Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 1, 682-691
2025
Publisher: Learning Gate
DOI: 10.55214/25768484.v9i1.4210

A compensation of VANETs with UAVs to optimizing the routing strategy

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Abstract: Vehicular Ad Hoc Networks (VANETs) played a vital role in the infrastructure of smart cities due to intelligent communication systems. VANETs exhibit unique characteristics, such as high speeds and unpredictable mobility, which lead to challenges such as overhead, delay, and link failure. Therefore, Unmanned Aerial Vehicles (UAVs) are introduced to mitigate ground-level issues, with communication managed through the air medium used to address these problems. Routing also needs to be enhanced for effective communication in UAV-assisted VANETs. This paper proposes an Advanced UAV Communication Strategy for VANETs (AUCS-VANETs) approach to optimize the routing protocol. The strategy selects the shortest route from source to calculate the vehicle's potential future delay and employs the Probability Distribution Function (PDF) through Bayes' model. We use NS2 and SUMO in the simulation as well as four parameters for testing ("Packet Delivery Ratio" (PDR), "End-To-End" (E2E) delay, "Routing Overhead" (RO), and "Throughput" (TP). The experiment results show that the AUCS-VANETs approach achieves higher PDR and TP, along with lower E2E delay and RO compared to earlier approaches.

Keywords: *AUCS-VANETs (Advanced UAV communication strategy for VANETs), Intelligent transportation systems (ITS), UAVs (Unmanned Aerial Vehicles), Routing strategy.*

1. Introduction

VANET is a wireless network that enables seamless connections among clients of wireless devices within proximity, eliminating the need for infrastructure like base stations [1, 2]. It facilitates easy connections without relying on such communication infrastructure. VANETs are employed across several Intelligent Transportation Systems (ITS) applications [3]. Nowadays, it is considered one of the fastest networks, leading to several weaknesses like transparency, delay, and data loss. In VANETs, the highest delay occurs due to ground-level problems. Unmanned Aerial Vehicles (UAVs) resolve this drawback completely by facilitating air-to-ground communication, allowing vehicles to bypass ground congestion and data loss [4-7].

UAVs improve the efficacy of vehicular communication possessing distinctive features such as target tracking, the capability to transmit significant volumes of data, great autonomy, and providing temporary hotspots a promising technology. A promising technology for improving vehicular communication, UAVs offer capabilities such as target tracking, providing temporary hotspots, and operating with high autonomy. Moreover, UAVs can cover vast areas, making them a cost-effective solution [8, 9]. Currently, UAVs are applied in many technologies such as geometry-based stochastic, deterministic models, and non-geometrical stochastic models. Digital mapping is one of the special features of UAVs. UAVs-assisted VANET, routing must be concentrated to further RO occurrence during communication. Effective routing becomes essential for data communication in the VANETs due to high-speed mobility and

History: Received: 9 December 2024; Revised: 30 December 2024; Accepted: 2 January 2025; Published: 13 January 2025
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dynamically changing topology [10, 11]. For that purpose, this paper introduces an improved communication strategy for UAV-aided VANETs. The paper's contribution is described as follows: (i) to expand the VANETs communication; (ii) to secure the network from ground-level obstacles; (iii) to developed UAVs-assisted VANETs technology.

A new routing approach is introduced in UAVs-aided VANETs called Advanced UAVs Communication Strategy for VANETs (AUCS-VANETs) to enhance the routing and reduce the RO during communication. Through this method, the routing process is enhanced by finding the shortest transfer data among the source and destination at the time of routing in an effective way. This proposed approach greatly increases the delivery rate and TP and reduces the network's E2E delay and RO.

2. Related Work

Oubbati, et al. [12] the authors presented a framework for an adaptive unmanned aerial vehicle (UAV) assisted geographic route with Q-Learning. This framework's high PDR and low E2E latency are its key benefits. This framework is not applicable in the case of a sparse vehicular network. Jiang, et al. [13] the authors performed a strong routing method for guaranteeing a communication stability high level by using an effective backbone for the rescue services. This framework offers high dependability. However, in this system, connection verification activities add extra network overhead, and the TP maximization calculation process takes more time. Oubbati, et al. [12] it was presented a multi-agent architecture for better UAV communication in VANET. This architecture eliminated data duplication and overlapping communication. However, results show that it increased energy utilization and sluggish data transmission.

Ahmed, et al. [14] the author presented a Deep Reinforcement Learning (DRL) framework using UAVs for an urban VANET scenario. The proposed framework performs better energy usage and coverage. This protocol believes that the network will always have a backup delivery method; hence it does not offer any protection in the event of a networking gap. In Raza, et al. [15] it was addressed a relay selection problem in VANET. The performance of the VANET network and communications are improved by this framework using UAV. Regarding delivery ratio, delivery delay, and signalling overhead, this framework offers higher performance. However, this led to an increase in energy usage.

Jobaer, et al. [16] the authors reported UAV-aided VANET communication approach for providing flexible communication by Intelligent Transportation Systems (ITSs). As a result, packet collisions are reduced, and energy use is optimized. Bakhtiari, et al. [17]the authors presented a system for interdependent task scheduling that can identify the driving environment on highways. With this framework, the total reaction time is reduced dramatically, and the system stability is increased. High packet loss is this framework's biggest drawback. He, et al. [18] it was proposed a ClouDiV protocol. The demonstrated improved performance over packet delivery rate, E2E latency, throughput (TP) and fewer dropped packets.

Wang, et al. [19] the author presented a new approach for solving the communication issue in unmanned aerial vehicle (UAV) assisted VANETs. The proposed approach is used to decrease the computational delay in the network caused by congestion. It is the combination of relax-and-round as well as a sequential convex approximation. Through this method, network delay is reduced but it fails to achieve a high delivery ratio and TP. For that purpose, an improved communication strategy for UAVs is proposed and it is detailed in the upcoming sections in this paper.

3. AUCS-VANETS Approach

The proposed method Advanced UAVs Communication Strategy (AUCS) in VANETs consists of communication approaches like “vehicle-to-vehicle” (V2V) data communication and “vehicle UAV” data transmission. To perform communication, the networks follow the IEEE 802.11p MAC protocol. The outlook of the AUCS-VANETs approach is shown in Figure 1. Both communication approaches are described below.

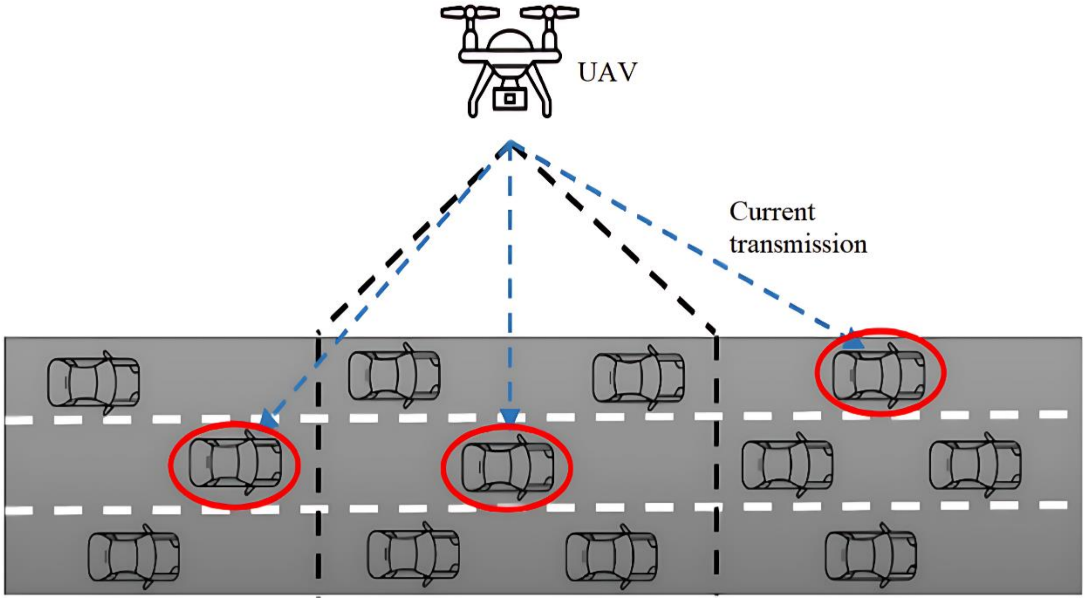

Figure 1.
The architecture of AUCS-VANETs approach.

In communication of the V2V model, every vehicle can be able to communicate with another vehicle that exists in its coverage area as well as through the vehicles that are extant in the line of prospect to the target. V2V data communication is termed as direct communication and multi-hop communication is termed as indirect transmission. The major disadvantages that occur in these types of communication are the presence of obstacles and congestion. This drawback is reflected in link failure and data loss. As so to overcome these network flaws UAVs are introduced in VANETs. UAVs are represented as air vehicles that can communicate effortlessly with vehicles and other UAVs.

3.1. Characteristics of UAVs

UAVs perform reliable communications using 3GPP standards and its support for PLMNs over several generations like 4G and 5G so that it can be able to support a maximum of industrial applications as well as help to expand the terrestrial to non-terrestrial regions. The maximum speed achieved by the UAVs is 320 Km/hr and able to transfer 1500 bytes of data with a communication range of a 50m radius. The general operations of UAVs are resource allocation, route discovery, and communication establishment. In general vehicle communication with others is shown in its zone area. Whenever the distance and obstacles in the route are high it takes the UAVs help to perform the data communication. UAVs are incorporated with several networking technologies to perform communication with one another. Figure 2 shows the structural view of the UAVs.

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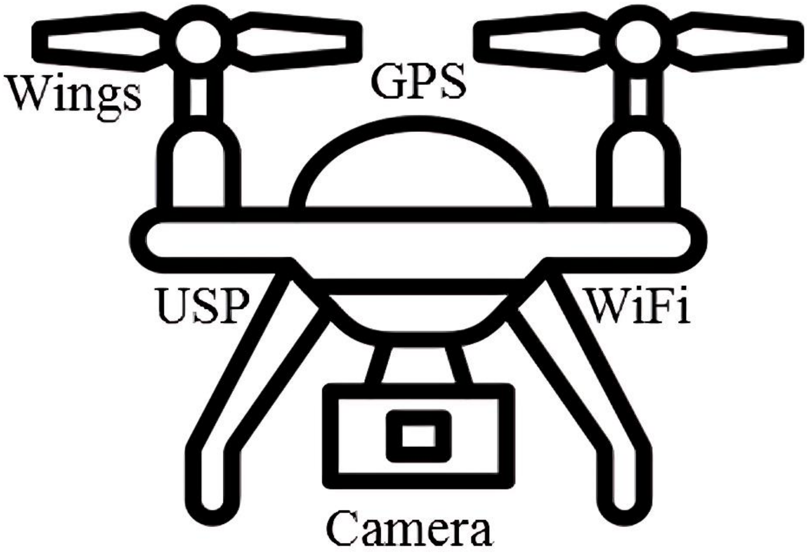

Figure 2.
The unmanned aerial vehicles (UAVs) structure.

3.2. UAVs Communication Strategy

In the methods, the main concentration is on the UAV's decision-making to perform routing. At the initial stage, the UAVs are designed to analyze the network topography to find a better way to perform data communication from the source to the destination. The UAVs will transmit a request message to the destination hence the coverage area of the UAVs is high if the destination is present in the same direction the shortest route can be found easily, and then the UAV forwards the message in that route. Once after identifying the network topography to find the shortest route Dijkstra's algorithm is used. If the UAVs fail to obtain the shortest route, then it is understood that the destination is far away and is out of the coverage area of the UAV. At the time UAVs to UAVs communication takes place. Then through that secondary UAV, the data is transmitted to the destination. This process is otherwise called a futuristic approach. Here the UAVs start predicting the future location of the vehicles according to the past travel history and it also measures the future potential delay caused by the link failure during the process of communication. The node that maintains the least future potential delay is selected. This node is also the closest to the destination, and through this process, the optimal route is determined. The mathematical expression to find the shortest route using Dijkstra's algorithm and potential delay is given in equation:(1).

$$P_{delay}\left(X_1, Dist, t_0, P_{t_0,} RE_{X_1}\right) < P_{delay}\left(X_2, Dist, t_1, P_{t_1,} RE_{X_2}\right) \tag{1}$$

In equation (1), the terms represent the potential delay factor, the distance of the (current sender), represents the current time, represents the predicted time at the current time, represents the residual energy of the current sender and the term denotes the potential delay of the link establishment. If the potential delay of the sender is less than its receiver, then that receiver is declared as its best neighbour of sight to the destination. The route selection must maintain minimum neighbours to reach its destination. To perform final routing confirmation, the probability distribution function is applied to the potential delay calculation. The mathematical expression to get the total route to achieve the endpoint is given in equation (2).

$$Total_{path} = P_{delay}\left(X_1, Dist, t_0, P_{t_0,} RE_{X_1}\right) * \min\left(l_1, l_2, l_3, \dots, l_n\right) \tag{2}$$

In equation (2), the terms denote the link estimation between the source to the destination. The probability distribution function (PDF) using Baye's model is expressed in equation (3).

$$PDF_{path} = Total_{path} * C_{path} \tag{3}$$

In equation (3), the term denotes the cumulative distribution function (CDF) of the route according to equation (3) that with a smaller number of neighbours to reach the destination is calculated. This is the process of improving the communication strategy for UAVs-assisted VANETs. Figure 3 shows the workflow of the AUCS-VANETs approach.

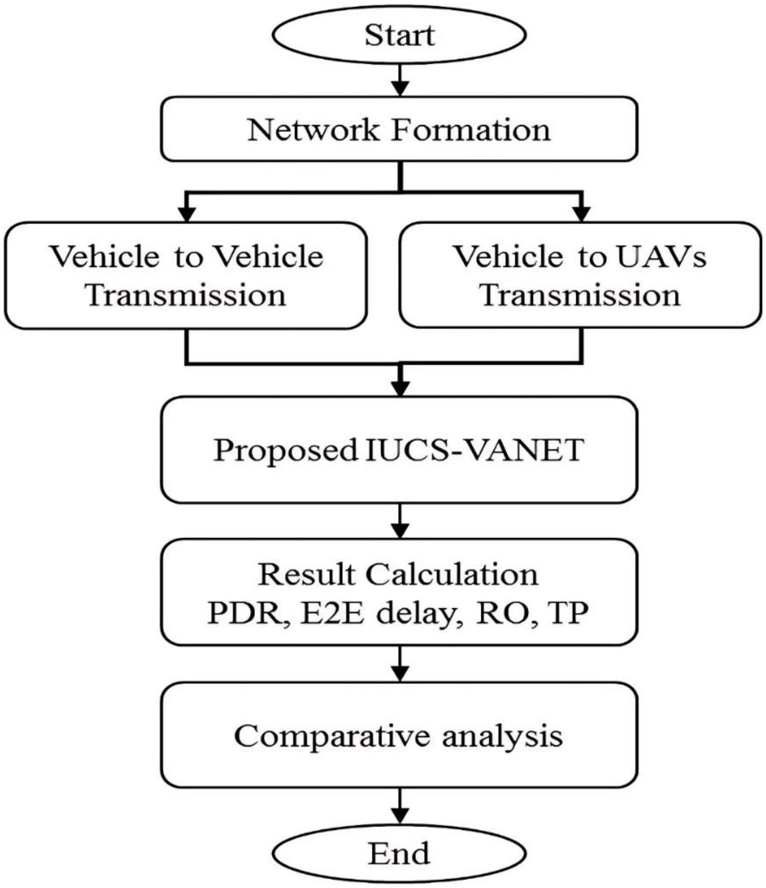

Figure 3.
The AUCS-VANETs approach.

4. Performance Analysis

The AUCS-VANETs is calculated to compare with TOCA and VCOL approaches. The results are estimated using packet delivery rate, E2E delay, routing overhead, and TP parameters. Table 1. shows the simulation settings.

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Table 1.
The parameters of simulation.

Parameters	Values
Time	500 ms
Measurement	1000m*1000m
vehicles number	300 vehicles
Power of transmission	0.500Joules
UAVs radius	400m
Initial energy	100Joules
Receiving power	0.050Joules
UAVs number	3 UAVs
software	NS2
Operating system	SUMO

4.1. PDR Calculation

Figure 4 represents the first parameter which is the packet delivery rate of the AUCS-VANETs approach. Also, it shows the packet delivery rate in TOCA with VCOL approaches. The results show that the AUCS-VANETs approach is more effective than the TOCA and VCOL and approaches in terms of PDR.

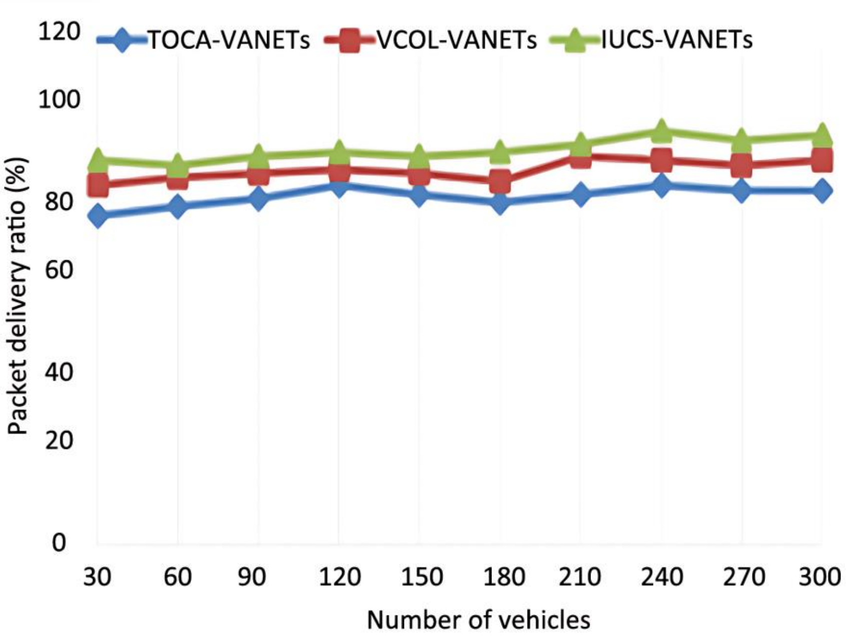

Figure 4.
The PDR calculation.

4.2. E2E Delay Calculation

Figure 5 represents the E2E delay of approaches like the TOCA-VANETs, VCOL-VANETs, and the AUCS-VANETs. The figure shows that the E2E delay results of the AUCS-VANETs approach are lower than both the TOCA and VCOL approaches. An improved communication approach is aimed to reduce the E2E delay of the network.

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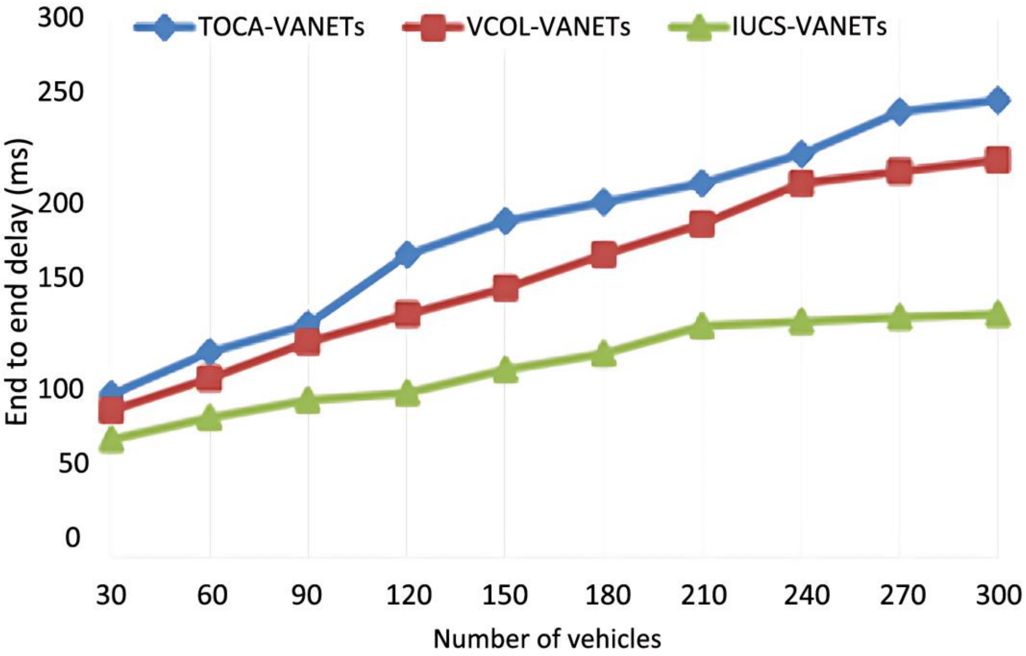

Figure 5.
The E2E delay calculation.

4.3. RO Calculation

Figure 6 presents the RO of approaches like TOCA, VCOL, and the AUCS-VANETs approach. The routing overhead refers to the packet number that is forwarded back to the source instead of being delivered to the destination. Figure 1 demonstrates that the AUCS-VANETs approach produced overhead very low compared with the TOCA and VCOL approaches.

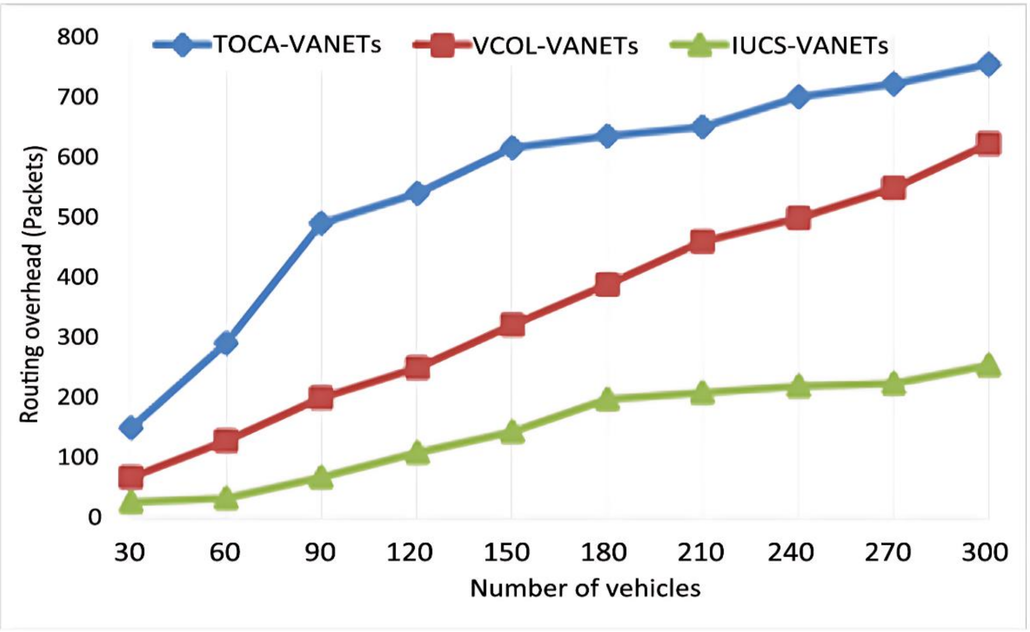

Figure 6.
The RO calculation.

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4.4. *TP Calculation*

Figure 7 shows the TP of methods which includes TOCA, VCOL, and the proposed AUCS approach. It is the overall range of packets transferred from the source to the destination during the process of communication inside the network. The figure shows that the AUCS achieves higher TP when compared with the TOCA and VCOL approaches.

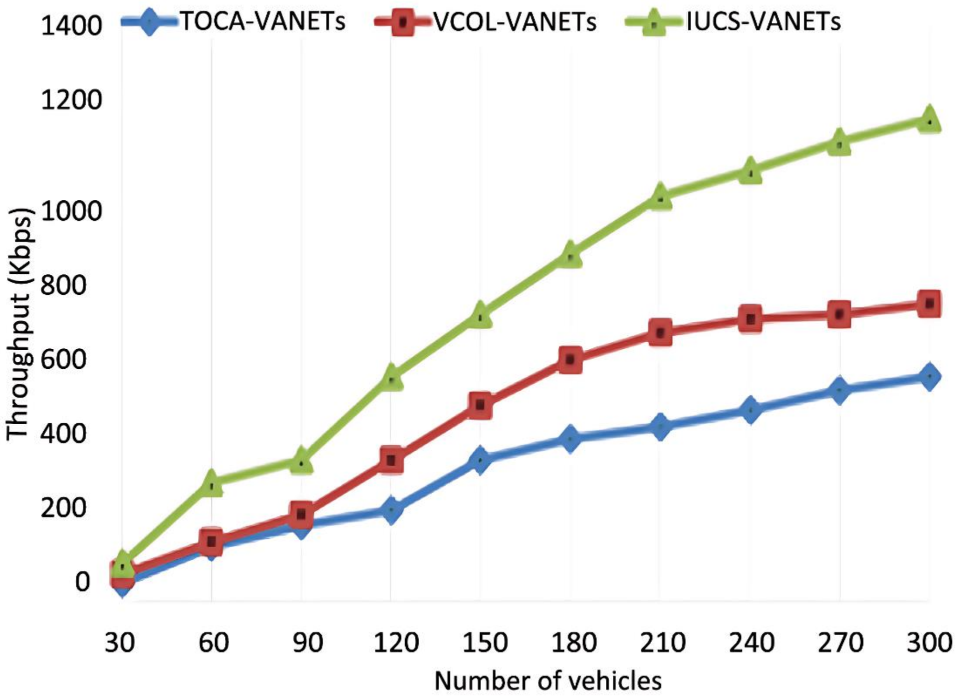

Figure 7.
The network TP calculation.

5. Results and Discussion

This section discusses the measures of the TOCA, VCOL, and AUCS-VANET approaches in terms of three parameters: PDR, E2E delay, RO, and TP. Table 2 presents the overall measures of those approaches.

Table 2.
Simulation parameters.

Parameters	TOCA	VCOL	AUCS-VANET
PDR	85%	92%	98%
E2E Delay	254ms	221ms	135ms
RO	754 packets	621 packets	254 packets
TP	547 Kbps	724 Kbps	1175 s

The PDR accomplished by AUCS-VANETs is 98%, while the TOCA and VCOL accomplished 85% and 92%, respectively. Since the AUCS-VANETs is 13% higher than TOCA and 6% higher than VCOL in PDR. The E2E delay accomplished by AUCS-VANETs is 135ms, while the TOCA and VCOL accomplished up to 254ms and 221ms respectively. Since the AUCS-VANETs is 120ms lower than TOCA-VANETs and 85ms lower than VCOL in the E2E delay. The RO accomplished by the AUCS-VANETs is 254 packets, while the TOCA and VCOL accomplished up to 754 packets and 621 packets respectively. Since the AUCS-VANETs s 500 packets lower than TOCA and 375 packets lower than

VCOL. The TP accomplished by the AUCS-VANETs is 1175 Kbps whereas, for the TOCA and VCOL, it reaches up to 547 Kbps and 724 Kbps respectively. So, the TP accomplished by the AUCS-VANETs is 600 Kbps higher than TOCA and 450 Kbps higher than VCOL. Hence the AUCS-VANETs accomplished is higher than the TOCA and VCOL approaches by using communication strategy.

6. Conclusion

This paper proposes UAV-aided VANETs to protect VANETs from ground-level obstacles. These networks mitigate issues caused by ground congestion and enhance security by facilitating communication through the air medium. A new approach is developed namely the Advanced UAVs Communication Strategy (AUCS-VANETs) to improve routing. The communication becomes effortlessly better by using the AUCS-VANETs approach which transmits the data in the shortest route at the routing level as a result the RO is greatly reduced at the time of communication. The PDR, E2E delay, routing overhead, and TP parameters are used to compare the performance with the TOCA-VANETs and VCOL-VANETs. The results show that the AUCS-VANETs approach produced a 13% higher PDR, 120ms lower E2E delay, 500 packets lower RO, and 600 Kbps higher TP when compared with the TOCA and VCOL approaches. In the future works to further improve the energy efficiency of the network clustering approach are needed to get concentrated.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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