Integrating security and privacy in mmWave communications

Ghadah M. Faisal[1], Hasanain Abdalridha Abed Alshadoodee[2], Haider Hadi Abbas[3], Hassan Muwafaq Gheni[4], Israa Al-Barazanchi[5,6]

[1]Department of Electrical Engineering, Al-Iraqiya University, Baghdad, Iraq
[2]Faculty of Arts, University of Kufa, Kufa, Iraq
[3]Department of Computer Technology Engineering, Al-Mansour University College (MUC), Iraq
[4]Department of Computer Techniques Engineering, Al-Mustaqbal University College, Hillah, Iraq
[5]College of Computing and Informatics, Universiti Tenaga Nasional (UNITEN), Malaysia
[6]Department of Computer Engineering Techniques, Baghdad College of Economic Sciences University, Baghdad, Iraq

Article Info

Article history:

Received Jun 5, 2022
Revised Jul 6, 2022
Accepted Jul 29, 2022

Keywords:

Dual level spectrum
Primary user
Probability of detection
Probability of false alarm
Secondary user
Secure communication

ABSTRACT

The aim of this paper is to integrate security and privacy in mmWave communications. MmWave communication mechanism access three major key components of secure communication (SC) operations. proposed design for mmWave communication facilitates the detection of the primary signal in physical (PHY) layer to find the spectrum throughput for primary user (PU) and secondary user (SU). The throughput of SC for PU with maximum throughput being recorded at 0.7934 while maximum throughput for SU is recorded at 0.7679. So, we will design a mmWave communication mechanism for solving this problem. The probability for sensing where the probability of detection (PD) is predicted at a defined range of 690 km with an estimated accuracy of 83.56% while the probability of false alarm (PFA) is predicted at a defined range of 230 km with an estimated accuracy of 81.39%. This conflicting but interrelated issue is investigated over three stages for the purpose of solving with a cross-layer model with MAC and PHY layers for a secure communication network (SCN) while reducing the collision effect concurrently with a 92.76% for both cross-layers. MATLAB 2019b would be forwarded in use as the increasing demand for augmenting the bandwidth in secure communications has actuated the evolutionary technology.

This is an open access article under the CC BY-SA license.

Corresponding Author:

Ghadah M. Faisal
Department of Electrical Engineering
Al-Iraqiya University, Baghdad, Iraq
Email: wdyaan1@gmail.com, ghadah.faisal@aliraqia.edu.iq

1. INTRODUCTION

Over the last decade, significant developments in mobile devices, such as smartphones, mobile phones, laptops, tablets, and personal digital assistants, have made those devices a constant companion of our everyday work as described in [1]. Already we have seen the advent of a revolutionary technological advance on mobile devices and arguably the most transformative: the marriage of mobile computing and seamless connectivity for widespread applications and services as explained in [2]. The underlying communication medium of wireless technology, the electromagnetic radio spectrum, is a precious natural resource. In the twenty-first century, no natural resource is more crucial to human prosperities than the radio spectrum. Invisible, ubiquitous, and limited in physical extent, it is the transmission medium by which wireless technologies convey limitless sources of information to revolutionize our access to the world around us as described in [3]. It is predicted that by 2025, we will have 50 billion connected devices, mostly wireless, in the world, and existing spectrum usage policy will be unable to deliver the “end of spectrum scarcity”. Meanwhile, smartest entrepreneurs in garages continue to launch killer apps to the airwaves. The mobile bandwidth for excellent voice calls appears to be underutilized because subscribers are increasingly interested in texting, Facebook posting, tweeting, and video streaming. A survey [4] shows, as of mid-2019, 27% of mobile consumers claimed that they have not made any cellular voice calls in a week, whereas that figure was about 23% in 2015. Users' interest in using things over mobile phones are changing drastically as shown in Table 1.

Table 1. MmWave spectrum occupancy status of different applications over 30-3000 MHz band with average 14% overall occupancy [4]

Application	Frequency band (MHz)	Minimum (%)	Average (%)	Maximum (%)
PLM, amateur	30-54	8	18	60
TV 2-6	54-87	30	35	42.5
FM	87-108	80	90	92
Fixed, mobile, others	225-406	6	10	15
LMR, others	406-475	15	15.5	18
SMR	798-840	0.5	2	3
Cellular	840-902	50.2	55	68
Unlicensed	902-928	0.5	2.5	11
Radar, military, GPS	1240-1710	0	0	0
PCS cellular	1710-2010	17	17.5	20
ISM	2400-2500	18	24.5	45
WiMAX	2500-2700	17	26	31
Surveillance radar, others	2700-3000	0	0	0

For the year of 2025, the measurement data from [5] is presented in Table 1 they found that the average overall occupancy was just 14% for the spectrum band of 30 MHz to 3 GHz. Based on their measurements, it is found that high occupancy was observed at lower frequencies (less than 1 GHz) such as for cellular phone, broadcasting radio, and TV, where high power with long range services is provided. On the other hand, low occupancy occurred at the higher frequency ranges (greater than 1 GHz) such as for satellite and radar operation as mentioned in [6]. Thus, in some cases, the FSA policy faces the spectrum underutilization problem. The research gaps that exist in the designing of dual level spectrum (DLS) sensing assisted access protocol are potentially threatening the advancement of secure communication (SC) capability and from them also unsolved questions, such as:

a. How does the spectrum sensing impact on the modeling of the access strategy to improve the access capability of secure communications?
b. Is the mmWave communication decision significant for the enhancement of the access decision for primary and secondary users?
c. If so, how can the spectrum sensing be embedded with the access strategy to overcome the DLS sensing-throughput trade-off issue in designing?
d. What is the best way to design the mmWave communication mechanism with access strategy for the purpose of overcome the DLS sensing-throughput trade-off issue in secure communications?

We will overcome the above-mentioned problems with more advance design of mmWave communication mechanism for secure communications. The core idea behind this research is to design and integrate the mmWave communication and the access mechanism by exploiting the cross-layer concept to overcome the sensing-throughput trade-off issue in SC for primary user (PU) and secondary user (SU). To do that, it must track down the aspects that are the main barrier behind the mmWave communication-throughput trade-off issue. Therefore, this research first will conduct a comprehensive investigation into the measurement of capacity variation of the DLS opportunity in relation to the sensing parameters with occupancy model. The proposed design will imply that the outcome of the mmWave communication mechanism determines the potential of the spectrum opportunity in secure communications. In addition, the probability of detection (PD) will be configured by the target value of the PD with probability of false alarm (PFA) which appears to positive impact on the variation of mmWave communication mechanism. The main contribution in DLS sensing-assisted mechanism is to interrelate the sensing outcome with the SC for PU and SU where ideally both are designed separately with proposed DLS mechanism. The evaluation process is discussed with a wide range of analysis to reveal the effectiveness of cross-layer design in achieving the research goal.

DLS policy brings the idea of SC for efficient spectral utilization to challenge outdated spectrum access policy based on fixed spectrum access. SC technology allows the SU to occupy a licensed spectrum that is owned by the PU, without producing any harmful interference as mentioned in [7]. Therefore, SU must empower the intrinsic capabilities to aware about its surrounding environments, tune up onto reachable RF, and adapt its operation to restrict harmful interference to the legacy users and obtain best effort service from its network. The introduction of new spectrum access policy also brings numerous technical challenges for real-world implementation. Since SC technology aims to operate in the best available spectrum, existing RF hardware must be upgraded with the capability of multi-band operation as mentioned in [8]. Smart software models must relate to the physical RF model with learning capabilities. The network model will be more complex due to the dynamic and high load balancing issue. The transmission protocol needs to be reconfigured because the primary and secondary network within a secure communication network (SCN) cannot be coordinated with a dedicated control channel. Overall, the SC technology has raised many research challenges as well as promoted huge opportunities for innovation, to bring about a new era of wireless industry. Figure 1 shows the secure communications as a mean of communication with enhanced with enhanced spectrum including dynamic access environment components of SC.

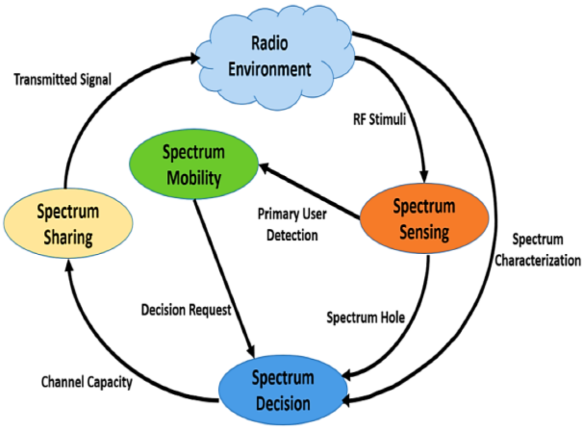

Figure 1. Secure communications as a mean of communication with enhanced with enhanced spectrum including dynamic access environment components of SC [8]

The key roles of these components are described as:

a. Spectrum sensing: this component allows the SU to monitor the scannable spectrum bands, measuring the radio information for finding the spectrum holes.
b. Spectrum mobility: the SU can characterize the spectrum hole with objective performance parameters through this component; for instance, channel state information (CSI) and capacity prediction could be accomplished using the spectrum analysis.
c. Spectrum decision: through this component, the SU performs the data transmission in the spectrum hole. Resource management, power control, and access strategy during transmission.

The SC operation promotes the concept of dynamic access in the underutilized spectrum for improving the spectral efficiency. There are no restrictions on the network architecture of the SCN unlike other wireless networks such as WLAN and cellular network as described in [9]. Therefore, many network models are adopted the SC concept for providing the best effort services in different applications.

The SC capability of an SU is such that the SU can interact with its reachable radio environment to determine the most efficient and target radio. The SU can choose the channel of interest and adapt with the dynamic access environment. Receiving section of the SU is responsible for executing the tasks residing into the first two components and the transmitting section mainly executes the tasks of the third component as explained in [10]. According to layer-based model (e.g., OSI model), these components are transformed into two major functionalities in two different layers, particularly in the PHY and the MAC layer. Specifically, sensing and analysis are carried out by the spectrum sensing operation in the PHY layer. The spectrum decision, including data transmission, are considered by the spectrum access functionality in the MAC layer. The IEEE standard mainly defines the PHY and the MAC layer operations for supporting the purposes of SC in radio frequency (RF). The network coverage under a BS is typically 10−30 km depending on the EIRP and antenna's specification described in [11]. The coverage of the SCN system can be further upgraded to 100 km based on special scheduling in the MAC and exceptional RF signal propagation in the PHY. To meet the requirements of PU protection and efficient mmWave communication utilization is needed in SC's. The SC capabilities comprise mmWave communication, database access services, channel set management, and geolocation services. MmWave communication has emerged as the key enabler of SC operation. The main task of sensing is to characterize the available spectrum hole through radio signal measurement in the tunable air interface without interfering the legacy system. The task of the spectrum sensing is classified into four steps [12]:

i) spectrum holes detection; ii) defining the resolution of spectrum holes; iii) determining the directions of arriving interference; iv) classification of signals.

Spectrum hole detection means finding the sub-band which is only occupied by white noise. Simply put, the detection of spectrum holes can be performed using existing RF detection techniques, for example, the energy-detection method. When the sub-bands are partially occupied by interference and noise, then the detection may further require power spectrum estimation. Figure 2 shows the taxonomy of existing sensing spectrum converged with secure communications.

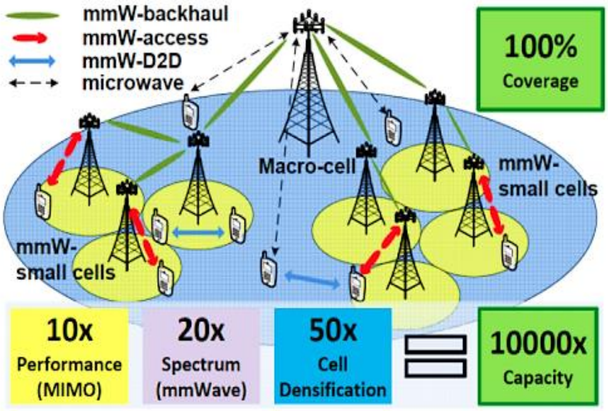

Figure 2. Taxonomy of existing sensing spectrum converged with secure communications [12]

As discussed above, the sensing operation mostly relies on a detection process which can be done by primary signal detection and interference-temperature measurement. Primary signal detection works according to the principle of RF signal detection. Many RF detection methods have been adopted as primary signal detection method in SCN such as energy detection.

2. METHOD

The implementation of SC technique has received considerable attention for its capacity to enable opportunistic access in DLS. The cognitive capabilities in the sensor networks empower the sensor node with the ability to access reachable channels opportunistically. This feature drastically the transmission reliability and energy-efficiency drastically of the DLS. Currently, DLS works in the industrial, scientific, and medical (ISM) bands which are typically unlicensed bands. The services provided through ISM bands are increasing rapidly due to the lack of licensing which apparently makes this band overcrowded. Therefore, current DLS include SC capabilities to find the underutilized spectrum band. The flow diagram has been shown in Figure 3 shows the mmWave communication of the physical layer is integrated with the access strategy of secure communications for improving both the throughput performance and interference protection of cross-layers with greater accuracy.

2.1. Dual level spectrum occupancy model for MmWave communication

According to underlying condition of SC operation, there are no cooperation and network association among the PU and SU. Therefore, SUs does not have exact networking knowledge about of traffic of PU. Hence, SUs can only gain knowledge about PU traffic by the spectrum measurement, and this has been introduced in this work extensively. Experimental measurements suggest that the spectrum occupancy can be modeled using certain statistical and/or mathematical models. DLS occupancy modeling is important for determining the full potential of the spectrum opportunities before accessing the spectrum for secure communications. Moreover, the accuracy of the spectrum sensing mechanism can be evaluated with the help of knowledge of the DLS occupancy model; hence, interference protection to PUs can be designed deliberately. For instance, interference to PU is minimized with the sensing parameters optimizations achieved by using the dynamic traffic model of the PU. Without paying attention to the approach, the statistical model of the DLS occupancy is comprehensively equipped to envision the SC operation but of barely sufficient accuracy to characterize the PU activity.

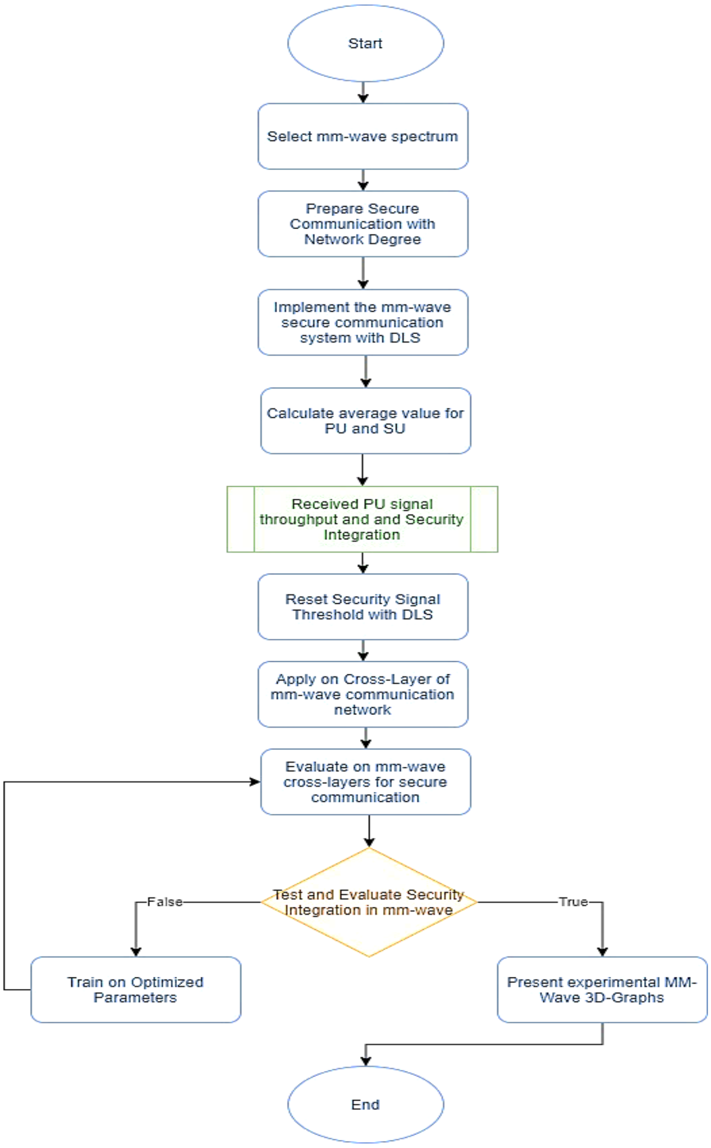

Figure 3. Flow diagram of approach being followed

2.2. Secure transmission mechanism

Inspired by the success of random-access technique, several data transmission protocols have directly adopted the random-access techniques, such as slotted ALOHA, CSMA/CA, in the SCN as mentioned [13]. For the multiple access scenario in SCN, two types of users with different prioritized access in the channel have been considered in [13]. For multiple access in the primary channel among multiple SUs, the existing access protocol such as slotted ALOHA and CSMA/CA are adopted for the SC scenario. In the given literature, two types of users with different prioritized access were considered. The CSMA/CA has an advantage over slotted ALOHA for SCN, as the CSMA/CA allows channel monitoring functionality before transmission which is essential for occupying the primary channel. Time-division multiple access (TDMA) is also used in SC with a cooperative MAC protocol as proposed. Nevertheless, without any inter-network collaboration and/or precise synchronization, the TDMA approach cannot guarantee sufficient protection to the primary network as explained in [14]-[19]. Figure 4 shows network configuration of SCN for data transmission through secondary base station (SBS) and primary base station (PBS).

The data transmission for DLS is proposed and based on a two-level access policy, where the interference protection to the PU and sensing time optimization is done at the first level, and packet scheduling based on the MAC protocol is enabled at the second level. The mmWave communication is performed before the carrier sensing so that the detection performance the channel is comparatively good, which can impact positively on the PU's protection [20]-[26].

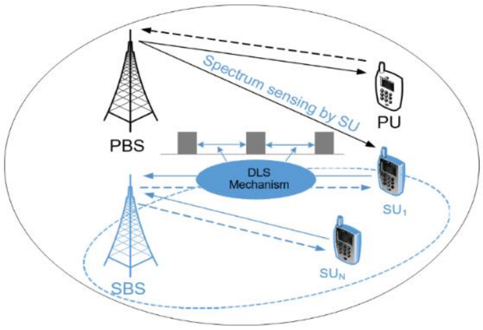

Figure 4. Network configuration of SCN for data transmission through SBS and PBS

2.3. Dual level sensing spectrum in secure communication network

This research providing the solution of the mmWave communication-throughput optimization problem of the DLS-based access mechanism. The main goal of the optimization is throughput maximization of the SU when the DLS mechanism is employed in spectrum access under the constraint of interference protection to the SCN. The main hurdle of sensing-throughput trade-off , is to detect the active user in the channel with a single step including a single-target PD. The proposed DLS mechanism overcomes this issue. However, the detection sensitivity such as a target PD in each level with required sensing time is a crucial design aspect for the deployment of the DLS mechanism. The conducted optimization provides the solution for this design aspect of the DLS mechanism. The proposed solution approach to the optimization problem in SC is formulated over three steps:

a. In the first step, the PFA is minimized regarding the PD at the first sensing stage while other system parameters remain unchanged. Before this minimization, the feasibility of minimum PFA is analyzed by convex analysis. From the feasibility analysis in MATLAB, the optimal boundary of the PD at first sensing is obtained. This PFA minimization ensures the significance of the DLS mechanism as the throughput improvement is hugely dependent on the minimized amount of PFA from the sensing. In addition, the required sensing time to obtain a decreased PFA also impacts on the throughput performance.
b. In the second step, the optimal boundary of the sensing period for a unique value of the maximum throughput is identified with the analytical DLS model in MATLAB. Due to the mathematical complexity in computing the Hessian matrix of the objective function regarding the optimizer, the solution is accomplished with a proposed semi-analytical algorithm.
c. At the last step, the feasible boundary of the optimizer is employed in the proposed algorithm to obtain the maximum throughput. For fair comparison and model validation, the proposed algorithm is compared with a purely numerical approach. The performance analysis indicates that the solution algorithms can enhance the throughput performance optimally under the constraint of PU protection within a limited computational complexity.

2.4. MmWave secure communication mechanism evaluation

In the evaluation of DLS mechanism over mesh, two different target PDs are set over the dual level sensing period where those two steps also achieve the overall PD. When the target PD is relatively low, then the detection mechanism produces a lower PFA for CR. As a result, the DLS opportunity is increased for SU transmission with the lower PFA. The detection capability of the DLS mechanisms is assessed with the ROC curve for different SC's. Also, the achieved opportunity is examined by measuring the access probability in relation to the sensing period and the channel idleness. The ROC curve analysis implies that the proposed DLS mechanism has better signal detection capability than the simple spectrum sensing mechanism on any SC. Access probability analysis shows that the DLS mechanism also achieves higher spectrum opportunity than the simple spectrum sensing mechanism, even when the PU is greatly protected with a high value of the target PD. Overall, DLS mechanism discovers a large spectrum opportunity which can be capitalized on through an advanced access protocol to significantly improve the throughput and interference protection.

3. RESULTS AND DISCUSSION

This research presents a comprehensive analysis of how the dual-level sensing mechanism impacts on improving the spectrum throughput for SC operation for PU and SU. Before the SU transmission, the capacity measurement of the spectrum opportunity is essential for setting an efficient DLS access mechanism. Therefore, DLS sensing opportunity is expressed using the underlying parameters of the spectrum sensing to gain insights into sensing in order to increase the spectrum throughput for SU. On the other hand, interference protection to the PU is provided by setting a high target PD value in the detection mechanism which increases the PFA. The detection mechanism cannot produce greater spectrum opportunity when the detection has a large PFA. This dilemma cannot be handled efficiently when a simple sensing mechanism is applied. To overcome this issue, a DLS mechanism is proposed based on two conditional sensing steps during the sensing period to jointly decide the channel occupancy status with proposed DLS method and depicts them with the help of DLS mesh plots. Figure 5 shows the mmWave 3D-mesh plot illustrating the security for PU with maximum throughput being recorded at 0.7934 while maximum throughput for SU being recorded at 0.7679.

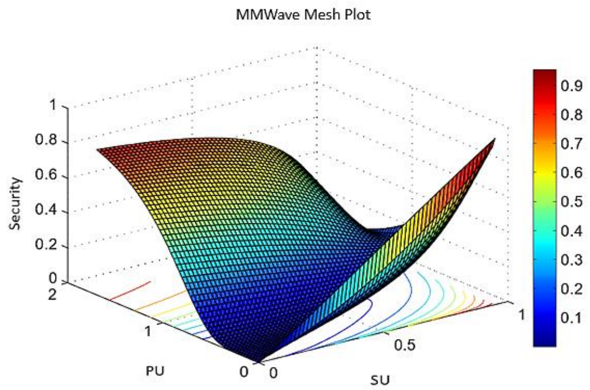

Figure 5. mmWave 3D-mesh plot illustrating the security for PU with maximum throughput being recorded at 0.7934 while maximum throughput for SU being recorded at 0.7679

In SCN, secondary users struggle to utilize the spectrum opportunity to its fullest extent while guaranteeing the legacy users protection from secondary users' interference. Therefore, multi-stage spectrum sensing gained a reputation for largely protecting the primary users; however, this sensing may require a longer sensing period which impacts on the reduction of throughput performance. Motivated by this fact, we develop a dual-level sensing (DLS) based access mechanism whereby the multi-stage detection sensitivity within a limited sensing period explores higher spectrum throughput, and then utilization of the regarding sensing outcome reduces the collision rate during the spectrum access. However, we provided an appropriate optimization in the DLS mechanism for selecting the detection sensitivity and the sensing period to achieve maximum throughput under the constraint of PU protection as shown in Figure 6.

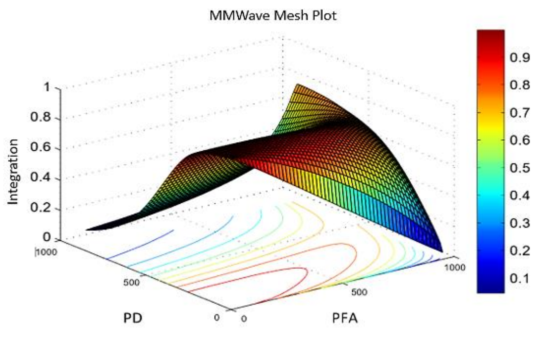

Figure 6. mmWave 3D-mesh plot illustrating the probability for sensing where PD is predicted at defined range of 690 km with as estimated accuracy of 83.56% while PFA is predicted at defined range of 230-km with an estimated accuracy of 81.39%

As the internal operation of DLS mechanism is conditioned with each other by the sensing decision therefore, any one of the sensing steps PD and sensing period can be relevant to use as optimizer to meet the target PD. We check the feasibility of minimum PFA by spectrum analysis with respect to the first detector's PD for the constraints of target PD and total sensing period. Through the comprehensive feasibility analysis, we proved that DLS-based access method reduced the overall PFA compared to SLS-based method at the same target PD regardless of extending the overall sensing period as sown in Figure 7.

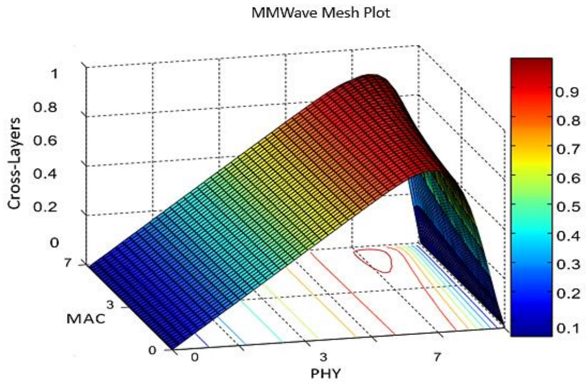

Figure 7. MmWave 3D-mesh plot illustrating the evaluation of DLS mechanism for cross-layers design of PHY (Layer-1) and MAC (Layer-2) for SCN while reducing the collision effect concurrently with an 92.76% for both cross-layers

In particular, the advantages of DLS mechanism towards collision reduction during multiple access has contributed to scaling the detector. As a result, the DLS process achieves larger opportunity with larger collision probability in SC. By using the contention process and the data transmission for packet transmission, the overall collision effect is reduced during the channel access by PD/PFA. A comprehensive mechanism is presented to demonstrate the enhanced detection and the throughput performance at various channel conditions in SC.

a. Firstly, an analytical model for PU and SU is developed by exploiting analysis, and further extended the packet service process in a multiple access SC operation to compute the normalized throughput of PU and SU
b. Secondly, a comprehensive assessment is carried out by the DLS mechanism for the validation and performance comparison for PD and PFA which implies that the proposed DLS mechanism provides stable probability regime with DLS sensing time and low SNR values.
c. Thirdly, the DLS mechanism is proposed for a PHY/MAC cross-layer design which utilizes the spectrum throughput and reduces the collision effect concurrently.

4. CONCLUSION

In this proposed research, we have designed a mmWave communication mechanism for secure communications. The proposed design has implied that the outcome of the mmWave communication mechanism determines the potential of the spectrum throughput for PU and SU in secure communications. The throughput of SC for PU with maximum throughput being recorded at 0.7934 while maximum throughput for SU being recorded at 0.7679. In SCN, SU strives to utilize the full potential of the spectrum opportunity while protection to the PU from interference caused by secondary users must be guaranteed. The probability for sensing where PD is predicted at defined range of 690 km with as estimated accuracy of 83.56% while PFA is predicted at defined range of 230-km with an estimated accuracy of 81.39%. This conflicting but interrelated issue is investigated over three stages for the purpose of solving with a cross-layer model with MAC and PHY layers for SCN while reducing the collision effect concurrently with an 92.76% for both cross-layers. The concept of the cross-layer model is an emerging design in mmWave communication mechanism that dramatically improves on the performance gains of the single layer approach. In the research conducted for this paper, the mmWave communication of the physical layer is integrated with the access strategy of the secure communications for improving both the throughput performance and interference protection.

ACKNOWLEDGEMENTS

The corresponding author is grateful to the Iraqi Ministry of Higher Education and Scientific Research (MOHESR) for technically supporting the current research.

REFERENCES

[1] A. M. Nor, "Access point selection in beyond 5G hybrid MmWave/Wi-Fi/Li-Fi network," *Physical Communication*, vol. 46, p. 101299, Jun. 2021, doi: 10.1016/j.phycom.2021.101299.

[2] S. Wang, Y. Long, R. Ruby, and X. Fu, "Clustering and power optimization in mmWave massive MIMO–NOMA systems," *Physical Communication*, vol. 49, p. 101469, Dec. 2021, doi: 10.1016/j.phycom.2021.101469.

[3] M. M. A. Al-Shareeda, M. Anbar, M. A. Alazzawi, S. Manickam, and I. H. Hasbullah, "Security schemes based on conditional privacy-preserving vehicular ad hoc networks," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 21, no. 1, pp. 479–488, 2021, doi: 10.11591/ijeecs.v21.i1.pp479-488.

[4] S. Huan, W. Chen, Y. Peng, and C. Yang, "Orthogonal chirp division multiplexing waveform for mmWave joint radar and communication," *IET International Radar Conference (IET IRC 2020)*, 2021, pp. 1222–1226, doi: 10.1049/icp.2021.0655.

[5] H. A. Ameen, A. K. Mahamad, S. Saon, D. M. Nor, and K. Ghazi, "A review on vehicle to vehicle communication system applications," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 18, no. 1, pp. 188–198, 2019, doi: 10.11591/ijeecs.v18.i1.pp188-198.

[6] H. R. Abdulshaheed, Z. T. Yaseen, A. M. Salman, and I. Al-Barazanchi, "A survey on the use of WiMAX and Wi-Fi on Vehicular Ad-Hoc Networks (VANETs)," IOP Conference Series: Materials Science and Engineering, Volume 870, *The International Conference on Engineering and Advanced Technology (ICEAT 2020)*, 11-12 February 2020, Assiut, Egypt, vol. 870, no. 1, 2020, doi: 10.1088/1757-899X/870/1/012122.

[7] S. Q. Salih, A. R. A. Alsewari, and Z. M. Yaseen, "Pressure vessel design simulation: Implementing of multi-swarm particle swarm optimization," *International Conference on Software and Computer Applications* 2019, doi: 10.1145/3316615.3316643.

[8] A. Ghazli, A. Alipacha, and N. H. Said, "Evolutionary approach to secure mobile telecommunication networks," *Indonesian Journal of Electrical Engineering and Computer Science,* vol. 24, no. 1, pp. 357–366, 2021, doi: 10.11591/ijeecs.v24.i1.pp357-366.

[9] M. F. Kadhim, A. Al-Janabi, A. H. Alhilali, and N. S. Ali, "Security approach for instant messaging applications: viber as a case study," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 26, no. 2, pp. 1109–1115, 2022, doi: 10.11591/ijeecs.v26.i2.pp1109-1115.

[10] I. Al-Barazanchi, W. Hashim, A. A. Alkahtani, H. H. Abbas, and H. R. Abdulshaheed, "Overview of WBAN from literature survey to application implementation," *2021 8th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*, pp. 16–21, Oct. 2021, doi: 10.23919/eecsi53397.2021.9624301.

[11] Y. Arjoune and S. Faruque, "Experience-driven learning-based intelligent hybrid beamforming for massive MIMO mmWave communications," *Physical Communication*, vol. 51, p. 101534, Apr. 2022, doi: 10.1016/j.phycom.2021.101534.

[12] H. R. Abdulshaheed, Z. T. Yaseen, A. M. Salman, and I. Al-Barazanchi, "An Evaluation study of WiMAX and WiFi on Vehicular Ad-Hoc Networks (VANETs)," *IOP Conference Series: Materials Science and Engineering, Volume 870, The International Conference on Engineering and Advanced Technology (ICEAT 2020)*, 11-12 February 2020, Assiut, Egypt, vol. 3, no. 12, pp. 1–7, 2020, doi: 10.1088/1757-899X/870/1/012122.

[13] J. Li et al., "Internet of things assisted condition-based support for smart manufacturing industry using learning technique," *Computational Intelligence*, vol. 36, no. 4, pp. 1737–1754, 2020, doi: 10.1111/coin.12319.

[14] R. Lopez-Valcarce and M. Martinez-Cotelo, "Full-duplex mmWave communication with hybrid precoding and combining," 2020 *28th European Signal Processing Conference (EUSIPCO)*, 2021, pp. 1752-1756, doi: 10.23919/Eusipco47968.2020.9287814.

[15] S. A. Shawkat, K. S. L. Al-Badri, and I. Al Barazanchi, "Three band absorber design and optimization by neural network algorithm," *Journal of Physics: Conference Series*, vol. 1530, no. 1, p. 012129, May 2020, doi: 10.1088/1742-6596/1530/1/012129.

[16] B. Guo, R. Li, and M. Tao, "Joint design of hybrid beamforming and phase shifts in RIS-Aided mmWave communication systems," *2021 IEEE Wireless Communications and Networking Conference (WCNC)*, 2021, pp. 1-6, doi: 10.1109/WCNC49053.2021.9417417.

[17] A. Al Farawn, H. D. Rjeib, N. S. Ali, and B. Al-Sadawi, "Secured e-payment system based on automated authentication data and iterated salted hash algorithm," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 18, no. 1, pp. 538–544, 2020, doi: 10.12928/TELKOMNIKA.V18I1.15623.

[18] A. H. Nalband, M. Sarvagya, and M. R. Ahmed, "Power saving and optimal hybrid precoding in millimeter wave massive MIMO systems for 5G," *TELKOMNIKA (Telecommunication Computing Electronics and Control*), vol. 18, no. 6, pp. 2842–2851, 2020, doi: 10.12928/TELKOMNIKA.v18i6.15952.

[19] Y. I. Alzoubi, A. Al-Ahmad, and A. Jaradat, "Fog computing security and privacy issues, open challenges, and blockchain solution: an overview," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 11, no. 6, pp. 5081-5088, Dec. 2021, doi: 10.11591/ijece.v11i6.pp5081-5088.

[20] I. Al Barazanchi, S. A. Sahy, and Z. A. Jaaz, "Traffic management with deployment of Li-Fi technology traffic management with deployment of Li-Fi technology," *Journal of Physics: Conference Series*, vol. 1804, no. 012141, 2021, doi: 10.1088/1742-6596/1804/1/012141.

[21] R. Chetan and R. Shahabadkar, "A comprehensive survey on exiting solution approaches towards security and privacy requirements of IoT," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 8, no. 4, pp. 2319-2326, Aug. 2018, doi: 10.11591/ijece.v8i4.pp2319-2326

[22] Y. K. Salih, O. H. See, S. Yussof, A. Iqbal, and S. Q. Mohammad Salih, "A proactive fuzzy-guided link labeling algorithm based on MIH framework in heterogeneous wireless networks," *Wirel. Pers. Commun*., vol. 75, no. 4, pp. 2495–2511, 2014, doi: 10.1007/s11277-013-1479-z.

[23] M. A. Saad, H. J. Alhamdane, S. Alani, A. H. Ali, M. M. Hashim, and B. Hasan, "Total energy consumption analysis in wireless mobile ad hoc network with varying mobile nodes," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 20, no. 3, pp. 1397–1405, May 2019, doi: 10.11591/ijeecs.v20.i3.pp1397-1405.

[24] B. Özbek, O. Erdoğan, S. A. Busari, and J. Gonzalez, "Hybrid beamforming strategies for secure multicell multiuser mmWave MIMO communications," *Physical Communication*, vol. 46, p. 101319, Jun. 2021, doi: 10.1016/j.phycom.2021.101319.

[25] A. N. Uwaechia and N. M. Mahyuddin, "A novel committee machine hybrid precoding and combining algorithm for mmWave massive MU-MIMO systems," *Physical Communication*, vol. 46, p. 101326, Jun. 2021, doi: 10.1016/j.phycom.2021.101326.

[26] Y. Hidayatullah, A. Marwanto, and I. M. I. Subroto, "Analysis of IPv6 jumbogram packages transmission using jumbo frame in mikrotik-based tunneling," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 24, no. 1, pp. 329–337, Oct. 2021, doi: 10.11591/ijeecs.v24.i1.pp329-337.

BIOGRAPHIES OF AUTHORS

Ghadah M. Faisal received her B.Sc and M.Sc degrees in Electrical Engineering/Communication Engineering from University of Mosul/College of Engineering/electrical engineering Department, Iraq in 1990 and 2015 respectively. Her fields of interests are microwave antenna miniaturization and design, passive microwave circuits design and developing ultra-wideband antennas and filters. She is currently Assistant Lecturer in the Electrical Engineering Department at Al-Iraqia University. One of Editorial Board Member in International Journal of Advancements in Technology since 9/7/2019. She can be contacted at email: wdyaan1@gmail.com and ghadah.faisal@aliraqia.edu.iq.

Hasanain Abdalridha Abed Alshadoodee he holds a bachelor's degree in Computer Technology Engineering from Islamic University, Najaf, Iraq. He also holds a master's degree in computer sciences from the University of Debrecen in Hungary, the European Union, and a doctorate in artificial intelligence, Department of Computer Science, from Tabriz University, in East Azerbaijan, Iran, from 2017, working as a lecturer in the Korean multimedia laboratory and engineering computing, Software Design and Electronic Tests, University of Kufa, since 2016. He has authored or co-authored more than 18 scientific journals and conference papers. Also, a book authored within the European Union. His research interests include information systems, web technologies, medical informatics, data mining, and analytics, big data, artificial intelligence applications, internet of things, and embedded systems. He can be contacted at email: hasanain.allawi@uokufa.edu.iq.

Haider Hadi Abbas received the B. Sc. degree in electronics and communication engineering from Baghdad University in 1994, Baghdad, Iraq, the M. Sc. degree in electronics engineering from University of Technology in 1997, Baghdad, Iraq, and Ph. D. degree in communications engineering from Baghdad University, Baghdad, Iraq in 2001. He has been an assistant professor of data and information security since 2014. He has authored more than 25 refereed journal and conference papers. His research interest includes data and information security, machine learning, internet of things, cloud related issues. He can be contacted at email: haider.hadi@muc.edu.iq.

Hassan Muwafaq Gheni Received his Bachelor (B.Sc) of Electrical & Electronic Engineering from Department of Electrical Engineering, Babylon university-Iraq-hilla in June 2016. In February 2018, he entered the master's program at the Faculty of Electrical and Electronic Engineer, Universiti Tun Hussein Malaysia. He is a lecturer at Al-Mustaqbal University College/Department of Computer Techniques Engineering His research interest is optical communication, IoT, wireless sensor network, communications, V2V system, Artificial intelligent. He can be contacted at email: hasan.muwafaq@mustaqbal-college.edu.iq.

Israa Al-Barazanchi received her Bachelor of Computer Science (BCS) from Department of Computer Science, Baghdad college of economic science university-Iraq-Baghdad in June 2002. In January 2010, she entered the master's program at the Faculty of Information & Communication Technology, Graduate School of Computer Science (Internetworking Technology), Universiti Teknikal Malaysia. She is Currently a student Doctor of Philosophy in Information and Communication Technology. She is a lecturer in Computer Engineering Techniques Department. Editor-in-chief for international union of universities journal. Member of Editor board in many Scopus journals for computer science field. Head of Researcher group. Member in many conferences panel and communications events. She is a Reviewer of various high impact factor journals. Her research activities are: WBAN, WSN, WiMAX, WiFi on vehicular ad-hoc networks (VANETs), communications, networking, signal processing, IoT, smart systems, blockchain. She can be contacted at email: israa.albarazanchi@baghdadcollege.edu.iq and israa44444@gmail.com.