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PERFORMANCE ANALYSIS OF DISTANCE-BASED RESOURCE ALLOCATION IN UAV-ASSISTED VEHICULAR AD HOC NETWORKS

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ABSTRACT

Intelligent Transportation Systems (ITSs) have undergone a revolution due to the widespread use of vehicular networks, which have made it possible for cars and infrastructure to communicate effectively. The performance Analysis of a Road Side Unit (RSU) and an Unmanned Aerial Vehicle (UAV) in a realistic urban setting is modeled using a vehicular network modeling framework. According to our proposed protocol, when a new vehicle enters a vehicular network at any random position. Then the proposed protocol calculates the distance between the vehicle and RSU and between the vehicle and UAV. Based on the distance calculated, the position of the random vehicle concerning the UAV and RSU is determined. To reduce interference, those vehicles that are nearer to the UAV are assigned to UAV, and those that are nearer to RSU are assigned to RSU. For Successful transmission, the received power of the vehicle is compared with the pre-determined Signal-to-Interference plus Noise Ratio (SINR) threshold. The UAV may offer better throughput than the RSU in a vehicular network simulation due to its higher altitude, transmit power, antenna gain, frequency, and coverage range. We can control the distribution of vehicles between the two coverage regions by changing the UAV_distance_threshold while keeping the RSU_distance_threshold constant. This creates a dynamic system where increasing the UAV_distance_threshold results in a higher proportion of vehicles being served by UAVs and vice versa. Hence our proposed setup can optimize the positioning and configuration of communication infrastructure while considering the coverage and performance of RSUs and UAVs.

Keywords: intelligent transportation system (ITS), internet of vehicles (IoV), unmanned aerial vehicle (UAV), road side unit (RSU).

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1. INTRODUCTION

A. Overview

Governments, businesses, and academia have all given vehicular networks much attention throughout the years due to their critical role in ITS and the support it offers for various ITS services [1]. The Internet of Vehicles (IoV), a ground-breaking idea created by the advent of smart cities and urban informatics, results from the ubiquitous real-time technology being added to the transportation infrastructure [2]. The IoV may already be realized in modern automobiles' supporting technologies. [3]. This update enables dispersed coordination and autonomous/dynamic navigation parameter change by giving cars real-time environmental awareness. The IoV seeks to improve performance, cut emissions, consume less energy, and provide drivers with a superior driving experience.

B. Motivation

The demand for improved connection, safety, and efficiency in ITS drives the adoption of vehicular networks with RSUs and UAVs. For cars to get real-time traffic data, obtain software updates, and connect with other vehicles and the surrounding infrastructure, RSUs act as fixed communication infrastructure beside roads. RSUs are restricted in terms of flexibility and covering area, however. Conversely, UAVs can provide dynamic and adaptable communication coverage, particularly in locations with sparse RSU deployment or rugged terrain. We can expand the scope and capacity of the communication infrastructure, improve situational awareness, make it easier for autonomous vehicles to coordinate, and allow new applications like aerial surveillance and emergency response by integrating UAVs into vehicular networks. To get beyond the limits of conventional vehicle networks and pave the way for a safer, more connected, and more effective transportation ecosystem, the combination of RSUs and UAVs offers an intriguing potential.

The Internet of Vehicles (IoV) idea has much potential, but it also has certain drawbacks, one of which is maintaining constant communication between communicative cars [4]. The goal of prior research has been to address this problem by considering several aspects of vehicular traffic, including vehicle speeds, density, and traffic flow [5]. For instance, the lifespan distribution of communication links and the difficulties in sustaining durable connections have been studied in Vehicular Ad Hoc Networks (VANETs), where the topology varies due to significant nodal mobility [6]. Another research [7] focused on creating a multi-hop communication channel using cooperative intermediate cars to serve as relays between a source vehicle and a remote RSU. The statistical connection properties of VANETs, such as nodal population size, geographical distribution, and cluster formation likelihood, were examined while user mobility was considered [8]. The comparable speed was also used to study how mobility affects inter-vehicle communication on motorways [9].

We consider a vehicular network in this research and analyze the SINR and received power for each vehicle from an RSU and a UAV. The simulation determines each vehicle's received power from the RSU and UAV by factoring in several variables, including transmit power, antenna gain, route loss, and noise figure. The simulation's findings shed light on the network's RSU and UAV coverage and performance. Further analysis and assessment are made possible by the code's creation of scatter plots that show the received power from the RSU and UAV at the locations of the vehicles.

C. Organization of the Paper

The structure of the paper is as follows. Section 2 discusses comprehensive literature on vehicular networks and the use of UAVs and RSUs as network infrastructure. Our proposed protocol is presented in Section 3, along with the distance calculations, coverage range estimation, and SINR threshold for successful transmission. Section 4 discusses the results of our proposed setup, contrasting the throughput capabilities of UAVs and RSUs. The conclusion and potential future directions are suggested in Section 5.

2. RELATED WORK

Internet of Vehicles now vociferously advocates for rapid vehicle connectivity upgrades to satisfy the new, stringent criteria imposed by its expected services (such as field-limited emergency help and rescue, traffic monitoring and highway surveys, enhanced data routing, etc.). Indeed, great efforts are being spent examining components' capacities (i.e., things), motivated by the acknowledged and unavoidable constraints of vehicle traffic dynamics and their naturally resultant adverse effects on vehicular connection performance. Due to their adaptability and ability to complete jobs that would be risky or time-consuming for human pilots in the past, UAVs have represented a notable technological advance. These aircraft can be remotely controlled or flown autonomously, and they have uses in a variety of industries, including disaster relief, military reconnaissance, and surveillance [10]. UAVs can be operated by ground-based operators via remote control or pre-programmed algorithms and are specifically made to fly without a human crew on board [11]. Additionally, the ongoing advancements in materials, sensors, and computing power have resulted in substantial advancements in UAV technology, resulting in improved range, endurance, and general functionality. The use of drones is growing in popularity. However, their market penetration and implementation are still in their early stages. UAV technology is widely used to expedite the automated transportation of commodities to remote sites. In addition, deploying UAVs to support development and building processes is crucial and could aid in achieving the objectives of smart cities and related cutting-edge real estate management [12]. Robust context-specific networks are thought to be made up of UAV swarms [13]. The authors of [14] looked at the usage of UAVs to support several static ground nodes using spatial division multiple access (SDMA). Similarly, [15]-[16] research focuses on using relays to enable mobile stations inside a cell that temporarily encounters overload or service failure to offload their traffic into neighbouring cells.

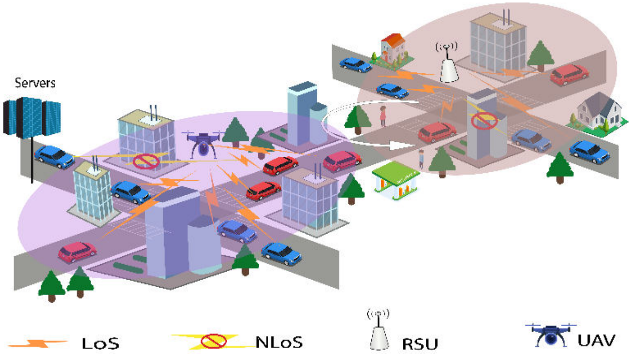

Figure-1. System Model.

3. METHODOLOGY

A. System Model

It is harder for RSUs to service every car as the vehicle density rises efficiently. In these circumstances, as seen in Figure-1. UAVs are deployed to help in serving some of the cars. The system model splits a 1000m x 1000m area into two coverage regions: a 100m radius RSU coverage area and a 200m radius UAV coverage area. When a new vehicle enters the network at a random position, the protocol calculates the distance between the vehicle and the RSU and between the vehicle and the UAV.

Determine whether the car is inside the RSU's or UAV's coverage area. The vehicle is considered inside the RSU coverage range if the distance between the vehicle and the RSU is less than or equal to the RSU distance threshold. The same is true if the vehicle's distance from the UAV is less

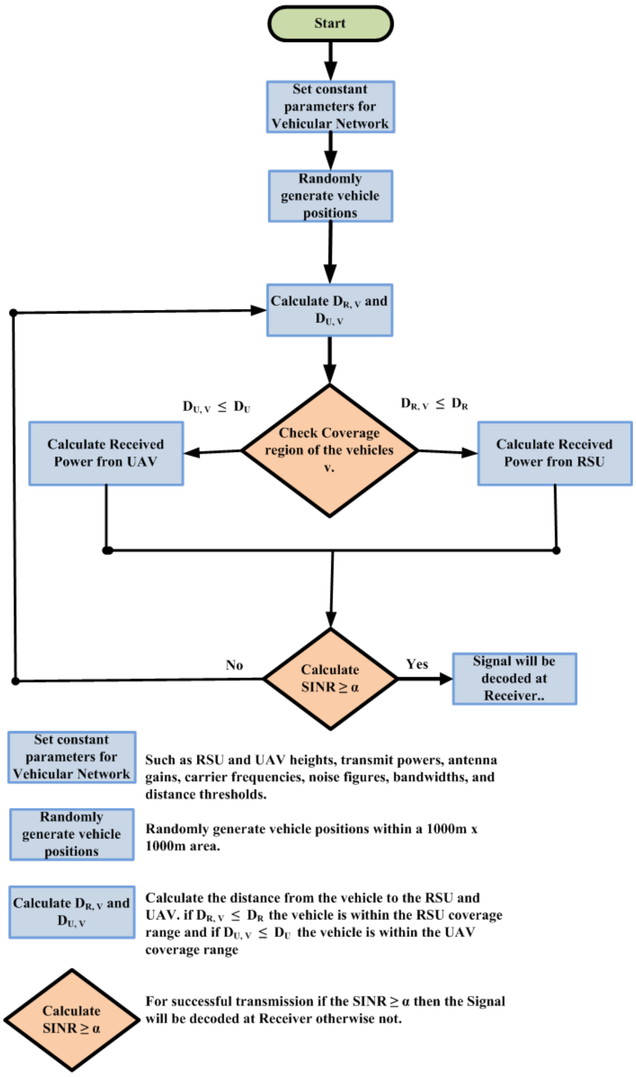

Figure-2. Proposed Protocol.

than or equal to the UAV distance threshold; in that case, the vehicle is inside the UAV coverage range.

The RSU or the UAV determines the received power according to the vehicle's location. The signal is then correctly received and decoded by the receiver if the SINR of the signal exceeds a pre-defined threshold [17]. If not, the vehicle will look for a channel with an SINR higher than the required level for adequate reception and decoding.

B. How Proposed Protocol Works?

According to our proposed protocol, as shown in Figure-2, when a new vehicle enters a vehicular network at any random position. Then the proposed protocol calculates the distance between the vehicle and RSU (D_R, V) and the distance between the vehicle and UAV (D_U, V). If the distance from the vehicle to the RSU is less than the RSU_distance_threshold (D_R), that is (D_R, V $\le D_R$), then the vehicle is within the RSU coverage range. If the distance from the vehicle to the UAV is less than the UAV_distance_threshold (D_U), that is (D_U, V $\le D_U$), the vehicle is within the UAV coverage range. If the vehicle is within the coverage region of RSU, then the received power is calculated at RSU; however, if the vehicle is within the coverage region of UAV, the received power is calculated at UAV. For Successful transmission, we have set SINR as a threshold, according to which if the SINR of a signal is greater than the considered pre-defined SINR threshold, then the signal will be received and decoded by the receiver successfully; otherwise, the vehicle will again attempt for another channel at which the SINR is greater than the pre-determined SINR threshold so that the signal is received and decoded by the receiver successfully.

4. RESULTS AND DISCUSSIONS

A. Network Setup and Constants

We have divided the 1000m X 1000m area into two coverage regions in our proposed model. The radius of the RSU coverage region is 100m, while the radius of the UAV coverage region is 200m. The height of the RSU is 10m, while the height of the UAV is 50m. The power of RSU is 20dBm while the power of UAV is 30dBm. The antenna gain of the RSU is 5dBi, while the antenna gain of the UAV is 10dBi. The carrier frequency of the RSU is 2.4GHz, while the carrier frequency of the UAV is 5.8GHz. Other parameters and their values are given in Table-1.

Table-1. The values of simulation parameters.

Parameters	Values
Number of runs	50
Area	1000m X 1000m
Height of RSU	10m
Height of UAV	50m
Position of RSU (x,y,z)	(250,-5,10)
Position of UAV (x,y,z)	(500, 50, 50)
SINR threshold α	10dB
RSU_antenna_gain	5dBi
UAV_antenna_gain	10dBi
RSU_frequency	2.4GHz
UAV_frequency	5.8GHz
RSU_noise_figure	5dB
UAV_noise_figure	3dB
RSU_bandwidth	10MHz
UAV_bandwidth	20MHz
RSU_distance_threshold	100m
UAV_distance_threshold	200m

B. Throughput of RSU and UAV

In Figure-3 throughput of RSU and UAV are plotted. The UAV has higher throughput than the RSU due to the following reasons.

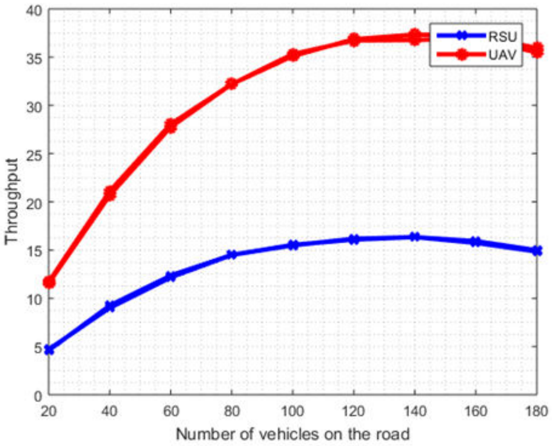

Figure-3. Throughput of RSU and UAV.

a) **Height:** Compared to the RSU (10 m) height, the UAV operates at a greater height of 50 m. With fewer obstructions and improved signal propagation, this additional height gives cars a better line of sight. As a result, the UAV reaches more cars and covers a broader area, which leads to a higher throughput.

b) **Transmit power:** Compared to the RSU (20 dBm), the UAV generally has a greater transmit power (30 dBm). The UAV's coverage area may be efficiently extended due to the higher transmit power, making it possible to service additional vehicles.

c) **Antenna gain:** The antenna gain of the UAV is more significant (10 dBi) than that of the RSU (5 dBi). Antenna gain increases the signal's intensity in the recipient's direction, enhancing the quality of the signal that is received. The UAV can provide more robust and dependable signals to cars with a more considerable antenna gain, improving throughput.

d) **Frequency:** As compared to the RSU (2.4 GHz), the UAV operates at a greater carrier frequency of 5.8 GHz. A more significant amount of data may be transferred in a shorter time because of higher frequencies' wider bandwidths, and faster data rates. As a result, the UAV may use a higher frequency range to achieve better throughput.

e) **Distance threshold:** Compared to the RSU (100 m), the UAV has a more significant distance threshold (200 m). The pre-determined distance threshold determines the UAV and RSU's coverage area. A broader coverage area enables the UAV to service more cars concurrently, boosting throughput.

The UAV offers better throughput than the RSU in a vehicular network because of its higher altitude, transmit power, antenna gain, frequency, and coverage range.

C. Combine RSU-UAV Throughput

The combined RSU-UAV throughput is shown in Figure-4. In a coordinated and cooperative vehicular network, the combined RSU-UAV throughput is equal to the sum of the throughput of RSU and the throughput of UAV. This clearly shows that interference between the channels of the RSU and UAV cannot occur in our proposed simulation.

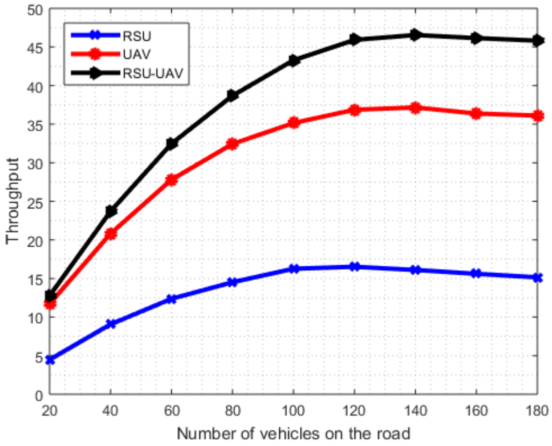

Figure-4. RSU, UAV, and RSU-UAV combine throughput.

D. Controlled Vehicle Distribution

In our proposed protocol, we have developed a mechanism to control the allocation of vehicles to either RSU or UAV within the vehicular network. Our proposed protocol calculates the distance between the vehicle and RSU (D_R, V) and the distance between the vehicle and UAV (D_U, V). If the distance from the vehicle to the RSU is less than the RSU_distance_threshold (D_R), that is (D_R, V $\leq$ D_R), then the vehicle is within the RSU coverage range. If the distance from the vehicle to the UAV is less than the UAV_distance_threshold (D_U), that is (D_U, V $\leq$ D_U), the vehicle is within the UAV coverage range.

By adjusting the value of D_U while keeping D_R constant, we can influence the distribution of vehicles between UAV and RSU coverage areas. Increasing D_U results in more vehicles falling within the UAV coverage region, leading to a higher proportion of vehicles being serviced by UAV, and vice versa.

The throughput of UAV under different D_U thresholds is illustrated in Figure-5, Figure-6, and Figure-7, providing valuable insights into the performance of our system at varying UAV distance thresholds.

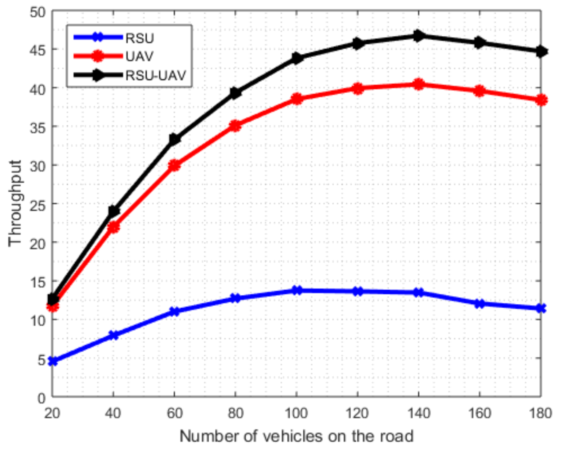

Figure-5. Increasing the burden on UAV with increasing the UAV_distance_threshold of D_U = 200m (Maximum value).

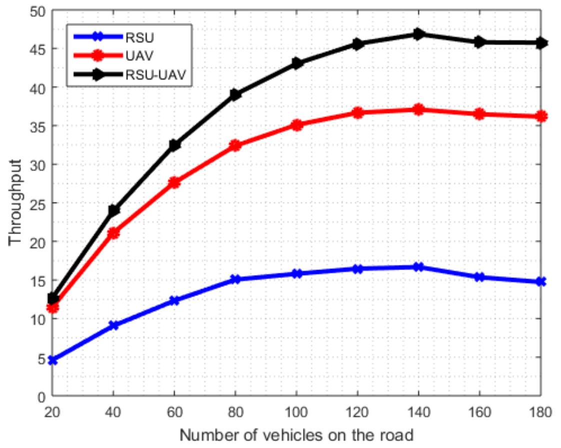

Figure-6. The burden on UAV with the UAV_distance_threshold of D_U = 100m (middle value).

5. CONCLUSION AND FUTURE WORK

In this paper, we developed and analyzed a vehicular network. The vehicle is allocated to an RSU or UAV based on the distance between the vehicle and the RSU or UAV. After the vehicle allocation, the SINR is analyzed for a successful transmission while considering the pre-determined SINR threshold. The results show that UAVs can offer better throughput analysis due to their height, transmit power, antenna gain, and distance threshold. In addition, our suggested protocol successfully divides up cars inside the vehicular network into RSU or UAV coverage regions using distance-based estimates. We can control the distribution of vehicles between the two coverage regions by changing the UAV_distance_threshold while keeping the RSU_distance_threshold constant. This creates a dynamic system where increasing the UAV_distance _threshold results in a higher proportion of vehicles being served by UAVs and vice versa. The total effectiveness and performance of the vehicular communication system are improved by this adaptable method. Moreover, the proposed network can be extended towards a dynamic vehicular network topology changes would make the simulations more realistic and give a more accurate assessment of the protocol's performance in real-world circumstances. Additionally, taking into account how other vehicles' interference and external elements like buildings or topography affect the protocol's resilience and flexibility is helpful. For RSUs and UAVs, optimizing power allocation tactics and looking at energy efficiency issues might result in more practical and affordable solutions.

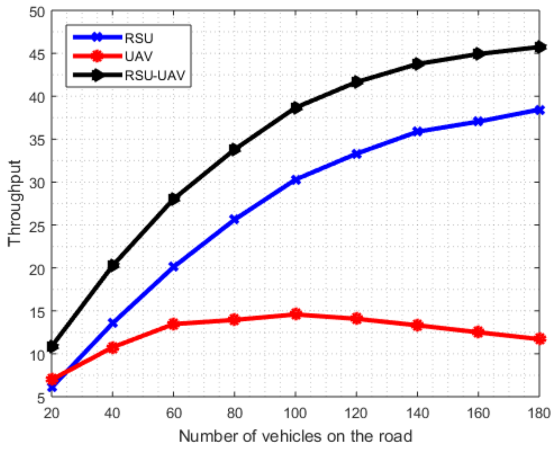

Figure-7. Decreasing the burden on UAV by decreasing the UAV_distance_threshold of D_U = 50m (Minimum value).

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REFERENCES

[1] Trombly A. and Alsmadi I. 2023. Resource Allocation Methods in VANETs: A systematic literature review.

[2] Saeed A., Aftab A. B., Junejo F. and Amin I. 2023. Current and Future Trends in an Intelligent Transportation System with Applications of AI. In Artificial Intelligence in Cyber-Physical Systems: Principles and Applications. p. 75.

[3] Farooq M. S. and Kanwal S. 2023. Traffic Road Congestion System using the Internet of vehicles (IoV). arXiv preprint arXiv:2306.00395.

[4] Panigrahy S. K. and Emany H. 2023. A survey and tutorial on network optimization for intelligent

transport system using the internet of vehicles. Sensors. 23(1): 555.

[5] Mehdi B., Moussaoui S. and Mohamed G. 2023. A geographic routing based on local traffic density and multi-hop intersections in VANETs for intelligent traffic system in smart cities (GRBLTD-MI). Wireless Networks. 1-20.

[6] Tan L., Kuang Z., Zhao L. and Liu A. 2021. Energy-efficient joint task offloading and resource allocation in OFDMA-based collaborative edge computing. IEEE Transactions on Wireless Communications. 21(3): 1960-1972.

[7] Cheng Y., Liang C., Chen Q. and Yu F. R. 2021. Energy-efficient D2D-assisted computation offloading in NOMA-enabled cognitive networks. IEEE Transactions on Vehicular Technology. 70(12): 13441-13446.

[8] Chen Y., Chang Z., Min G., Mao S. and Hämäläinen T. 2023. Joint Optimization of Sensing and Computation for Status Update in Mobile Edge Computing Systems. IEEE Transactions on Wireless Communications.

[9] Chen X., Dai W., Ni W., Wang X., Zhang S., Xu S. and Sun Y. 2023. Augmented Deep Reinforcement Learning for Online Energy Minimization of Wireless Powered Mobile Edge Computing. IEEE Transactions on Communications.

[10] Sadiq B. O. and Salawudeen A. T. 2020. FANET optimization: A destination path flow model. International Journal of Electrical and Computer Engineering. 10(4): 4381-4389.

[11] Fabra F., Calafate C. T., Cano J. and Manzoni P. 2017. On the impact of inter-UAV communications interference in the 2.4 GHz band. In Proceedings of the 13th International Wireless Communications & Mobile Computing Conference (IWCMC). pp. 945-950.

[12] Materwala H., Ismail L., Shubair R. M. and Buyya, R. 2022. Energy-SLA-aware genetic algorithm for edge-cloud integrated computation offloading in vehicular networks. Future Generation Computer Systems. 135, 205-222.

[13] Vemireddy S. and Rout R. R. 2021. Fuzzy Reinforcement Learning for energy efficient task offloading in Vehicular Fog Computing. Computer Networks. 199, 108463.

[14] Shu W. and Li Y. 2023. Joint offloading strategy based on quantum particle swarm optimization for MEC-enabled vehicular networks. Digital Communications and Networks. 9(1): 56-66.

[15] Ismail L. and Materwala H. 2021. Machine learning-based energy-aware offloading in edge-cloud vehicular networks. Procedia Computer Science. 191, 328-336

[16] Haroon, M. S., Abbas, Z. H., Muhammad, F., and Abbas, G. 2020. Coverage analysis of cell-edge users in heterogeneous wireless networks using Stienen's model and RFA scheme. International Journal of Communication Systems, 33(10), e4147.

[17] Abbas, Z. H., Haroon, M. S., Abbas, G., and Muhammad, F. 2020. SIR analysis for non-uniform HetNets with joint decoupled association and interference management, Computer Communications, 155, 48-57.