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RESEARCH ARTICLE

Line-of-Sight-Based Coordinated Channel Resource Allocation Management in UAV-Assisted Vehicular Ad Hoc Networks

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ABSTRACT In Vehicular Ad Hoc Networks (VANETs), the Road-Side-Units (RSUs) that act as base station for serving vehicles may experience significant traffic and congestion during peak hours due to the density of vehicles. To solve this problem, we suggest a coordinated strategy including Unmanned-Aerial-Vehicles (UAVs) on-demand use to supplement and service RSUs and other vehicles. Better resource allocation strategies are required to handle this issue because RSUs and UAVs may share the same set of channels, which will lead to interference. In this research, we propose a UAV-Assisted Protocol (UAVa) to improve network performance, especially throughput. The platform for resource allocation between UAVs and RSUs established by our suggested protocol is cooperative and well-coordinated. The criterion of channel allocation is based on the probability that a Line-of-Sight (LoS) link will exist between the vehicle and the UAV/RSU. The UAV serves the car if the LoS probability is high; otherwise, the RSU offers the service. Signals are successfully decoded to reduce interference if their Signal-to-Interference-plus-Noise-Ratio (SINR) is higher than a set SINR threshold. In contrast, other signals are subject to a back-off timer. We show through simulations that including UAVs is more effective and provides a reliable communication system in VANETs. By implementing a probabilistic access mechanism, our coordinated vehicular network efficiently lessens the stress on RSUs while on the load to UAVs, especially in locations with high traffic density. The LoS connectivity and optimized channel allocation offer better quality of service through RSU and UAVs in this cooperative environment.

INDEX TERMS Vehicular ad-hoc networks (VANETs), road-side-unit (RSU), unmanned-aerial-vehicle (UAV), line-of-sight (LoS).

I. INTRODUCTION

A typical Infrastructure-based VANET consists of an RSU offering limited control and data communication channels to vehicles for serving them as laid in the IEEE 802.11p standard. In certain situations, like bumper-to-bumper traffic, where several vehicles in the service areas are increased, these channels may get exhausted and cause stress to RSU. The stress may be alleviated if a supplementary serve with a better path loss channel is offered to the vehicles. The paper [1]

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examines the particular difficulties faced by UAV networks, highlighting the demand for specialized protocols and the promise of SDN for successful, secure, and reasonably priced missions in the public and civil spheres. The study [2] presents a novel random access protocol for vehicular-to-infrastructure communications that, supported by extensive simulations, achieves significant throughput improvements (9%–38%) in dense networks by utilizing capture effects and optimizing access probability based on network density. Our research underscores the critical need for efficient resource allocation in VANETs during peak traffic hours. Especially in the case when we call UAV to the cell of RSU, interference can occur between the channels of RSU and UAV. To address this challenge, our study builds upon the foundation laid by the random access protocol in [2]. Our research aims to manage resources between RSU and UAV through resource allocation techniques, in our case, a probabilistic access protocol for channel allocation between the two in a cell, and to alleviate congestion on RSUs while harnessing the potential of UAVs in cooperative vehicular communication environments.

A. CONTRIBUTIONS

The critical contributions of our work are as follows:

1) PROBABILISTIC ACCESS SCHEME

In this work, we suggest a unique resource allocation strategy between the UAV and RSU, where the UAV serves the vehicle if there is a high probability or likelihood that they will have a LoS link, and the RSU serves the vehicle if there is a low probability that they will have a LoS link. The total performance of the vehicular network is optimized by this probabilistic access system, which provides efficient and dynamic resource allocation based on the link circumstances.

2) DOUBLE BASE STATION CONTROL SYSTEM

We offer a twin base station control system to enable real-time change of the transmission power for vehicles supplied by either the RSU or the UAV. Our reduced transmission power management method outperforms a continuous power control scheme in terms of network throughput by figuring out the ideal configuration to maximize throughput. This strategy works well for supporting the RSU when resources are limited and is especially useful when network density is high.

3) LOAD BALANCING BETWEEN RSU AND UAV

Our suggested probabilistic access approach includes a threshold for allocating channels to the RSU or UAV. We balance the load between the RSU and UAV by modifying the channel allocation threshold or Probability of LoS for the UAV. The UAV is burdened more when the channel allocation threshold is reduced, whereas the RSU is burdened more when raised. This cooperative strategy entails the UAV cooperating with an operational RSU to service cars, offering a possible remedy for enhanced RSU operations.

B. PAPER ORGANIZATION

The remainder of the paper is laid out as follows. Section II provides literature work in a table. Section III provides a system description with subsections of the transmission scheme and communication model. Section IV provides the proposed protocol, while the simulations and their outcomes are thoroughly discussed in Section V, validating the contributions of our proposed scheme.

II. RELATED WORK

A thorough summary of research on the intersection between UAVs and vehicular networks is given in Table.1. The research covers various approaches and findings, tackling issues like resource allocation, energy management, and practical application. Some of the noteworthy discoveries include the use of UAVs in conjunction with RSUs to improve throughput and content delivery, the investigation of UAVs as a sustainable energy source for IoT wireless nodes, and the creation of novel techniques like flying fog units and proactive caching for increased system efficiency. Common issues still exist, though, such as UAV energy management, complicated resource allocation, and possible problems with practical deployment. The table below highlights the diverse range of research endeavors focused on refining UAV integration to augment performance and connectivity within vehicular networks.

For UAV-assisted vehicle mobility forecasting, the authors of [15] employ RLS and MVC algorithms, which enhance system performance in urban and highway scenarios. The authors in [16] introduce a dynamic spectrum slicing framework for space-air-ground-integrated networks (SAGIN), leading to a 26% throughput improvement via real-time resource optimization [17]. Suggests SDN-based SAGIN-IoV edge-cloud architecture, demonstrating enhanced resource scheduling in experiments. Meanwhile, [18] emphasizes dynamic positioning and adaptation for improved throughput in continuous vehicle communication, utilizing RSUs, UAVs, and UAV assistants. For a Vehicle-Drone hybrid VANET (VDNet), the authors of [19] create a distributed vehicle location prediction algorithm demonstrating exceptional efficiency in a sparse VANET. Using YOLO v5, [20], [21] develops a real-time image-based ADAS system that exhibits high road object identification accuracy. Table.2. offers a list of notations for the readers' reference.

III. SYSTEM DESCRIPTION

A. TRANSMISSION SCHEME

This section describes our suggested transmission methodology, which makes use of random access protocols and probability-based analysis to reduce the complexity of current Carrier Sense Multiple Access (CSMA) techniques. In traditional CSMA, a vehicle checks the availability of the channel before transmission; if it is empty, the car sends its packet; if not, a back-off timer is set and decremented until the channel

TABLE 1. Literature review.

Methodology	Results and Advantages	Limitations
[2] CSMA with capture effect and 2D Markov Chain.	UAV provides 9%-38% throughput improvement for variable network densities, reducing vehicle transmission power and enhancing delivery and coverage.	Excludes resource management and employs a straightforward mobility.
[3] Utilizes UAV as a power source for IoT wireless nodes and employing dynamic game theory for optimal resource allocation.	UAV efficiency in powering IoT wireless nodes is highlighted, addressing limited energy issues through numerical simulations.	Implementing such approach in real world will have challenges associated with UAV-based power transfer in IoT.
[4] Proposes a vehicular network design dividing content delivery between RSUs and UAVs with diverse strategies.	Simulations demonstrate that overlapping content delivery increases RSU-UAV throughput, establishing a clear network structure for balanced resource utilization.	Energy management for UAVs and resource allocation is still a problem
[5] Introduced flying fog units for resource allocation and provisioning to reduce communication delay in congested edge locations.	Improved system efficiency by 9% and reduced wait times are achieved through UAV utilization as computing infrastructure, supporting dynamic workload management.	Drawbacks of implementing UAVs for workload management.
[6] To assess how non-cooperative cars affect VANET connectivity, a mathematical model is created.	UAVs contribute to enhancing end-to-end path connectivity, particularly in addressing challenges posed by uncooperative automobiles in VANET connectivity	Focuses not on fully but rather on a partially collaborative VANET, thus results may vary.
[7] Channel-aware congestion control (CACC) algorithm.	Packet loss is minimized, and delivery ratio is improved through a channel-aware congestion control algorithm that adjusts transmission power and data rate.	Limited discussion on V2V safety applications.
[8] Path loss, fading, and stochastic geometry were used to analyze junction interference.	Flexible design tools provide insights into network performance, offering analytical formulas for essential vehicular network indicators.	Validating the model, adoption of advanced MAC schemes as well as 5G D2D features.
[9] UAVs-RSUs Collaboration using Markov Decision Process (MDP) and Proximal Policy Optimization (PPO).	Simulation-based algorithms optimize content delivery in vehicular environments, maximizing delivery in Intelligent Transportation Systems (ITS) using UAVs and ML techniques.	Resource allocation and energy management for UAVs is still a problem.
[10] Tutorial on using UAVs for wireless communications.	UAVs are explored for increasing the capacity, coverage, dependability, and energy efficiency of wireless networks, addressing obstacles and compromises.	Issues with channel modeling, performance analysis, and energy efficiency.
[11] C-V2X and UAV integration for difficult vehicular circumstances.	Initial user growth of 10% is observed with one UAV, and improvements persist even with 100% active vehicles, enhancing vehicular network connectivity and performance.	Interference may restrict UAV resource consumption; cost-effective for tiny base stations.
[12] Researched self-adaptive control for base stations operating in the 28 GHz frequency spectrum when allocating power to drones.	Incorporating drones into multi-tier networks is crucial for increased capacity and coverage, enabling quick deployment in disaster zones to improve connection.	Energy management is still a problem.
[13] Heuristic algorithm, mixed-integer quadratically constrained issue solved through joint RSU/UAV planning solution.	A heuristic approach provides subpar solutions with sensitivity analysis, but offers flexible connectivity, adjusts to traffic changes, and supports cost- and energy-effective design.	Heuristic approach and NP-hard complexity, are research limitations.
[14] For VANET MAC performance, a comparison of IEEE 802.11p CSMA and STDMA is suggested.	STDMA outperforms CSMA in VANET settings, ensuring prompt channel access for any number of nodes, thereby improving VANET dependability with excellent reliability and low delay.	Alternative prospective MAC strategies are not examined through comparison.

TABLE 2. The definition of simulation parameters.

Notation	Description
α	SINR Threshold
B_1, B_2	The path loss exponent and NLoS attenuation factor respectively
${D^t}_{R\to v}, {d^t}_{U\to v}$	Distance between vehicle V_i and RSU/UAV
${G^t}_{R\to v}, {G^t}_{U\to v}$	Transmission power gain between vehicle V_i and RSU/UAV
K	Stands for the antenna gain.
η_0	The thermal noise power
$P^{(U)}, P^{(R)}$	Path Loss exponent for G-to-A and G-to-G respectively
${\mathbb{S}^R}_{v,n}, {\mathbb{S}^U}_{v,n}$	The received SINR of vehicle V_i over channel n at RSU/UAV
${T^t}_{R\to v}, {T^t}_{U\to v}$	The throughput of the RSU/UAV downlink to vehicle V_i
ω	Represents the total bandwidth
Z_R, Z_U	Height of RSU/UAV

is empty which can be notorious in a highly dense vehicular environment. In our model, we want to skip the extra step of sensing in CSMA to resolve collision problems in dense.

Our recommended technique enables a new vehicle to enter a road segment to access both LoS and Non-Line-of-Sight (NLoS) channels. With no coordination between RSU and UAV, the network will face increased interference. The problem can be alleviated through channel resources management by the following methodology; The UAV receives the channel if the probability of LoS link is greater than 0.5; otherwise, the RSU receives it. Both RSU and UAV have power limitations within their respective areas to minimize interference between the two cells, as illustrated in Fig.1.

We use the SINR as a benchmark to ensure reliable transmission. The signal is deemed to have been successfully received if its power reaches this predefined threshold α; otherwise, it is not accepted for further processing. At the RSU and UAV, $S^R_{v,n}$ and $S^U_{v,n}$ represent the received SINR of vehicle v over channel n. Calculating a signal's SINR is as follows [2], [7], [10], and [11]:

$$\mathrm{S}^{R}_{\mathrm{v,n}} = \frac{\rho_{\mathrm{v,n}} \left|{h^{R}}_{\mathrm{v,n}}\right|^2 \ \mathrm{K}\left(\,{\mathrm{d}^{R}}_{v}\right)^{-\mathrm{P}^{(\mathrm{R})}}}{\eta_0 + \sum_{v\neq v, v\in V_n} \rho_v \left|{h^{R}}_{v,c}\right|^2 \ \mathrm{K}\left(\,{\mathrm{d}^{R}}_{v}\right)^{-\mathrm{P}^{(\mathrm{R})}}} \tag{3.1}$$

$$\mathrm{S}^{U}_{\mathrm{v,n}} = \frac{\rho_{\mathrm{v,n}} \left|{h^{U}}_{\mathrm{v,n}}\right|^2 \ \mathrm{K}\left(\,{\mathrm{d}^{U}}_{v}\right)^{-\mathrm{P}^{(\mathrm{U})}}}{\eta_0 + \sum_{v\neq v, v\in V_n} \rho_v \left|{h^{U}}_{v,n}\right|^2 \ \mathrm{K}\left(\,{\mathrm{d}^{U}}_{v}\right)^{-\mathrm{P}^{(\mathrm{R})}}} \tag{3.2}$$

In these equations, $\rho_{v,n}$ it signifies the transmit power of the vehicle v, specifically over channel n, v_n denotes the total number of vehicles engaged in communication via channel n. The thermal noise power represented η_0 is an inherent factor in the communication channel and cannot be eradicated. The path loss exponent for the G-to-A channel is denoted by $P^{(U)}$,

FIGURE 1. System model.

and similarly, the path loss exponent for the G-to-G channel is represented by $P^{(R)}$. Moreover, K stands for the antenna gain.

B. COMMUNICATION MODEL

The link transmission is controlled by both LoS and NLoS, and the RSU works on TDMA, where each time slot t is allotted to just one vehicle. The following equation may be used to determine the probability that RSU will use a LoS connection:

$$P\left[LoS = S^t_{R\to v}\right] = \frac{1}{1+\Upsilon_1 e^{(-\gamma_2(\theta^t_{R\to v}-\gamma_1))}}, \quad \forall v \in V^t \tag{3.3}$$

The environmental constants for urban and rural scenarios are represented by Υ_1 and Υ_2 respectively. Moreover, $\theta_{R\to v} = tan^{-1}(Z_R/d^t_{R\to v})$ denotes the elevation angle in degrees between the RSU and vehicle v at time slot t. To assess the likelihood or probability of a NLoS link, the following expression can be employed:

$$P\left[NLoS = S^t_{R\to v}\right] = 1 - P\left[LoS = S^t_{R\to v}\right] \tag{3.4}$$

$G^t_{R\to v}$ is an expression for computing the transmission power gain of vehicle v during time slot t is given by:

$$G^t_{R\to v} = \begin{bmatrix} \left(D^t_{R\to v}\right)^{-B_1} & S^t_{R\to v} = LoS \\ B_2\left(D^t_{R\to v}\right)^{-B_1} & Otherwise \end{bmatrix} \tag{3.5}$$

The path loss exponent, denoted as B_1 and the NLoS attenuation factor, represented by B_2 play crucial roles in determining the $G^t_{R\to v}$. Where $D^t_{R\to v}$ can be calculated as:

$$D^t_{R\to v} = \sqrt{\left(d^t_{R\to v}\right)^2 + Z_R^2} \tag{3.6}$$

$D^t_{R\to v}$ Represents Euclidean distance between the RSU and vehicle v at time slot t. The following equation may be used to compute and depict the instantaneous throughput of the RSU downlink to vehicle v:

$$T^t_{R\to v} = \omega\log[1+\frac{\rho_R h^t_{R\to v}}{\mathrm{N}^2}] \tag{3.7}$$

where ρ_R represents the RSU's transmitted power, ω represents channel's bandwidth, and N represents noise in the channel. For a vehicle v from the UAV at time slot t, the probability of channel state $S^t_{U\to v}$ and $G^t_{U\to v}$ may be computed using the channel-power-gain:

$$P[LoS = s^t_{U\to v}] = \frac{1}{1+\gamma_1 e^{(-\gamma_2(\theta^t_{U\to v}-\gamma_1))}}, \quad \forall v \in V^t \tag{3.8}$$

$$G^t_{U\to v} = \begin{bmatrix} \left(D^t_{U\to v}\right)^{-B_1} & s^t_{U\to v} = LoS \\ B_2\left(D^t_{U\to v}\right)^{-B_2} & Otherwise \end{bmatrix} \tag{3.9}$$

The following equations yield the instantaneous throughput $T^t_{U\to v}$ of the UAV downlink to vehicle v at time slot t:

$$T^t_{U\to v} = \omega\log[1+\frac{\rho_U h^t_{U\to v}}{N^2}), \forall v \in V^t, \mathrm{t}] \tag{3.10}$$

where Z_U represents the UAV's height where as $d^t_{U\to v}$ is the horizontal distance from vehicle v to the Base of UAV, ρ_U is the UAV transmission power, and $\theta^t_{U\to v} = \frac{180}{\pi}\arctan\left(\frac{Z_U}{d^t_{U\to v}}\right)$ is the angle in degrees.

The following provides uplink throughput denoted by $T^t_{v \to U}$ between vehicle v and the UAV at time slot t:

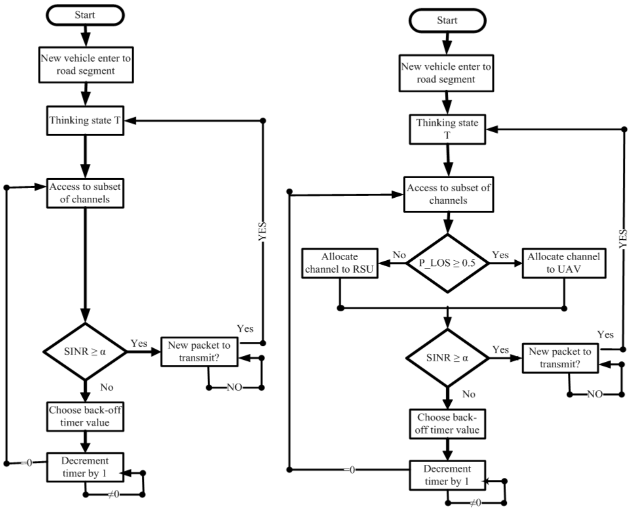
$$T^t_{v \to U} = \omega \log[1 + \frac{\rho_V h^t_{U \to v}}{N^2}], \quad \forall v \in V^t, t \tag{3.11}$$

Here ω represents the total bandwidth, ρ_V denotes the transmitted power of vehicle v, and N represents thermal noise. The RSU and UAV use different spectrums to prevent interference from occurring between their signals. Consequently, only within the boundaries of these particular sites are viable communication linkages formed. Notably, the RSU, cars, and UAV all have different transmission powers, as shown by:

$$\mathrm{p}_R > p_V > p_U \tag{3.12}$$

IV. PROPOSED PROTOCOL

Our novel technique, which differs from the usual protocol, presents a fresh method for channel allocation when a new vehicle reaches a road section. The vehicle enters a thinking state (T) upon ingress and can then access a subset of channels. Evaluating the likelihood or probability of LoS and NLoS connectivity is crucial to channel allocation. The UAV receives the channel if the probability of LoS is greater than 0.5; otherwise, the RSU receives it. When channel allocation is complete, the received SINR is evaluated against the predetermined threshold α. The signal is properly deciphered if the SINR rises over this limit. However, the vehicle enters a back-off timer state if the SINR drops below the threshold α as shown in Fig.2.B, the timer value is decreased with each try, and when it equates to zero, the vehicle tries to access the subset of channels once more. This comparison analysis shows how effective our suggested methodology is at controlling vehicle access in high-traffic settings and dynamic channel allocation based on LoS probabilities. By implementing a probabilistic access mechanism, our Proposed coordinated protocol efficiently lessens the stress on RSUs while increasing the load on UAVs, especially in locations with high traffic density, without wasting resources as in the case of non-coordinating existing protocols.



A. Existing Protocol

B. Proposed Protocol

FIGURE 2. Existing vs proposed protocol.

V. RESULTS AND DISCUSSION

A. THE VALUES OF SIMULATION PARAMETERS

We define the simulation parameters and their related values in this paragraph while considering a three-lane highway scenario. With a difference between the fast, medium, and slow lanes, where automobiles move at speeds of 30 m/s, 20 m/s, and 10 m/s, respectively, the vehicles are dispersed randomly between these lanes. Vehicle placements along the route are decided randomly when they enter a horizontal road section with a 0 to 500 km length. The analysis focuses on a particular stretch of road where an RSU-UAV pair works together to serve the cars. The specified contention window's (CW) voice streaming optimization. Table.3. presents additional simulation settings and information that includes all the critical variables required for a thorough assessment of the RSU-UAV collaboration in vehicular networks.

TABLE 3. The definition and values of simulation parameters.

Simulation parameters	Values
Height of UAV	50m
Position of RSU (x,y,z)	(250,-5, 30)
Position of UAV (x,y,z)	(250, 10, 50)
Access Probability q	0.2
Probability of LoS link p	0.5
SINR Threshold α	1
Path Loss exponent for G-to-A $P^{(U)}$	2.5
Path Loss exponent for G-to-G $P^{(R)}$	3.1
Environment constant urban area Υ_1	0.6
Environment constant rural area Υ_2	0.11

When a new vehicle reaches a road segment in the proposed coordinated vehicular network, it gains access to a certain number of channels as it transitions into the thinking state (T), i.e., the vehicle is assumed to have a packet to send. For channel allocation between the RSU and UAV, it is important to calculate the probability of LoS and NLoS links. The channel is allotted to the UAV based on LoS criterion discussed earlier and follows CSMA with capture effect for transmission and decoding of packets as discussed in earlier sections.

References [2], [4], [9], and [14] indicates that UAVs excel in LoS links due to their favorable path loss component ($P^{(U)} = 2.5$) for G-to-A communication, surpassing the G-to-G communication of RSUs to vehicles ($P^{(R)} = 3.1$), affecting received signal power. Considering both LoS and NLoS links is vital in dynamic UAV scenarios, given changing flight paths and obstacles. The LoS component significantly influences performance, ensuring superior signal quality and reliability. Precise modeling of LoS and NLoS scenarios is crucial for optimizing communication in practical UAV applications. The outcomes for our suggested coordinated vehicular network are shown in Fig.3. The overall throughput climbs as the number of automobiles handled by either RSU or UAV rises. There are more chances for channel assignment to UAV since LoS connections with a probability above 0.5 occur more frequently. As a result, the throughput of UAVs is higher than that of RSUs. The findings demonstrated here support the benefits of our suggested coordinated vehicular network and indicate how the use of UAVs in conjunction with RSUs has the potential to enhance communication performance.

B. RSU, UAV, AND COMBINED RSU-UAV THROUGHPUTS

Two crucial factors are the 'Number of vehicles' is shown on the x-axis, while the 'throughput' is shown on the y-axis. The blue line represents the throughput of RSU for vehicles served exclusively by RSU. The red line represents the throughput of UAV for vehicles served exclusively by UAV. The black line represents the combined throughput for vehicles served by both RSU and UAV, with the choice depending on the quality and probability of LoS connectivity. In one-time slot, a vehicle is served with a part of the content by RSU, and after the handoff, depending on the quality of the channel, this vehicle is served with the other part of the content by UAV in another time slot. According to our probabilistic access scheme, the UAV receives the channel if the probability of LoS is greater than 0.5; otherwise, the RSU receives it. As the UAV usually hovers over dense traffic areas with a height greater than RSU's, most vehicles appear on direct LoS for UAV. Therefore, the probability of LoS link for UAV is mostly greater than 0.5, so more channels and vehicles are allocated to UAV, which results in higher throughput for UAV in our proposed simulation, as shown in Fig.3.

C. EVALUATION OF THE EXISTING SIMULATION AND THE PROPOSED SIMULATION

An increase in vehicles may result in identical throughput for UAV and RSU owing to random access in the Existing non-coordinated network simulation, potentially resulting in interference as shown in Fig.4. However, in our proposed simulation, as the number of automobiles rises, the throughput of the UAV improves more noticeably due to LoS communication, exceeding that of the RSU and lowering the chance of interference as shown in Fig.3.

The comparison between the existing and the proposed simulations is shown in Fig.5. This comparison shows that by implementing a probabilistic access mechanism, our proposed coordinated protocol efficiently lessens the stress on RSUs while increasing the load on UAVs, especially in locations with high-traffic density, without wasting resources unlikely as in the case of non-coordinating existing protocol as shown by its simulation result in Fig.4 of Ref. [2]. We rely on the result of [2] with 9%-38% throughput improvement compared to CSMA with further improvement by our proposed protocol in terms of mitigation of interference and load balancing between RSU and UAV, as shown in Table.4. The RSU can only cover fewer cars for the chosen simulation

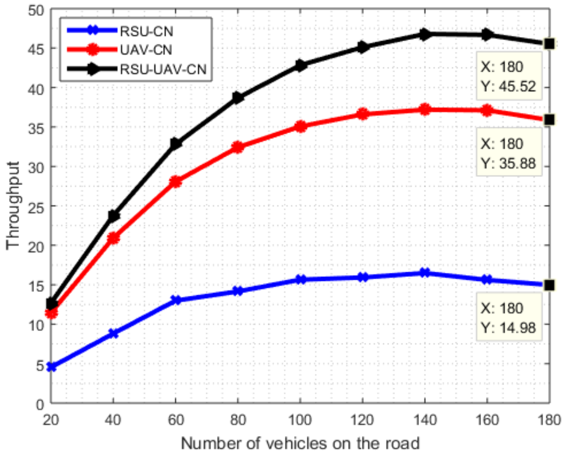


FIGURE 3. Conducting a throughput comparison among RSU, UAV, and combined RSU-UAV of the Proposed Coordinated Network at probability of LoS link $p = 0.5$ (Middle value).

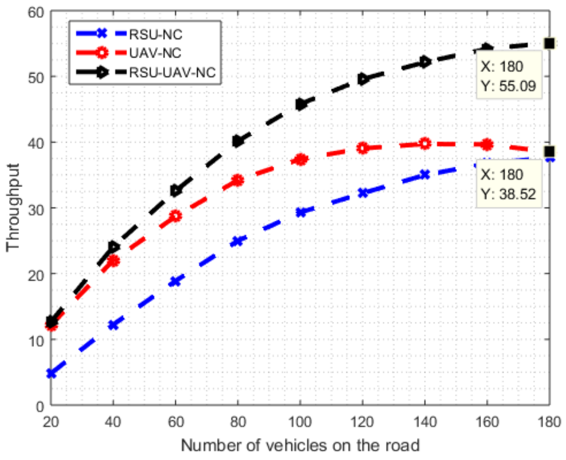


FIGURE 4. Conducting a throughput comparison among RSU, UAV, and combined RSU-UAV of the existing non coordinated network.

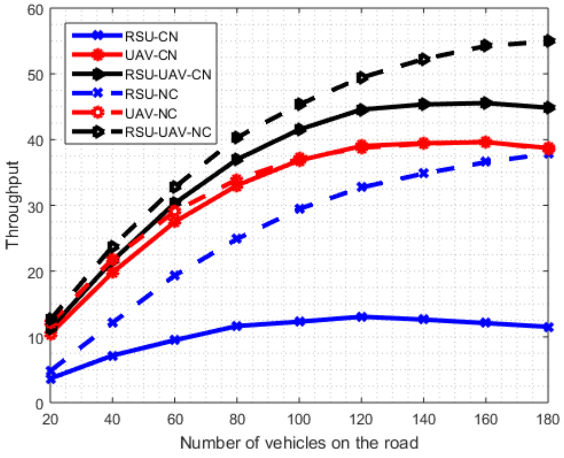


FIGURE 5. Throughput of the proposed coordinated vs existing Non-Coordinated network.

parameters and network density shown in Fig 3. These results reveal the effectiveness of our suggested coordinated vehicular network and demonstrate how using UAVs may improve resource allocation and communication performance in vehicular contexts.

Due to our proposed resource allocation technique (Probabilistic Access Scheme), UAV, RSU exclusively serves vehicles entirely with the required content size or by both RSU-UAV, each with different content without overlapping to prevent wastage of resources. Consequently, the combined RSU-UAV-CN throughput (solid black line) is lower than the existing combined RSU-UAV-NC throughput (dashed black line), which demonstrates the positive impact of our Probabilistic Access Scheme as shown in Fig.5. In conclusion, the coordinated content delivery approach in our coordinated network effectively eliminates overlap between RSU and UAV during handoff, ensuring precise content delivery matching the total content size [4]. This approach demonstrates the success of interference control and resource allocation techniques in crowded vehicular networks.

TABLE 4. Difference between existing and proposed protocol.

Features	Existing Protocol	Proposed protocol
Protocol Type	Random Access Protocol	Probabilistic Access Scheme
Channel Sensing	Capture effect for collision resolution.	Allocation based on LoS probability and SINR thresholds
Resource Management	Resource Management have not been considered.	Efficient Resource Management and load balancing between RSUs and UAVs.
Channel Allocation	Randomly allocated between RSU and UAV.	Allocation based on LoS probability.
Network Type	Non coordinated Vehicular Network.	Coordinated Vehicular Network.
Improvement	9%-38% Throughput improvement compared to CSMA.	9%-38% Throughput improvement along with Resource management and Load balancing.

D. LOAD DISTRIBUTION BETWEEN RSU AND UAV

Our proposed probabilistic access technique has a certain threshold p for channel assignment to the RSU or UAV. In more detail, the UAV will serve the vehicle if there is a higher chance of a LoS link than the threshold p; otherwise, the RSU will do so. We may see the load distribution between the RSU and UAV by changing the value of the channel assignment threshold p for the UAV. The load on the UAV grows when the channel allocation threshold or Probability of LoS p for UAV decreases i.e. ($p = 0.25$), as seen in Fig.6. However, as illustrated in Fig.7, raising the channel allocation threshold p for UAV i.e. ($p = 0.75$) exerts a greater load on the RSU.

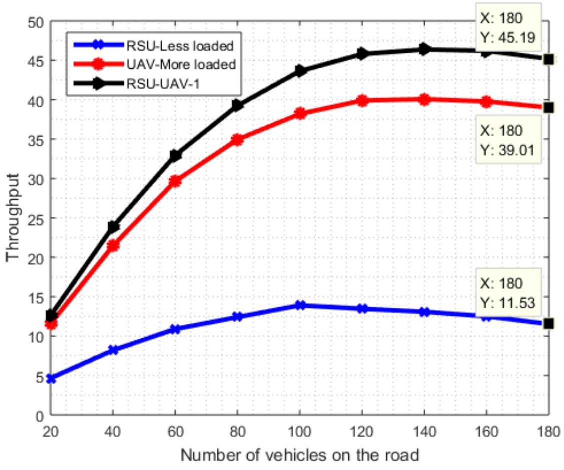


FIGURE 6. Maximizing the load on UAV by lowering the threshold of probability of LoS $p = 0.25$ (Minimum value).

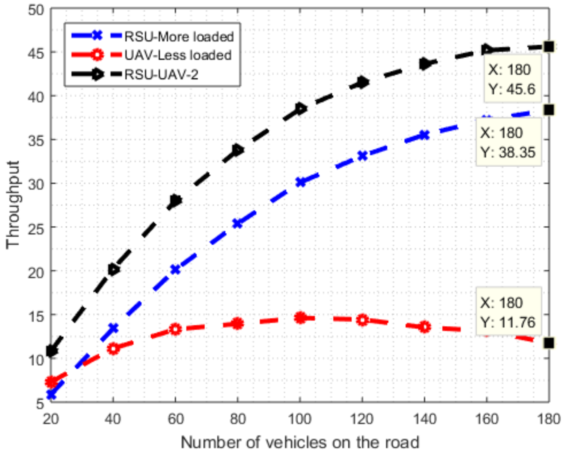


FIGURE 7. Minimizing the load on UAV by raising the threshold of probability of LoS $p = 0.75$ (maximum-value).

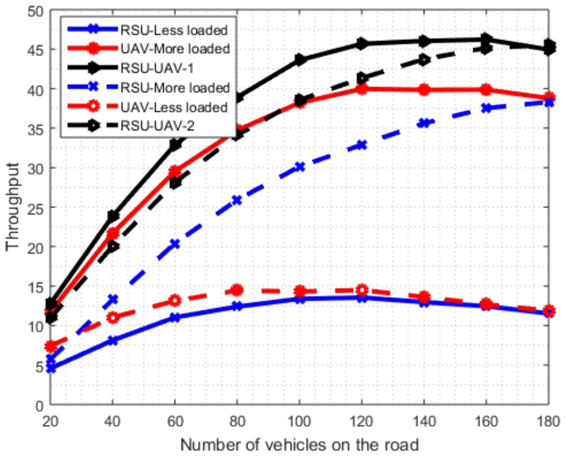


FIGURE 8. Comparison between Fig.6 ($p = 0.25$), and Fig. 7. ($p = 0.75$).

Notably, as shown in Fig.3. a larger proportion of cars are still served by the UAV at the median channel allocation threshold p value i.e. ($p = 0.5$). This is due to the UAV's deliberate location, which hovers over regions with higher traffic density and puts more cars in the UAV's direct LoS than the RSU. As a result, there is a larger chance of a LoS link between a UAV and a vehicle than there is between an RSU and a vehicle. As a consequence, the UAV can serve a greater percentage of cars, which boosts its throughput in comparison to the RSU. These findings highlight the efficiency of our suggested method for balancing load between the RSU and UAV and the possibility for increased throughput by utilizing UAVs to service cars in densely populated locations. The comparison of both scenarios is illustrated in a single Figure, as depicted in Fig.8.

VI. CONCLUSION AND FUTURE WORK

This manuscript develops a probabilistic access scheme with predetermined SINR values and resource allocation criteria, developing a coordinated and load-balanced vehicular network. With this strategy, we successfully lighten the load on RSUs and improve network performance in high-traffic locations. Our simulations and mathematical analysis show that, principally due to improved LoS communication and channel conditions, the UAV outperforms the RSU in a shared network.

Our contributions include developing a probabilistic access scheme for efficient resource allocation based on LoS probability and SINR thresholds, demonstrating through simulations that UAVs outperform RSUs in shared networks due to improved LoS communication, and creating a coordinated vehicular network to distribute demand on UAVs and alleviate RSU stress, reducing interference. In the future, we plan to explore advanced resource management strategies for ITS, focusing on curved highways, incorporating UAVs and machine learning techniques to enhance content delivery reliability in challenging scenarios.

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