/ctte.2017.8260928>
- [30] Sharma, S., Awan, M. B., & Mohan, S. (2017). Cloud enabled cognitive radio adhoc vehicular networking (CRAVENET) with security aware resource management and internet of vehicles (IoV) applications. *2017 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS)*. <https://doi.org/10.1109/ants.2017.8384186>
- [31] Silva, C., Nogueira, M., Kim, D., Cerqueira, E., & Santos, A. (2016). Cognitive radio based connectivity management for resilient end-to-end communications in VANETs. *Computer Communications*, 79, 1-8. <https://doi.org/10.1016/j.comcom.2015.12.009>
- [32] Singh, H. (2020). Security in Amazon web services. *Practical Machine Learning with AWS*, 45-62. https://doi.org/10.1007/978-1-4842-6222-1_3
- [33] Singh, S., Chiu, Y., Tsai, Y., & Yang, J. (2016). Mobile edge fog computing in 5G era: Architecture and implementation. *2016 International Computer Symposium (ICS)*. <https://doi.org/10.1109/ics.2016.0151>
- [34] Song, X., Wang, K., Lei, L., Zhao, L., Li, Y., & Wang, J. (2020). Interference minimization resource allocation for V2X communication underlying 5G cellular networks. *Wireless Communications and Mobile Computing*, 2020, 1-9. <https://doi.org/10.1155/2020/2985367>
- [35] Sun, G., Liu, F., Lai, J., & Liu, G. (2014). Software defined wireless network architecture for the next generation mobile communication: Proposal and initial prototype. *Journal of Communications*. <https://doi.org/10.12720/jcm.9.12.946-953>
- [36] Vourgidis, I., Maglaras, L., Alfakeeh, A. S., Al-Bayatti, A. H., & Ferrag, M. A. (2020). A prediction - Communication P2V framework for enhancing vulnerable road Users' Safety. <https://doi.org/10.20944/preprints202001.0017.v1>
- [37] Wan, R., Ding, L., Xiong, N., & Zhou, X. (2019). Mitigation strategy against spectrum-sensing data falsification attack in cognitive radio sensor networks. *International Journal of Distributed Sensor Networks*, 15(9), 155014771987064. <https://doi.org/10.1177/1550147719870645>
- [38] Yogarayan, S., Razak, S. F., Azman, A., & Abdullah, M. F. (2021). Vehicle to everything (V2x) communications technology for smart mobility in Malaysia: A comprehensive review. *Journal of Southwest Jiaotong University*, 56(4), 534-563. <https://doi.org/10.35741/issn.0258-2724.56.4.7>