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Performance Evaluation Based on Multi-UAV in Airborne Computer Network System

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Abstract: Airborne wireless communications have a great influence on everyday life making life convenient the development of various types of Unmanned Aerial Vehicles (UAVs) has become in the fields of electronics and communications are possible. Several efforts have been made to develop multi-drone communications protocols and aviation-dedicated networks (FANETs). However, the network protocol behavior has been simulated in this paper using the framework of AVENS, a hybrid wireless network simulation framework, which is integrated with the LARISSA Model, X-PLANE, and the OMNET++ Simulator. The locations of the UAVs of 15 aircraft were studied and the throughput parameters, time, received packets, and propagation time was calculated. The data was successfully transmitted in the form of a UDP Video Stream using the IEEE 802.15.4 protocol, the propagation time of 17.4569 us, received packets of 52%, the throughput of 88,832 Kbps, and a lifetime of 46.9547s was calculated. In addition, a comparison was also made between the proposed system and other research in terms of the number of drones, packets, propagation time, and the simulator used.

Keywords: Airborne computer, Avionics, AVENS, Drone, FANET, LARISSA, OMNET++, UAV.

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1. Introduction

Embedded systems in avionics are high-integration hardware and software sets that are part of a larger system, and they often conduct real-time monitoring and control activities. Technological advancements in airborne computer network systems have provided these systems with increased processing power, memory, and the ability to adapt to a multitude of purposes, as well as to communicate with any other device, whether built-in or not. If an embedded system's failure might result in the loss of life, it is termed safety-critical [1-3]. A UAV is a vital embedded system application. Several articles have proved the viability of deploying such vehicles as indispensable tools for many applications as follows air surveillance, tracking, position and precision agriculture, reconnaissance, ground, sea, and target analysis, traffic monitoring, transportation logistics, environmental monitoring, and other tasks [4-8]. In the case of decreasing the time and expenses required to complete a task, numerous UAV strategy is usually explored [9]. This strategy, however, has some communication difficulties. Ad hoc networks are commonly used to address them, and this is due to the extreme mobility of UAVs. In particular, ad hoc networks for ground vehicles are referred to as VANETs (Vehicular Ad Hoc Networks), while those for aerial vehicles are referred to as FANETs (Flying Ad Hoc Networks) [10]. In general, wireless technologies and most protocols are designed with 2D communications, and high mobility in mind (ground vehicles) or limited mobility (people). FANETs are fundamentally different from standard ad hoc networks of connection, data distribution, bandwidth, customer support, flexibility, three-dimensional nature, and so on ((MANETs (Mobile Ad hoc Network) and VANETs)). FANET communication is focused on A2A (Aircraft-to-Aircraft) and A2I (Aircraft-to-infrastructure) communication. As a result, the degree of node mobility in FANETs is greater than in MANETs and

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VANETs, and the topology changes frequently; the communication range must be longer than in other networks, and data distribution techniques are required [11]. Both VANETs and FANETs create difficulties for conducting practical tests in [12], which demonstrated the results of autonomous UAV launching, flying, and landing tests. In cases like these, it is not practicable or convenient to modify so many variables related to infrastructure, communications system, and the findings, as well as the results for that particular set of variables. As a result, the use of simulations may both accelerate and enhance the development process by allowing for the easy testing of a wide range of parameters. Several published research articles describe the benefits of VANETs, such as the availability of exact and well-tested communication protocol models and the usage of a network simulator, like NS-2 [13, 14], NS-3 [15], OPNET [16, 17], and OMNET++ [18-20]. The drawbacks in [19, 20] OMNET has been used, several drones and one ground station, the protocol problem arises when some messages are lost and there is a loss of time, complexity, and energy. In [21], the Modified Slip Mode Control System (MASMC) for unmanned aerial vehicle movement control demonstrated the effectiveness of a non-linear adaptive control strategy when used for small quadcopter drones only. To apply altitude and trajectory tracking control, a modified adaptive slip mode algorithm was developed using an adaptive law based on the Lyapunov stability approach. MATLAB Simulink software was used to compare sliding mode control and conventional PID control on a small spider parrot drone. The results showed that the modified adaptive slip mode control was able to reduce error performance indicators of ISE (integral of squared error) at 1,041 square feet. In [22], the authors utilized FuGSPID (Fuzzy gain-scheduled PID) to stabilize the altitude by using only a homemade quadcopter. Particle Swarm Optimization (PSO) was chosen to improve the console's performance or to determine the best configuration using both simulations in MATLAB and experiments. The results of the mathematical discrimination are useful for reducing the number of instructions and loops, which allows microcontrollers to run at their fastest speeds when performing tasks with minimal repetition. In [23], unmanned navigation with obstacle avoidance based on cellular communications has been proposed, and the performance in indoor scenarios with drone movements has been demonstrated. Whereas, drones were only used in the indoor environment. Obstacle avoidance, drone positioning, and navigation target perspective are all part of it. UAVs in the indoor environment can obtain a wide range of maps using LTE (Long-Term Evolution), and the system has a stable connection thanks to GCS. An LTE connection outperforms a Wi-Fi connection in mapping efficiency by 57.5 percent. Flight computation time was approximately 200 seconds. In [24], UAM (Urban Air Mobility) was used in NOMA (Non-Orthogonal Multiple Access) cellular systems in forward and reverse links and was matched by Monte Carlo simulation. The results showed that the probability of a strong user increases with the increase in the elevation angle of the UAM. The discontinuity probability decreased with the SNR in the forward link, and the discontinuity potential showed an error ground caused by interference from the GU in the reverse link. Based on the developments, researchers and engineers have been employing VEINS without using the framework AVENS. [25], a simulator that not only simulates network protocols as well as the accurate structure of simulators from normal vehicles. Despite the existence of various VANET simulators [26], VEINS is the most widely utilized and approved in the research. FANET research, on the other hand, continues to publish results based only on broad network simulations. These are the tools, however, that do not handle the height as well as orientation constraints imposed by a telecommunications network, nor do their mobility models constitute a true FANET [27-29]. There is, to the best of my knowledge, there is no simulator able to represent realistic FANET mobility models because part of the terms and node mobility assume that directed transmitter radiation patterns include isotropic or omnidirectional radioactivity. As a result, factors peculiar to the aerial scenario are not completely considered [30]. In [31], simulators have been utilized for FANETs, and with the requirement to investigate the features of UAVs, the drawback only calculated packets were for 3 and 5 UAVs. AVENS provides the Air Vehicle Network Simulator. The integrated technology is intended to make a substantial contribution to the sophisticated FANET simulations embedded inside an FAA-approved flight simulator. AVENS can also build OMNET++ code automatically based on the LARISSA architecture. OMNET++ is a C++ simulation toolkit and framework that is flexible, modular, and component-based and is designed particularly for the development of network simulators [32] UDP Video Stream data was transmitted but there were obstacles to transmitting small videos. The OMNET++ was chosen so that changes to its specialized modules and frameworks could be made easily. In the simulator of the proposed system, changes were made to the INET framework to achieve more realistic models and it was linked to the Visual Studio with X-PLANE.

The motivation for us in this work was through research [23], from which we were inspired by the idea of this work and our launch began with it, as our goal was how to transfer data in the form of UDP (User Datagram Protocol) video stream via drones and how to increase the number of drones Without loss in data transmission. In this paper, the well-known problem is how to transmit data in UDP video stream without loss in the data being transmitted and how to calculate throughput, propagation time, and the number of packets and in this regard, we were helped with that by the use of OMNET++ simulation with AVENS that communicates with the X-PLANE through which the movement of the drones is carried out and the coordinates of the drones are known, which is done by an XML file, and because of AVENS, we have a platform integration.

This paper consists of section 2 structures for LARISSA and AVENS, section 3 work suggested and parameters used as well as software implementation used, section 4 simulation results and discussion, and ection 5 conclusion and future work.

2. LARISSA and AVENS structures

One of the problems with drone research and development is the need for comprehensive testing to ensure its reliability and accuracy. To test and verify new parameters of flying a drone or a group of drones each time they change is an impractical situation. The use of simulation before field testing allows for cheaper and more feasible development of these systems. To automate simulations, LARISSA (Layered Architecture Model for Interconnection of Systems as an Automatic Code Generator) has been used to provide automated code generation for OMNET++. In Fig. 1, it can be seen that LARISSA is a multi-layered architectural model that connects systems [33]. It divides the components of drones or is called unmanned aircraft system (UAS) into aerial and ground segments.

The aerial segment is hierarchically composed of six layers: 1. Physical, 2. Distributed RTOS (Real-Time Operating System), 3. System abstraction, 4. Monitoring and Control, 5. Navigation and Services, and 6. The layer of the mission. While the ground segment is divided into 1. The physical layer and 2. The ground control station (GCS) layer. These layers can be represented by models guiding the development of UAS, defining how different components such as sensors, control circuits, GPS, payload, ground control station communication, and others are interconnected [34]. AVENS (Aerial Vehicle Network Simulator) is a part of the proposed system to provide a test base for simulating and controlling the flight of UAVs, using differently controlled, and scalable configurations. So, the main objectives of AVENS are to provide a simulation test for virtual experiences of network coverage and communication among UAVs that fly in cooperation or share the same airspace.

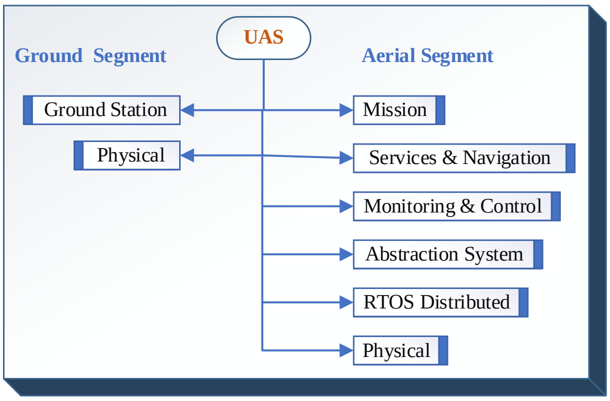


Figure. 1 The LARISSA overview

The purpose of AVENS is to provide a platform for the analysis of ad hoc mobile networks, where drones are mobile nodes that share the wireless medium to exchange messages. The goal is to use an air vehicle control flight simulator and a network simulator to get network measurements, such as transmission rate, throughput, packet reception, lifetime, etc. [31]. The OMNET++ Network Simulator with X-PLANE Flight Simulator, which is integrated with LARISSA in AVENS, are the two key simulation platforms chosen for integration. LARISSA offers a dependable and simple method for automatically generating OMNET++ code from abstract UAV models. The structure of AVENS is depicted in Fig. 2.

In particular, AVENS improves simulation accuracy and reliability by obtaining navigation

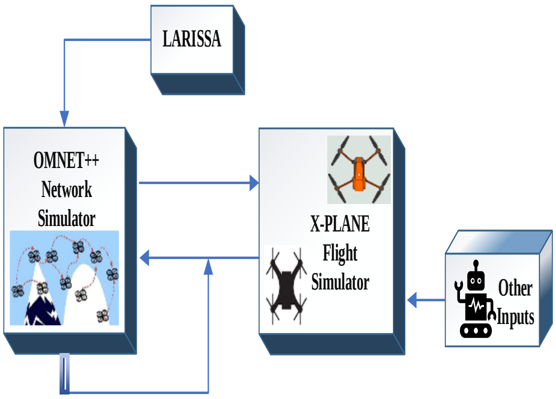
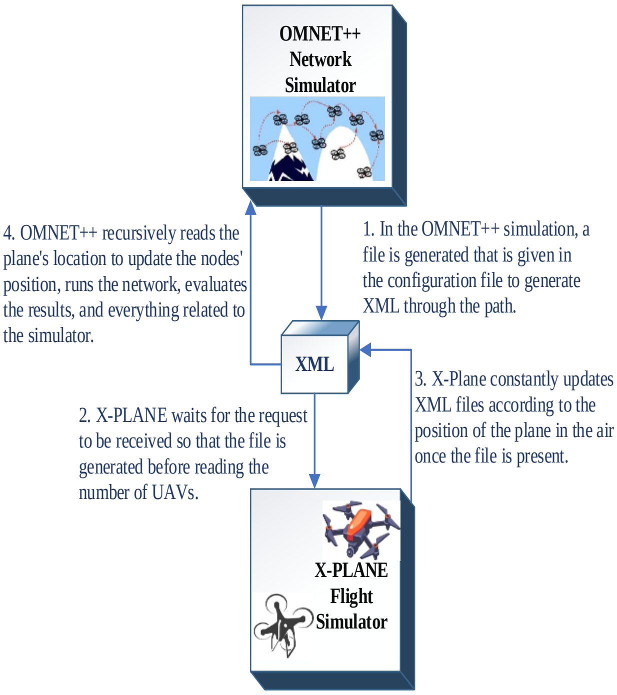


Figure. 2 AVENS structure

model information from the X-PLANE navigation pattern and updating drone positions on OMNET++, which is used to simulate network circumstances where nodes move depending on X-PLANE coordinates [34]. The simulators are integrated using a plug-in on the X-PLANE side and a module on the OMNET++ side, both of which are responsible for transferring information via an XML file. Once the LARISSA configuration files are available, the new OMNET++ module file handler must be introduced into the user simulation and its settings are appropriately adjusted [19]. The INET Framework is an open-source OMNET++ family of networking models. This framework has been expanded with a new mobility model called arbitrary mobility. This new module extends the INET module. In this context, Arbitrary Mobility has been added to properly execute and specify the path that connects to the XML file [10]. More specifically, the new file handler module generates an XML file that contains the number of drones in the simulation as well as all position data, which is initially set to zero. Following that, you implement a simple state machine (1) that waits for X-PLANE to recognize it; (2) that reads the simulation's coordinate references; and (3) that iteratively updates the UAV position by adjusting the navigation position parameters based on the XML file data until the simulation is complete. On the X-PLANE side, a plugin has been created to gather all of the plane's position data and save it to an XML file. Fig. 3 shows the connection between the OMNET++ module and the X-PLANE plug-in [3]. Steps 3 and 4 in Fig. 3 illustrate a loop that runs for the duration of the simulation. At the moment, X-PLANE is in charge of the mobility pattern while keeping aircraft limits in mind. OMNET++ simulates the network states based on the nodes' relative location, which is determined using X-PLANE positions. X-PLANE presently restricts the number of UAVs to one primary controllable aircraft plus others. There is a restriction on the OMNET++ side. Each simulation runs a single instance of X-PLANE, resulting in lower memory and CPU utilization [34]. Each aircraft may be modified with varied attributes, allowing numerous types of aircraft to be defined. To this end, it should be noted that the class model used in the X-PLANE plug-in and OMNET++ module may be simply modified to accommodate any additional data that the user requires to be transferred [33].

3. The proposed work

An unmanned aerial vehicle (UAV), commonly referred to as a drone, is a plane that has no onboard, there are a human pilot, crew, or passengers. Drones are a component of the Unmanned Aircraft System (UAS), which additionally includes a ground control unit and a communications system with unmanned aircraft. UAV flight can be controlled remotely by a human pilot as a remotely piloted aircraft (RPA), with varying degrees of autonomy as autopilot assistance, or even fully autonomous aircraft without human intervention. In the proposed system, several drones were designed and added to the cluster head using OMNET++ simulation to simulate the network with the X-PLANE program to make the Traffic Generator as in Fig. 4, which shows the block diagram of the proposed system. In drones, wireless data communication networks are used to facilitate interaction between the base station and the drone. These networks are open and unprotected. Therefore, potential interception or eavesdropping can cause security concerns and an adversary can snooze or hack the transmitted information. The LARISSA and AVENS Structures were used in the proposed system as shown in Fig. 1 and 2, where LARISSA is integrated with OMNET++, which in turn is communicated with the X-PLANE via XML file as shown in Fig. 3. These sensors are limited in terms of bandwidth, power, storage, and memory. Because of the limited resources, it is impractical for WSNs to use typical security mechanisms to transfer data between drones. So, the proposed system makes Adhoc networks have hierarchical topological structures. The network was separated into many groups using hierarchical arrangements. These



1. In the OMNET++ simulation, a file is generated that is given in the configuration file to generate XML through the path.

2. X-PLANE waits for the request to be received so that the file is generated before reading the number of UAVs.

3. X-Plane constantly updates XML files according to the position of the plane in the air once the file is present.

4. OMNET++ recursively reads the plane's location to update the nodes' position, runs the network, evaluates the results, and everything related to the simulator.

Figure. 3 Communication between OMNET++ and X-PLANE

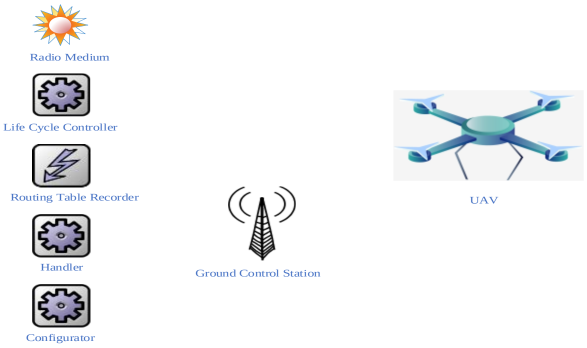


Figure. 4 Block diagram of the proposed system

configurations improve network quality of service (QoS), increase network scalability, and simultaneously boost network throughput. The proposed system provides a lighter weight structure and security by employing a hierarchical system that offloads computational cost workloads from limited resource devices to powerful equipment to construct a system hierarchical structure. Aviation Dedicated Networks (FANETs) is a flying Ad-Hoc network that has been a dedicated framework for effective network security for UAVs to connect them. FANET simulation discusses the various custom networks and the main design challenges of FANET, where the ID is distributed via the configurator, to simulate the physical layer via radio medium, and the data in the form of UDP video stream is transferred from the drones to the cluster head and vice versa. These UDP video stream data that are placed in the simulation OMNET++ can be generated and transferred to the X-PLANE which can be operated in the X-PLANE. Fig. 5 shows the flowchart of the UAV system which can be described as follows:

- Creating parameters that are used for throughput, packets received time of receiving, etc.
- Creating the number of UAVs.
- The initialized Arbitrary Mobility and the AVENS, which is a framework, are then connected to the OMNET as network simulation, and the mobility update interval is 2s.
- After the program is executed correctly to avoid the collation that occurs between the node (drones), the plugin is built and linked with the X-PLANE, and after the implementation is done correctly, the path of the XML file (D:\\UAV\\pluginInterface.XML) is selected to determine the position of the drone as traffic generation.

3.1 Parameter evaluation

The design and the idea of routing protocols using IEEE 802.15.4 for WSNs encounter some issues and limitations, including throughput, propagation time, autonomous management, radio, and protection. The parameters listed below are used to assess the lifetime and throughput of WSNs.

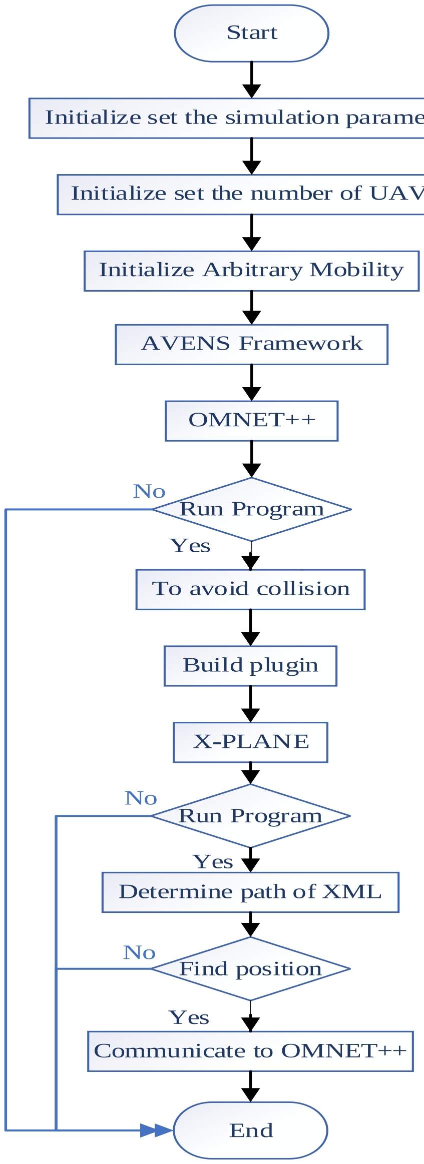


Figure. 5 A flowchart of the proposed work

3.1.1. Propagation time

The propagation time is the primary inverter delay for the number of UAVs. Thus, it measures the speed at which these drones can operate. It is the amount of time it takes for a signal or wave to move from one point in data transmission to another. Transmission time is also known as propagation delay, or the time it takes a bit of data to move from the beginning of a link to its destination [35]. The equation below shows the propagation time of the physical link that can be calculated by dividing the distance by the speed of UAVs.

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$$PT = \frac{D}{S} \tag{1}$$

Where

PT: is Propagation Time.
D: Distance.
S: Speed.

3.1.2. Throughput

The throughput is the mean total traffic correctly collected by the hub in each superstructure. The network throughput and node life give insights into the large-scale wireless sensor network. The bit quantities received by the time unit coordinator will be used to assess performance (second). The IEEE 802.15.4 protocol was utilized to measure throughput. Because of the low latency and low traffic circumstances given by this protocol, it is more efficient in terms of throughput in WSN [36]. The equation below shows the throughput from the packet of size to the packet at the time when the nodes were passed.

$$Thr = \frac{Ps}{Tp} \tag{2}$$

Where

Thr: is Throughput.
Ps: Packet size.
Tp: Time of packet.

3.2 Software implementation

The software component of the proposed system consists of the following:

- AVENS: is the framework for the flying Ad-Hoc Network.
- INET: AVENS needs INET files. When the developers developed the AVENS framework, there were some nodes and some protocols that were present in INET., hence, the developers called them from INET and added them to the AVENS side.
- OMNET++: In this simulation, we set the framework to simulate the network.
- Visual Studio 2012: It is used to build a plugin X-PLANE.
- X-PLANE10: It is used to build traffic generation.

Fig. 6 shows how the architecture of the software is implemented. Specifically, the parameters of the simulation are shown in Table 1.

4. Results of simulation and discussion

Different scenarios were applied in this section to assess the performance of the proposed system.

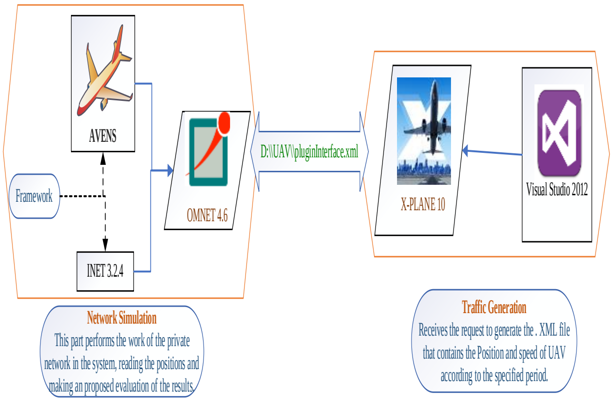


Figure. 6 Architecture of software for the proposed system

Table 1. Parameters of the simulation

Parameters	Value
Number of UAVs	5-15
Simulation area	2500*2500*2500 m^3
Frequency band	2.4 GHz
Data	UDP Video Stream
Video size	10MiB
Packet length	1000bytes
No. of GCS	1
Threshold	3000bytes
Power	-110dBm
Sensitivity	-104dBm
MAC	IEEE802.15.4
Energy generator	100mW
Mobility	dynamic mobility
Bit rate	2Mbps
Simulation time	100000 sec

4.1 Scenario 1: mobility in XML

In this section, the positions of the XML file handler will be discussed, where the XML file handler is related to the OMNET++ and X-PLANE simulations. The UAVs are drawn in 3D. In particular, five UAVs were placed as in Fig. 7, where the spacing of the UAV sites is observed, which is in the form of XYZ. Then, 10 UAVs were tested, as in Fig. 8. It is noted that the UAV sites are close to each other. In another experiment, 15 UAVs were used, as in Fig. 9, where it was observed that the drones were very close to each other without any collision among them, which is illustrated in Fig. 5.

4.2 Scenario 2: plugin with X-PLANE

In this section, the operation of drones is studied according to changing environmental conditions, as it was noted that the operation of drones is commensurate with all changes that occur in environmental conditions, whether the weather is

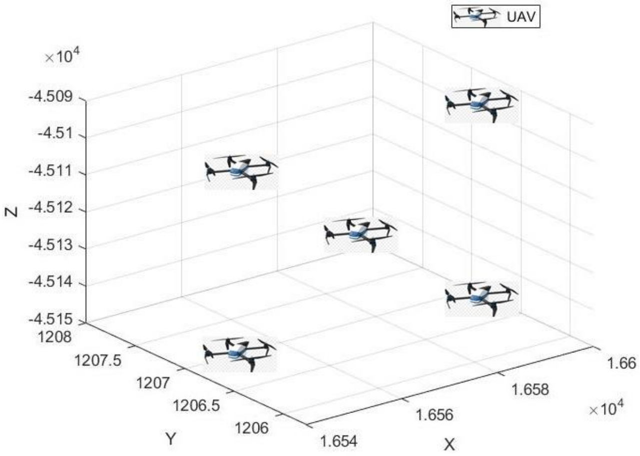


Figure. 7 Positions of five UAVs in the XML file

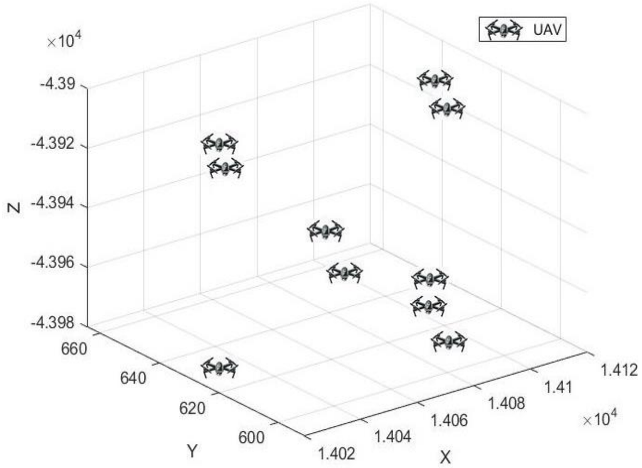


Figure. 8 Positions of 10 UAVs in the XML file

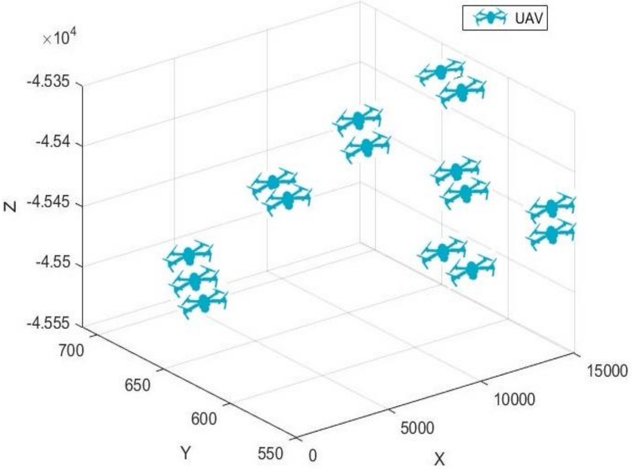
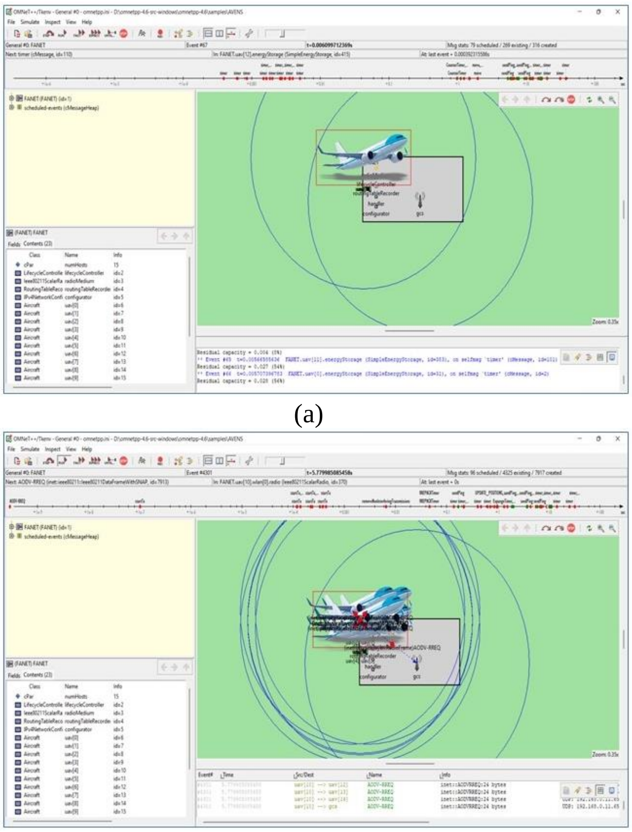


Figure. 9 Positions of 15 UAVs in the XML file

dark, bright, or foggy. This is done with the help of the plugin, which has been linked with Visual Studio 2012 and the X-PLANE, thereby operating the drones in any circumstances and transmitting private data in each unmanned aircraft. It is noted in Fig. 10 that the UAVs are in OMNET++ simulation and the data is transmitted in the form of a UDP video stream. In Figure a, which is on the left side, the OMNET++ simulation is at the beginning of its operation, where the coordinates of the drone are (0,0,0) at the beginning of its starting point without its association with X-PLANE. On the other hand, in Figure b, which is on the right side, the movement of the drone is observed after it is connected to the X-PLANE, where the movement of the drone is observed. In Fig. 11 to 13, the operation of the UAV is observed in different environmental conditions. The type of the airport is Seattle Tacoma Intl (KSEA) and the type of aircraft that was used in this work is Cessna 1725P.


(a)

(b)

Figure. 10 OMNET++ with UAVs: (a) 15 UAV without X-PLANE and (b) 15 UAV with X-PLANE

Figure. 11 X-PLANE with dark weather

Figure. 12 X-PLANE with cloudy weather

Figure. 13 X-PLANE with sunshine and foggy weather

4.3 Scenario 3: parameters metrics

In this section, the highest value of the propagation time was recorded in the drones that transmit data in the form of UDP video stream for drone number five when using five drones, where its value was 26.60 ms, as seen in Fig. 14. When using 10 drones, the highest value was reached in the tenth drone 4.33 ms, as seen in the same figure, and when using 15 drones, the highest value in the fifteenth drone reached 17.45 ms, as shown in the same figure. The throughput and lifetime were measured in Fig. 15. The lifetime value was observed when using five drones, which amounted to 735.05 per second and throughput of 136,448 kbps, when using 10 drones, it reached 108.69 per second and the throughput was 78,336 kbps, and when using 15 drones, it reached 46.95 per second, and the throughput was 88,832 kbps. Various numbers of UAVs were used (5, 15, and 10) and it was noted that the received packets reached values of (0.0405 (81%), 0.026 (52%), and 0.018 (36%)), respectively, as shown in Fig. 16. The frequency domain and the time domain were calculated according to the coordinates of the drones, which are Latitude = "46", Longitude = "-124", and Height = "121.13", as noted in Fig. 17. Normalize Frequency is (x π Rad\Sample). It is observed that in drones, Time Domain = 1400 and Frequency Domain = 0.8, which was more stable, while in 10 drones the time domain became 800 and the frequency domain became 0.9. In 15 drones, it became unstable due to the increase in the number of drones, which means an increase in the number of drones' data in the form of UDP stream video that is sent and received. The leakage factor, relative side lobe attenuation, and main lobe width (-3dB), respectively in the five UAV were (8.23%, -12 dB, and 0.35938), in the 10 UAVs, they were (9.17%, -13.1 dB, and 0.17188), and in the 15 UAVs, they were (9.22%, -13.2 dB, and 0.17188).

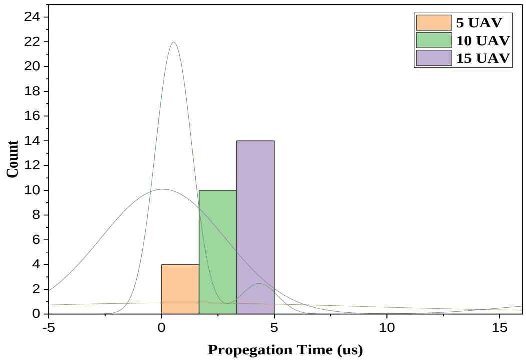


Figure. 14 Propagation time of UAVs

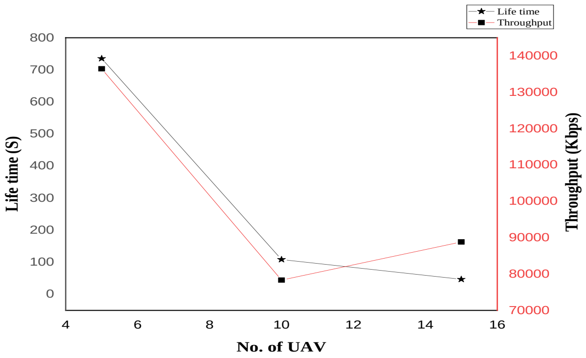


Figure. 15 Time and throughput of UAVs

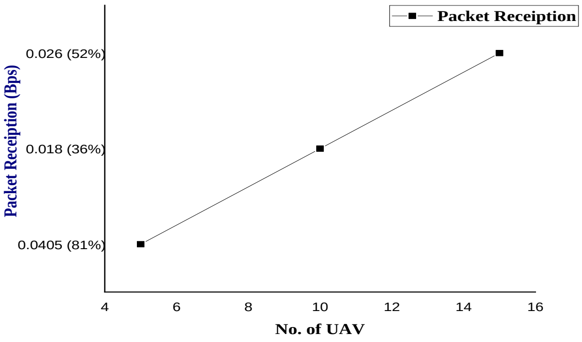


Figure. 16 A received packet of UAVs

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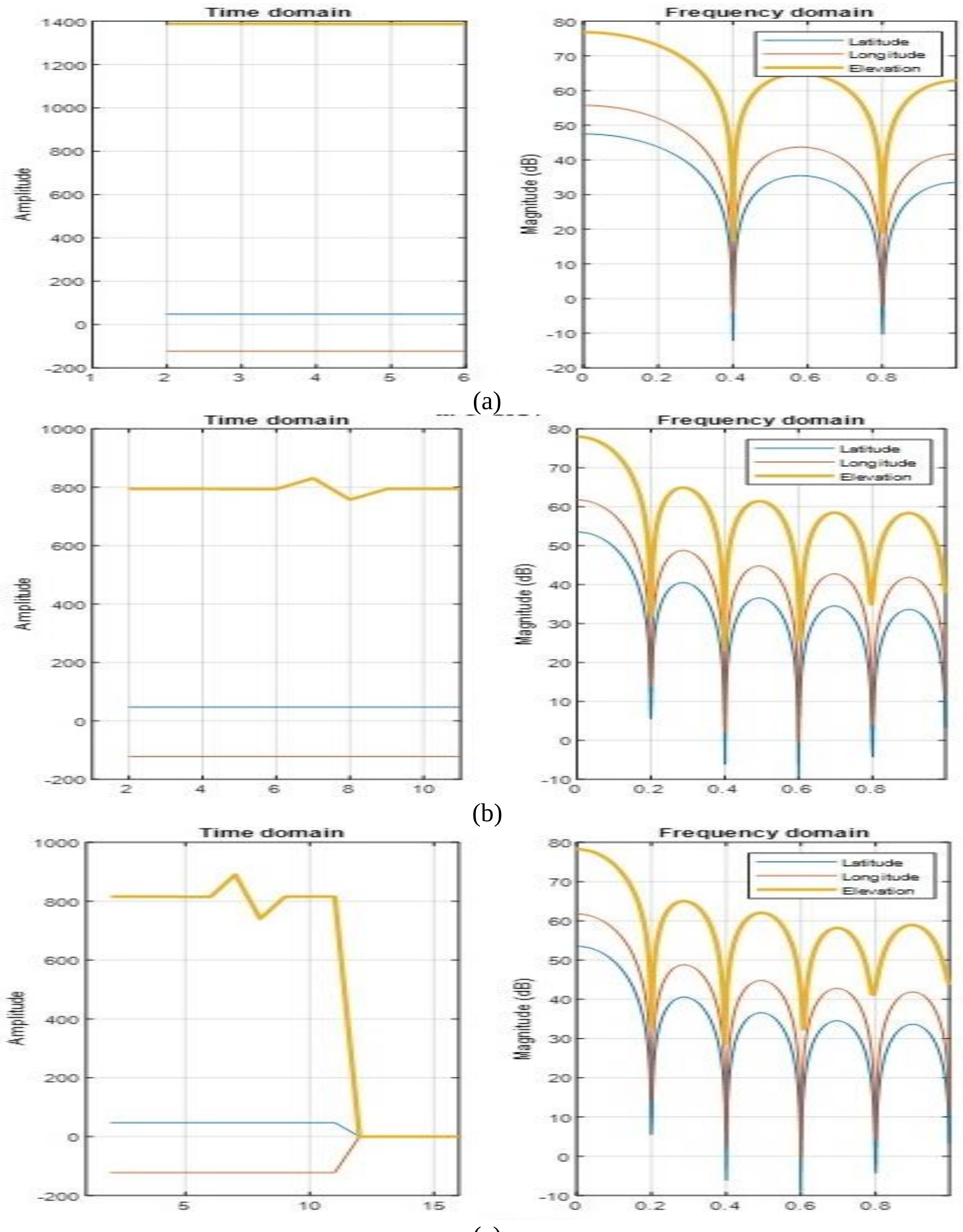
4.4 Comparison with existing works

This analysis contrasts profoundly with packets to accommodate a different number of aircraft. The other business group targeted packages that may differ equally without regard to priority to deal with emergencies. To increase design scalability. They have interaction with several drones. Objectives of this work. Drones put the ability to manage a position of any kind and in different environmental conditions. In terms of quality of service and simulation, compared to the corresponding job as shown in Table 2. In this work, all the design features of OMNET simulation are connected with the framework of the AVENS that is connected with the X-PLANE, the data which is of the type UDP Video Stream is because it the faster protocol does not wait for the client acknowledgment and retransmit of the missing packet and a few of the latencies and it is well transmitted the data and obtained the throughput and good reception of packages. Because the AVENS framework is used to test the simulation between the network and the communication of the drones, and when combined with the X-PLANE, which provides less computing power, it is a reliable and easy way to generate automatic code for OMNET, so the proposed method is better.



(a)

(b)

(c)

Figure. 17 Frequency and time of UAVs: (a) 5 UAV, (b) 10 UAV, and (c) 15UAV

Table 2. Comparison with existing works

Author	Simulator	Packet	Propagation time	Throughput	No. of drones
E. A. Marconato et al. [31]	AVENS	655bps	---	---	5
Y. J. Choi et al. [23]	Jetson	---	1.96 us	---	1
Implemented	AVENS	0.0405 Bps (81%)	26.603781 us	136448 Kbps	5
		0.018 Bps (36%)	4.337563 us	78336 Kbps	10
		0.026 Bps (52%)	17.4569 us	88832 Kbps	15

The proposed method As shown in Table 2 is better because of the components that were used and that were mentioned in paragraph (3.2) where the framework AVENS and LARISSA structure as shown in Fig. 1 and 2 were used with OMNET++ simulations that are combined with the X-PLANE through an XML file that be mentioned in Fig. 3 to configure the proposed system mentioned in Fig. 4, where the use of In the proposed system 5, 10, 15 drones, while in the research [31] only 5 drones were used, and in the research [23] only one drone was used.

5. Conclusion

In this paper, the AVENS framework was used with LARISSA that is combined with OMNET++ simulation as a network simulation, and Visual Studio with X-PLANE was used to create the plugin as a traffic generation, and after integrating LARISSA with OMNET++ which the Avance framework is connected to with the X-PLANE through the XML file processor to specify a path. The drones were successfully located for 15 aircraft, the data was transmitted smoothly in the form of a UDP video stream, and they reached a propagation time of 17.4569 us, received packets of 52%, the throughput of 88,832 Kbps, and a lifetime of 46.9547s was calculated. In particular, when using the platform integration, it will give good performance and robustness efficiency in the processors for the cases that were taken through the integration of platforms. Specifically, the proposed approach gave impressive results with the possibility of this integration, keeping in mind that the use of the AVENS platform in this work is different from that in the previous research works. For future work, attempts will be made to change the number of drones (5, 10, and 15, as used in this work), where we expect to increase the number of drones to 50 or 100. In addition, security and safety will be added to the AVENS framework, which is called FANET in OMNET++ simulation, to ensure safety when transmitting data in drones.

Conflicts of Interest

The authors declare no conflict of interest.

Authors Contributions

Mohammed Najm Abdullah and Khulood Eskander Dagher contributed a hybrid wireless network simulation framework using the framework of AVENS. Mohamed Najm Abdullah explained the proposed work. Khulood Eskander Dagher presented the simulation results with the LARISSA Model, X-PLANE, and the OMNET++ Simulator. Both authors are discussed the simulation results.

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