



# A Novel Deep Energy Efficient Hello Packet Scheduling for Ad Hoc Networks in Unmanned Aerial Vehicles

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## Abstract

From the previous pandemic stage, the world is emerging with a demand for wireless communications for the various essential mission-related data collection, dissemination, and deliveries in areas where humans can't reach. One of the most notable innovations in the field of aircraft vehicles is the formation of an aerial ad hoc network (AANET) by a group of aircraft vehicles communicating collectively in an ad hoc fashion. AANET has been widely explored in various critical missions, but due to its high mobility characteristic, they anticipated challenges like packet loss, energy drain, and link breakages. Since AANET fuels in the air are battery-driven, the flight speed exponentially decreases due to sudden drifting, etc., which affects network performance, energy consumption, and flight time. This paper reveals the limitations in the era of AANET and designs a novel, deep, energy-efficient hello packet scheduling strategy using a deep learning strategy with the NS3. This would extend the lifetime of the UAV flight by saving energy and enhance the performance metrics that are required. This proposed research may help to better understand the temporal and spatial characteristics of the AANET in 3D targeted scenarios and sustain significant network performance metrics like packet delivery, throughputs, end-to-end delay, energy consumption, etc.

**Keywords:** Unmanned aerial vehicle; Aerial Ad hoc networks; Throughput; Energy efficiency; Packet scheduling.

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## 1. Introduction

After the pandemic period of COVID-19, aircraft vehicles emerge in demand, with 5G technology hovering over every sustainable development like transportation, smart farming, delivery logistics, etc. The smart electrical unmanned aerial vehicle networks, *i.e.*, aerial ad hoc networks (AANETs), are adapted in every wireless environment differently due to their peer-to-peer communication. Particularly, due to its dynamic nature, it leads to non-breaking communication without any human intervention, which creates a new advantage in wireless networks. Although it becomes a grave problem in the world of automation, some of the challenges that its operation poses are due to its high velocity and sudden drifting directions. Since it still lacks the proper mobility model that could work in all scenarios, an approximate model is utilised in any new scenario, which degrades its network performance

and consumes much battery in sudden turns. Furthermore, due to their deployment at heights, aerial vehicles have a wide range of projection, allowing them to explore large traffic volumes in cities, assisting 5G technology. AANET is also facing a critical task in sustaining the UAVs in airspace, which is the most prominent problem due to their high mobility and sudden turns. Although having great efforts with functionality, flexibility, easy installation, and lesser expenses, UAVs serve for mostly armed purposes such as rescue action, observation, volcanic supervision, storm estimation, danger investigation, and remote sensing, etc. However, AANETs are still limited to using traditional heuristics like the routing algorithms of AODV to incorporate Hello packets, and they are unable to broadcast simultaneously in the network. Since every UAV supervises its own flight and establishes communication in peer fashion, it is certain to select an appropriate paradigm that proves competency in wireless and enhances network performance. There are a number of adhoc networks, among which AANET is the demandable one (a subset of Mobile Ad Hoc Network (MANET) whose communication is carried by HELLO control). packets<sup>[1,2]</sup> whose transmissions are different according to routing strategies that affect their operation, which is the biggest research gap. While constructing the links

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among UAVs, one UAV broadcasts the Route-Request (RREQ) packet to the next-hop UAV and waits for acknowledgment of the relevant information, such as their positions, velocities, orientations or directions of movement, *etc.* Although the links are established between hops, due to their high mobility, control packets get affected, which requires redesign the routings<sup>[3,4]</sup> to sustain the network.

In particular, if the previous routing and hello messaging schemes are read, it is seen that AANET needs to be run with the minimum human intervention that led to the major concern of present-day research. However, today's research focused primarily on maximising the flight time that depends on the battery power in AANET. To the best of my knowledge, this research targeting QoS with network performance (throughput, packet delivery ratio, and jitter delay) in 3D-scaling mobility and deep learning-based hello controls has not been carried out. This research solves the challenges of route maintenance and throughputs that get affected, leading to delays in the transmission of data. Meghanathan<sup>[5]</sup> first discovers the stable path by using a novel routing strategy based on beaconless slow speed nodes. Yassein *et al.*<sup>[6]</sup> convoluted that speed of nodes are the biggest deciding factor in accommodating the no of vehicles and the mobility movements over the network. Oliveira *et al.*<sup>[7]</sup> investigated the UAV mobility impact by experimenting hello packets over random waypoint mobility model. By briefing the above various studies, it is emphasised to boost the network performance where the research gets a chance to investigate the mobility and velocity onto beacon intervals with new deep learning techniques that can be recognised in this paper.

Another new progression of 5G UAV-assisted communications gives a place to bridge the gap due to its miniaturisation, versatility, and low expenses, whose new characteristics are summarized as follows:

(1) Elevated Projections: 5G communications select UAVs due to their economy at heights. Since aerial vehicles serve in the air at high altitudes, there are few or no obstacles in the path of communication, which gives reliable line of sight (LoS) channels. But with this consideration of three-dimensional space, their positions in the z direction are one of the major factors, which could be a con, where one UAV may come into the path of another UAV, in which case a collision condition might occur that needs to be handled by appropriate mobility directions.

(2) Superior versatility: In comparison to conventional fixed-position networks, modern aerial vehicles remotely distributed with high velocity become a boon in providing a quick response path in disaster and emergency situations (as in COVID-19). Besides, it seems to have a good performance and more projection area to cover.

(3) Limited energy: Due to its separated infrastructure, it has an imperfect onboard power supply that suffers in preserving the links and increasing energy consumption while drifting in different directions. That would be a recent area of research where it needs to be optimised to extend the lifespan

of air for a long time. Henceforth, due to battery-driven applications, it is necessary to look into network threat tradeoffs.

Since the long flight in air is a great concern in wireless, which is directly or indirectly explored by the various revolutionary adapting literature on energy harvesting techniques, It comprehends the survey of communications, which reveals the open challenges. This section describes an appealing comparison of MANET and AANET with models, along with numerous implications and their significance. Continuing with Section 2 critical analysis with the various methodologies carried out to find the suitable models of mobility for specific applications according to their topologies Also discussed was the experimentation setup and the proposed methodology to attain the significance of research. Results are implicated in the detailed discussion that justified the proposed design in Section 3. Lastly, conclude with a brief summary of the significance of the proposed work and open the research challenges for future research in Section 4.

Emerging green networking needs in a world where ICT modernization has created a new dilemma that affects energy consumption and network performance This study will primarily focus on routing heuristics and the mobility model, which influence the performance of the AANET to be optimised while assisting in the longevity of the UAV in flight. Unquestionably, numerous mobility models and routings are used for planning, but our revolutionary, one-of-a-kind deep learning model presents the enhancement of network performance, which not only saves energy but also increases the lifetime of aircraft, which is desirable in green networking.

### 1.1 Network model of AANET vs MANET

With the successive demand and emerging technology, MANET gives a waiver to the AANET class, which is famous for its dynamic nature and high mobility. The network design with the vehicles and links/routes between them is symbolised in the form of a graph  $G(V, E)$  with  $V$  vertices and  $E$  edges. Each link is a subset with some distance from  $V_1$  to  $V_2, 3N$ , which are tracked by their unique ids and geometric positions. Since MANET considers this subset with 2D Euclidean distance, where each vehicle broadcasts beacon messages to maintain the communication network. While this is being altered with consideration of 3D space in AANET, whose distances and positions are shared with the addition of z-direction coordinates, due to which it gets more coverage areas and maximum surveillance possible in those areas where it is hard to reach, Besides, it is a battery-driven vehicle, so their operation has a high energy consumption that affects their lifespan, which is still a research barrier. Not only this, but the above-mentioned beacon messages are broadcast by some routing schemes that need to stand up to the changing topology in AANET, which is desirable. This is most important to understand the impact of routing in AANET, which is slightly different from MANET.

The UAVs, like mobile nodes in MANET, create the

network by exchanging the HELLO beacons in changing topologies periodically from one node to the next. This way, each vehicle node is aware of its network and identifies that there should be no node that is to be escaped from the mission. If a vehicle node is regularly acknowledged, it gives proof of its presence in the network, but if it is unacknowledged, it needs to revert back with a message for the new route discovery process based on the underlying node density (the number of nodes left after escaping).

This retransmission of beacons should be at a certain backoff interval.<sup>[8]</sup> But when this interval clock runs out, then the node seems to be out, or just say link broken. On the other side, when the hello packets are transmitted periodically, it consumes much power and is also prone to collisions in network traffic, which decreases the throughput and packet delivery.<sup>[9]</sup> This gives a challenge to a new research arena where AANETS with high mobility projected (sensing a large area and communicating at high altitudes) should be optimised on the basis of speeds and mobility in place of beaconing at regular fix intervals. Therefore, routings impact AANET QoS, so the deep investigation discussed in Section 2 is the basis on which a novel routing paradigm modulated with deep learning for falling velocities is proposed in Section 3, which also helps in extending the flight span of UAVs. Before proceeding to technical observations, some of the real-time applications have been given below, which show the success of AANET in this demanding world.

Recently, with the COVID-19 outbreak, AANET awareness has been spreading widely around the various applications in industrial as well as government organisations. AANET applications are broadly categorised into two types of communications: (1) one-way aerial (air to air) and (2) two-way radio relay (air to ground). The researcher<sup>[10-12]</sup> found aerial applications can also be bifurcated on the basis of vehicle depth, acceleration, power rations and topologies which helps in recent research challenges like network performance, flight time etc. With the eruption of COVID-19, aerial communication plays its role ingeniously where Chamola *et al*<sup>[13]</sup> give the numerous UAV applications while integrating the sensors. UAVs can reach fast in critical missions without human intervention, where various undesirable tasks can be achieved with high performance at very low cost and in very little time.<sup>[14]</sup> Some of the tasks have been described here.

**Traffic Monitoring:** With the wide wireless coverage, flexibility and rapidity UAVs are well versed in traffic detection.<sup>[15]</sup> Guido *et al*.<sup>[16]</sup> progress the traffic data by fabricating sensors onto UAV. Another time Kattenborn *et al*.<sup>[17]</sup> found the new way of online acquisition, estimate the traffic in various catastrophes or natural calamities through on board UAVs. Various case studies based on such tracking demonstrated in.<sup>[18]</sup>

**Environmental Monitoring:** These days' governments periodically sense the updated data for climatic conditions, volcanic eruptions, and mountain icefalls using UAVs.<sup>[19]</sup>

When the UAV's dynamic characteristic created problems, researchers took advantage of it and utilised the property in collecting samples under dynamic conditions, such as in torrents where the level of water estimated time to time to plan for recovering damage in the fastest manner, where aerial communication is the only way. Furthermore, to detect the safety states of a pandemic eruption or volcanic eruption that is not easy to reach, as seen in Fig. 1, UAVs can easily reach and can collect the impossible information from the top of such disasters within seconds.<sup>[20]</sup> NASA RQ-14 Dragon Eye drones is one such innovative that updates of volcanic gives plume near San Jos'e, at Costa Ricawhere.<sup>[21]</sup> During any disaster or pandemics, there is a need of fastest communicated infrastructure to overlay the rescue operation where uavs become a boon in wireless technology. UAV not only helps in sensing pollutants but also exist for high resolution atmospheric monitoring which found in.<sup>[22,23]</sup>

**Delivery:** Various companies like German DHL,<sup>[24]</sup> USA based Google and Amazon<sup>[25]</sup> thrills the UAV for transportation,<sup>[26]</sup> medical supplies given by UAVs in emergency,<sup>[27]</sup> one such example of Federal Aviation Administration (FAA) that help in medical emergency in 2015<sup>[28]</sup> where one UAV which deployed for monitoring sends the GPS coordinates to medical UAV to transport delivery<sup>[29]</sup> at particular location. Such delivery by UAVS was also foreseen in.<sup>[30]</sup>

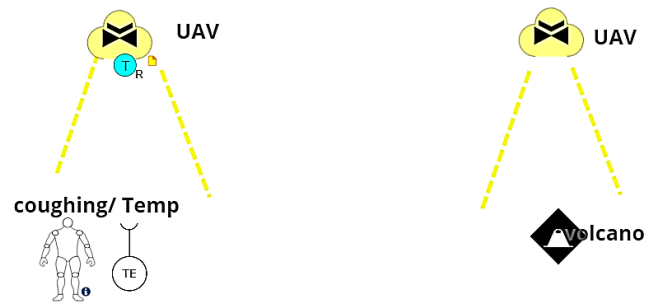


Fig. 1 UAV based Covid Monitoring.

**Coverage:** UAVs are very constructive in areas where the hindrances of high hills or dense forests make them isolated from other world *etc*.<sup>[31]</sup> They make availability of the wireless /cellular in such areas by deploying the flying access points as seen in Fig. 2. They replace the ground base stations and act as a relay node in the network especially in disaster or a malfunctioned vehicle node which is one of its vital roles.<sup>[32,33]</sup>

**Military Target:** Initially UAVs are manufactured only for confidential military applications as seen in Fig. 3. But with emerging demands these are deployed in various fields such as civil sector, medical applications, parcel service's *etc*. Eminent UAVs are used for martial purpose such as artillery guidance, transportation supplies, broadcasting, border monitoring, emissary uavs, vehicle war, anti-naval support, minesweeping raking, *etc*.<sup>[34]</sup>

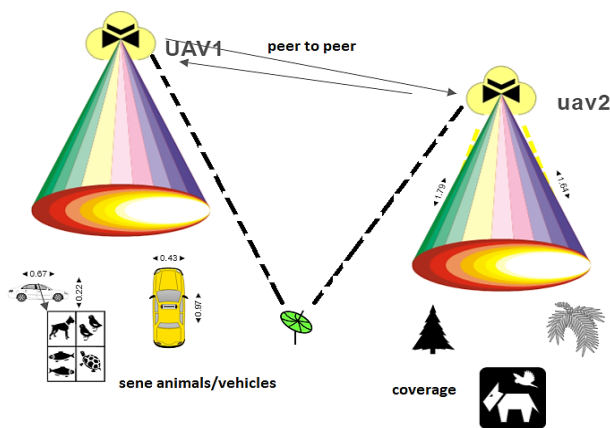


Fig. 2 UAV based Wireless Coverage illustration.

Although the numerous applications had been elaborated with different schemes were anticipated in AANET demulsify the beacons intervals still meet with many pitfalls. The author<sup>[35]</sup> found if there is a vehicle node that doesn't broadcast any beacon for a long time, then it is considered out of the network, which needs to retransmit the acknowledgment packets sensing the new route discovery and suppress the hello intervals to maintain the hello links. Consequently, due to their dynamic nature and self-flight characteristics, one UAV doesn't know about another neighboring UAV's hop, as both are silent in the network and thus acquire the entire communication. The next hindrance is its fast mobility, which generates an overhead and squanders the energy in preserving links by periodically broadcasting hello packets.

The presenter<sup>[36]</sup> suggested a new type of heuristic computed with vehicle velocity explored for MANET to disseminate the hello packets in a transmission range. Though, complementary factors like air volume and node density was also painstaking in AANETs.<sup>[37]</sup> A dynamic neighborhood-based algorithm (DNA-BSP) was developed to resolve the broadcast storm by eliminating the beacons redundancy by 98% density and exponentially decreasing velocities parameters,<sup>[44]</sup> and boosting packet delivery.<sup>[38]</sup> Though the authors investigated the broadcast storm problem, they did not consider energy consumption, which is a stochastic progression. One such adaptive energy-efficient hello scheme was proposed to handle the energy harvesting AANETs by the author,<sup>[39]</sup> where it emerges the new way to eradicate the consumption. However, another author<sup>[40]</sup> found that the methods that focus on the speed-based hello intervals do not take into account the characteristics of mobility and flight in the z direction for the 3D movements, which need to be scaled based on the time velocity that would be considered to compute the hello scheduling that should be based on the learning behavior of the UAVs. Henceforth, the proposed work deals with such reliability and various other factors like node density decreasing the velocity. The author<sup>[41]</sup> gave the protocol named VRU\_vu (vehicle road user protocol with vehicle and UAV) that disposes the data packets from one vehicle to another and secondly, VRU\_u (VRU for UAV to UAV), where it routes the packets and hits in a plummeting

end-to-end delay of approximately 13% and overhead of approximately 40%. Nevertheless, owing to various studies, the network lifetime of UAVs and their energy consumption are becoming a big focus of research that needs to be addressed. Amongst routing heuristics, one of the QTARs (Topology-aware routing with Q-learning) outperforms in several performance metrics under distinct circumstances where the new heuristic to disseminate the hello beacons in dynamic topology is suggested.<sup>[42]</sup> Thus, there is limited learning that is prone to routing strategies and mobility in dynamic 3D environments, which is an open research challenge in the broad domain of wireless AANET.

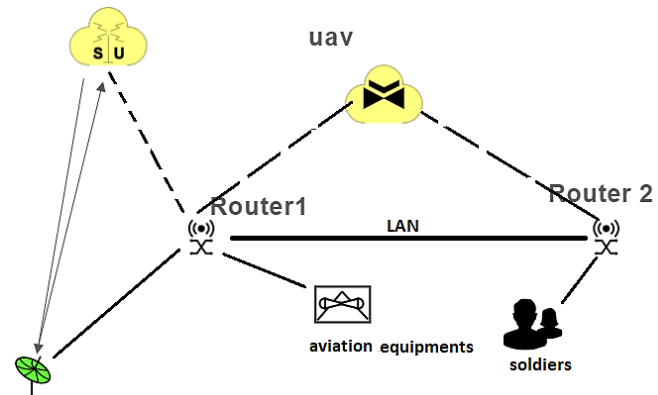


Fig. 3 UAV mission application.

In this paper, the major contribution is to expand the flight time, which is indirectly linked to its energy and quality of service (QoS), and contribute to a smart method of beaconing the hello controls in AANET routing heuristics while considering their exponentially moving velocities, which are diminishing with time.<sup>[43]</sup> To acclimatize the drastic transformations in topology, deep learning methodology proposed the computation of hello intervals considering node density and exponentially decreasing velocities parameters,<sup>[44]</sup> which automatically adjust the intervals of packets and lessen the burden of changing any infrastructure in the network. Due to the unusual behaviors of UAVs, their topology varies rapidly. Thus, an adaptive mechanism is required that induces the great learning averages based on previous velocities to solve the dynamic nature network in such a way that hello packets schedule at long intervals for slow speeds and at short intervals for high speeds.<sup>[44]</sup> As a result, the energy consumption at low speeds is reduced, and the flight time is extended due to their throughputs. Numerous factors, viz. 3D dynamic scenarios, node density, flight time and energy consumption are investigated by using proposed design of Hello packet scheduling with deep exponentially weighted moving average speed whose details is described in design section in this paper.

The major working functions on which model designed abridge in this paper as follows:

1. A realistic inhibition model designed for decelerating velocity with deep learning EWMA based on current

observations and suppressing the beacons accordingly that cuts the energy drains and aids the network performance metrics without revolutionizing the architecture of the network. 2. The proposed deep converged-Hello model is obtained by considering abrupt behavior of aerial vehicles, which moderates routings that realize better network metrics in 3D scenarios.

In this proposed model Ad hoc on demand distance vector (AODV) routes using deep converged hello scheduling and taken as a benchmark to compare. Thus, the AODV is taken as most significant routing used in MANET and AANET as seen from the various previous studies. With the experimental perspective the proposed model also uses AODV for simulation whose outcomes justified the performance metrics (e.g. throughput, packet delivery, end to end delay and energy consumption). With the proposed deep converged hello scheme, AODV protocols thrive by saving about 26J to 48 J of energy in 30 minutes, which seems like a great boon in AANET, and enhance the throughput by 60–90% compared to conventional schemes. The proposed model yields a better performance by using appropriate 3D dynamic scenario with suitable hello scheduling with deep exponentially moving average velocity in high or low densities for accomplishing the unbreakable communication.

**1.2 Characteristic of AANET**

Each application of UAVs outlines different working strategies which indirectly or directly depend on their characteristics. Some of the characteristics for the UAVs deployment are being discussed below.

**A. Node mobility:** Each vehicle in AANET has the most significant mobility in comparison to the traditional MANET and VANET, which is due to its elevated accelerations that vary from 20 to 450 km/h.<sup>[45]</sup> Such high acceleration exacerbates the new problems of power consumption, link

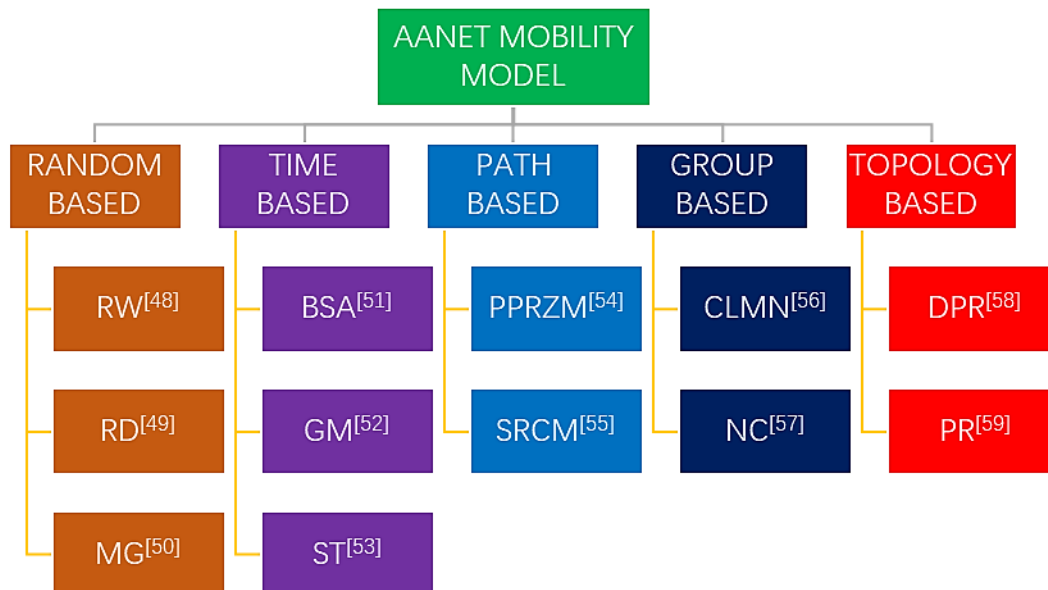
failure, disruptions, communication delays, and additional routing problems.

**B. Mobility models:** Since the UAV's direction and velocity change unexpectedly, which is dynamic in nature, the Marauder plan of flight path cannot be adhered to. This gives threat to the routing computation<sup>[46]</sup> in each linking. Moreover, numerous mobility models have been defined for AANETs, as portrayed in Fig. 4, selected according to the nature of the application, but they need to be aware of some pitfalls and the advantages they have over communication, which are elaborated as follows:

**1. Randomized mobility models** These are the inexperienced models whose flights are sovereign, as seen in Random Walk (RW),<sup>[47]</sup> Random Way-Point (RWP) and Random Direction (RD),<sup>[48]</sup> where it randomly selects the direction and flies for a specific time. Another restricted mobility with fixed movements in both horizontal and vertical, like on roads and in the air, is predicted by the Manhattan Grid (MG) model.<sup>[49]</sup> Such models are appropriate for urban cities where straight roads are followed by vehicles.

**2. Time/space dependent mobility models** Since the aerial vehicles suddenly drifted off course due to the various hindrances in the air. Such drifting direction also causes the power consumption as they consume energy in hard turns, which decline the network's performance. Certain mathematical computations with a bias factor based on previous accelerations smooth such motion based on Boundless Simulation Area (BSA)<sup>[50]</sup> and Gauss-Markov (GM)<sup>[51]</sup> that facilitate spinning in aerial vehicles.

**3. From the time-space model Smooth Turn (ST)** is one of the mobility models<sup>[52]</sup> that helps move the curved trajectories. Such models are very successful in the 3D scenario where the



**Fig. 4** Variety of mobility models used in AANET.

projection from the heights is done. Due to this reason, the proposed model is used for our targeted mission-critical application.

**4. Path-planned mobility models** When any mission had a predefined path, as in the travel salesman problem, then such models helped a lot with UAV trajectory. When there are different types of paths available in a route, some of which are curved and some of which are random, the UAV chooses a random path, and then follows another, and this process may be repeated until the destination is reached. One such example of it is semi-random circular movement (SRCM),<sup>[53]</sup> which bears a resemblance to the ST model. Another example is the stochastic paparazzi mobility model (PPRZM),<sup>[54]</sup> which helps in directing some movements in the forms of an oval, an eight, a scan, straight, and random with forward directions. Such models are mostly used in the image recognition system.

**5. Group mobility models** It is defined by constraints in spatial movements that help in random movement around a fixed position; one such model is Reference Point Group Mobility (RPGM).<sup>[55]</sup> Particularly, RPGM helps the UAV move with a reference point in a convinced column in forward, then it turns randomly with nomadic nodes. Such models are deployed for reconnaissance.

**6. Topology based mobility models** Due to the UAV tremendous mobility it impacts a great in deploying with different topologies targeting to different missions such as Distributed Pheromone Repel (DPR) mobility model,<sup>[56]</sup> which UAV's made for reconnaissance and search missions that require pheromone-based movements. The author<sup>[57]</sup> proposed another self-deploy point coverage mobility model that can be used for calamities and projecting large coverage's of people while maintaining the links in a peer-to-peer fashion over the flight. This type of model is succeeded by the hexagonal grid.

**C. Node density** Node density is the magnitude of the number of UAVs that can fit into 3D airspace. It should be the minimum size so that it is never prone to collision in a network. Also, finding the approximate numbers of UAVs will help trade off the expenses of UAV drones, which greatly impact sustainable economies. Since each UAV with its own long-range transmission disseminates in airspace following the essentiality of flight with a specific based array network density.<sup>[58]</sup>

**D. Network topology** To adapt to the high mobility nature of AANET, aerial vehicles use star or mesh topologies that change abruptly due to the drastic nature of UAVs subsequently in AANET, where these topologies may have pros and cons.

#### **E. Power consumption and network lifetime**

Since the aerial vehicles are battery-driven and aimed at the

green revolution. It gives rise to a new problem of network flight longevity, which is directly impacted by it. Although it causes problems due to various factors such as hardware, distances, and other hindrances, the most peculiar are the routing heuristics and their topologies. The requirement of energy savings in AANET will not only direct the network lifetime but also conserve nonstop communication.

In comparison to a single agent, different hybrid architectures of energy-oriented hunting optimize the monitoring and collection of temporal (time) information, which is useful for target hunting, terrain exploration, and environment mapping. Here, the authors resolved the hunting difficulties using deep Q-network reinforcement learning (DQN) methods.<sup>[59]</sup> Aside from the obvious awareness of communication contexts, data transmission performance and physical reality are intertwined. As a result, the traditional, independent studies of sensing and transmission cannot satisfy the requirements of future green ad hoc networks for low latency and energy efficiency. The author<sup>[60]</sup> suggests a resource allocation problem-solving low-complexity algorithm and an environment-aware integrated sensing and communication (ISAC) network association architecture that handles both sensing range and transmission strategy.<sup>[61]</sup> In the area of energy mission-based control projections, this provides fresh inspiration.

In the areas of smart factories, intelligent transportation, and augmented or virtual reality, where both data- and computation-intensive systems must meet strict latency and reliability criteria, there is also a contribution. In order to provide mission-critical services, a seamless space-air-ground integrated network (SAGIN) is created with the goal of 6G.<sup>[62]</sup> By utilizing a variety of communication, processing, and caching resources, this extremely dependable and low-latency edge intelligence may serve mission-critical applications. In the revolution of green adhoc networks, where network performance and energy efficiency keep the highest priority, these kinds of current works bring a lot of benefits.<sup>[63]</sup>

## **2. Proposed design and simulation**

### **2.1 Design preparation**

In this section, a novel design is proposed based on the deep learning-based hello schemes with the relative scaling of mobility directions in 3D to schedule the hello packets. This model is based on mission-critical parameters; therefore, it is well suited for rescue and reconnaissance. The model schedules the hello packets for small gaps at high frequency and for larger gaps at lower frequency. Although no experiments on the three-dimensional z-directional relative velocities that drift in the air have yet been conducted, numerous techniques conveyed

smoothing of turns in the Markov mobility models and RWP models, but none considered z-direction mobility, which is considered in the proposed model to be the significant factor of our research. Various studies proposed several models based on mobility and routing, but none worked on factors like throughput, energy, and lifespan of UAVs. This proposed design enlightens such factors and opens the door to research innovations in this area.

### 2.2 Proposed architecture

In this section, considering the various challenges of hello packet scheduling in AANET, a novel method based on decision parameters is proposed, where the major concern is to schedule the packets standing with unexpected mobility. Since it is seen that AODV is one of the most proactive routing protocols, which yields great results in MANET, the major drawback of AODV is the default period of broadcasting, which was 1 sec, which needs to be improved in a dynamic way so that it does not harm the mobility nor decline the network performance and also saves the power for long flight times in the air, which is being experimented with in the new proposed model. One such strategy is proposed by Imtiaz in<sup>[44]</sup> where network density-based hello messages are transmitted, but it also lacks accuracy when the UAV gradually decreases the flight speed in the 3D mobility model. So, by the various past practical analyses, one of the methods of the Statistical Package for Social Science (SPSS) is to smooth the accelerations. The proposed model's purpose is to schedule the hello control messages at an exponentially decreasing speed, which will be quantified using deep learning. In this proposed model, biasing errors are added that promote the average velocity based on the learning behavior of past velocities and determine the fine interval. Also computing the minimum number of the UAVs based on node density in airvolume so that no UAVs would become an obstacle in the path of other UAVs, or let's say there should be no collisions in the given airvolume, that is the safety condition, which was also a factor in wasting power in collisions and that will aid to its economy rate.

Figure 5 described the scenario of the UAV flight, where it gives the real time idea –how the proposed model will utilize the scaling factor in 3D GMM and moderate the beacons using intelligent deep learning technique. To better understand the internal working of the proposed design Fig. 6 elaborated the flowchart of the complete process which demonstrate if there is any event occur (UAV targeted for monitoring) means to cover the large area with the minimum node density for its best economy UAV sent a hello packet to discover neighbor. In such case there is a hello clock which keeps listening for acknowledgements. As soon the neighbor replied, it broadcast

while updating the clock with new time, but if it does not get any acknowledgement then it is declared as link breakage or out of coverage. In such a condition clock needs to be reset immediately to discover new neighbors' that should be computed based on new density and rebroadcast the hello packet based on new modified velocity (which is further discussed in designing section).

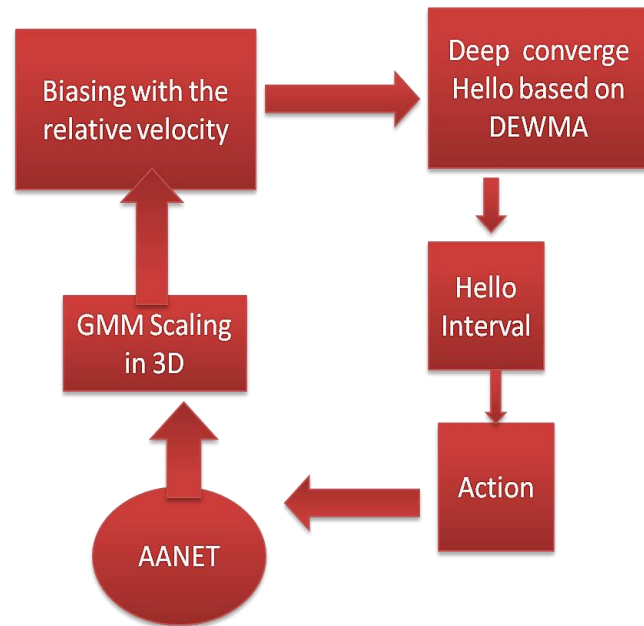


Fig. 5 Scenario of proposed system.

One more static challenge on its timer clock, which transmits periodically at 1 sec, will be weakened at the highest degree of mobility, where the clock needs to update more than usual to maintain the links in the mission accordingly and broadcast beacons in short intervals. This is the most obvious manifestation where the proposed model not only considers the minimum node density with large coverage but also provides a safety measure in which one UAV will never be an obstacle in the path of another UAV that impacts the network performance as well as power consumption.

The proposed model named deep energy efficient hello packet scheduling (DEEHS) was simulated on NS3 and tested out on the testbed with power consumption and throughputs while deploying the model on 3D infrastructure, considering the less collisions or no collisions according to Fig. 7. If one wants to run and test the benchmark, then one should follow Fig. 7 to implement the model in AANET and compute the performance metrics of different algorithms to determine the significance of our model. In this research article, the proposed design is compared with traditional AANET schemes—adaptive AANET,<sup>[44]</sup> the energy efficient routing<sup>[70]</sup> with the related missions, and conditional parameters yield better gains.

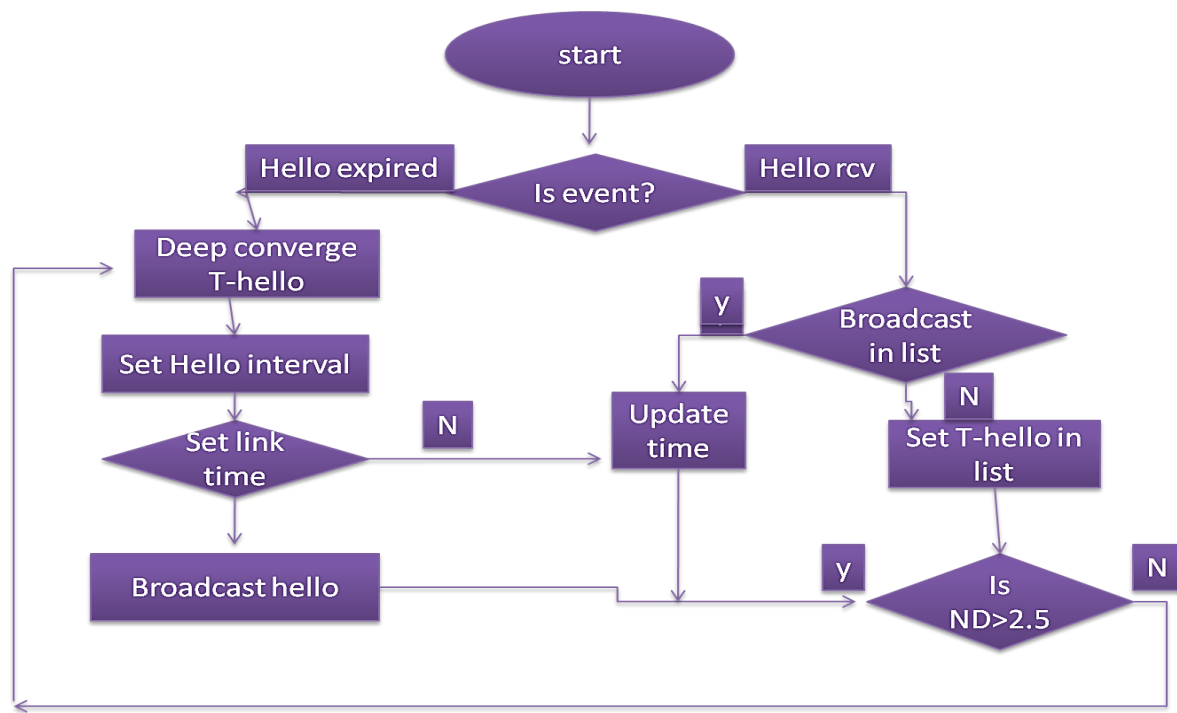


Fig. 6 Flowchart of the Proposed System

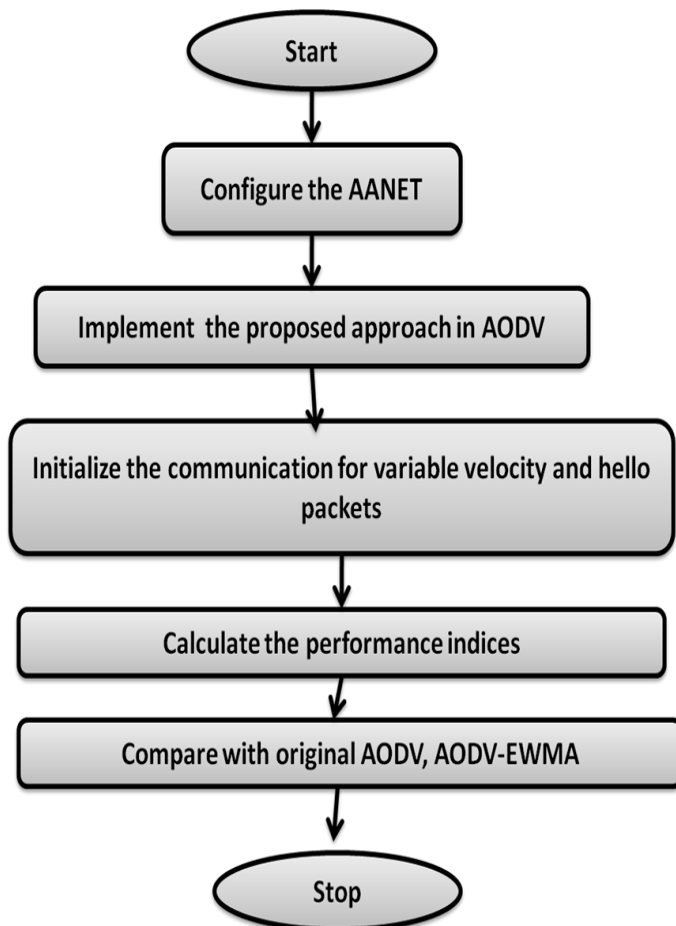


Fig. 7 Computation of performance indices with DEEHPS design.

### 2.3 Mobility scaling characteristic

The proposed model is designed in such a way that it assumes

the entire UAVs move in a volumetric box experiencing a 3D space, which gives them freedom to move in all directions within their transmission range (Tr). In such an environment, the movement of UAVs seems to flutter in limitless airspace. In particular, start with a minimum of 3 UAVs to accommodate the mission area. The complete paper is ecstatic and thrilled with the term network performance," which covers the throughput, end-to-end delay, etc. As a result, this design explored the research challenges of lifetime flight and energy consumption in applications like surveillance, exploration, and rescue, etc. Changing velocities are collectively updated and the time interval is computed based on an updated UAV state controller embedded in the AODV, where it discovers the links by stifling beacons and crafts the energy and various throughputs.

The major contribution of the design is to revolutionarily tune the hello controls and timer clock according to UAV flight acceleration, which was gradually declining with time due to various hindrances in the flight path. For instance, with the highly accelerated mobility motion in 3D volume space, it is alluded to that it is possible to broadcast hello controls in short intervals (that are computed on the basis of node density and declining velocities) that can reproduce the network topology. For slow-speed drones, intervals can be as large as possible to reduce energy drains and boost performance. Interestingly, UAVs do not tend to change links frequently in low-density networks as compared to dense networks; therefore, hello beacons can be desired with long intervals, which is attractive. In the following section, initially scales, computes the network density with its implications, and discusses the remaining

mechanisms exhaustively.

**2.4 Gauss mobility model characteristic**

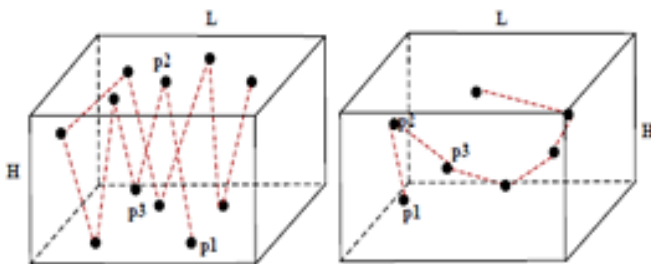
This mobility model focuses on the numerous addresses of position and sudden changes in speed per unit time. Such models are mostly for recreation purposes when a new route needs to be analyzed. While carrying out communication in 3D, it is necessary to pick a suitable model. Gauss Markov Mobility Model (GMM) is one such model for quickly changing airborne communication. It was presented by Dan Broyles, Abdul Jabbar, and James P.G. Sterbenz<sup>[64]</sup> and improved by T. Kunz and M. St-Hilaire<sup>[65]</sup> in 2014. Here the study states that the speed of a moving node after attaining some distance at multitudes exhibits the stochastic cycle. In the 3D movement, when the nodes are going to cross the line of the re-enactment region, they tend to flip by 180 degrees. This model avoids the boundary of the re-enactment region and never crosses the boundary. GMM confines the boundary, which varies with the degree of abnormality in the various developments. The UAV is continuously organized due to its drastic turns and speeds. This model utilizes inward memory to discover the track of UAVs. Based on this model, hubs alter the path and speeds. Speeds of the UAVs are recomputed based on past ventures using equations (1), (2), and (3).

In the 3D smooth walk model, mostly UAVs move in the x and y directions by flipping 180 degrees due to bouncing turns, and speeds reflect exponentially as seen in Fig. 8(a). The new development is displayed in Fig. 8(b), which handles such an issue by presenting the idea of relative speed in the proposed design. Here the UAV seems to be surrounded by a box of length L on the level plane in the y direction that needs to move with contrast in the z direction in 3D space, which is a realistic challenge during such irregular movements. Equations (1), (2), and (3) show how the velocity V along with the x, y, and z directions can be determined by the accompanying conditions:

$$V_x = V \cos \text{pitch} \cos \text{direction} \tag{1}$$

$$V_y = V \cos \text{pitch} \sin \text{direction} \tag{2}$$

$$V_z = V \sin \text{pitch} \tag{3}$$



**Fig. 8** GMM (a) Movement without relative speed (b) Movement with relative speed.

Since it can't be able to accommodate in z directions which needs to be compensate with scaling factor H/L that helps in

speed along the Z course. The velocity in z direction now computes by equation (4):

$$V_z = \frac{H}{L} V \sin \text{pitch} \tag{4}$$

Thusly, such scaling lessens the tendency of incessant turns in upper and lower directions due to which it reduces the hello consumption and yields the performance.

**2.5 Network density**

To fulfill the network requirements, first compute the number of UAVs that can be accommodated in the required airvolume that is entitled to mission space. It is seen that two UAVs need to be associated with the AANET; they must merge into the 3D airspace. The UAVs transmit in omnidirections with the planned mission in x directions (X, 0), y directions (0, Y, 0), and z directions (0, 0), into an airspace. Let us consider the transmission range for UAVs in a spherical 3D scenario, and to accommodate them, airspace volume is being divided by drone (UAV) spherical volume, which gives the minimum number of drones to send in the projected area as computed by equation (5).

$$\text{No of UAV} = \frac{\text{air space}}{\text{drone volume}} = \frac{3*x*y*z}{4*pi*r*r*r} \tag{5}$$

Since it is presumed that the UAV is a spherical body, in practice this is not possible, so it is indeed necessary to compute the approximate network density while considering the three drones in communication. Equation (6) demonstrates how the network density is computed based on mission airspace and the number of required drones.

$$\text{Network density} = \frac{\text{drone in mission}}{\text{required drone}} \tag{6}$$

**2.6 Deep energy efficient scheduling paradigm**

With the new characteristics of the AANET like high velocity, abrupt turns and path decision etc. the hello intervals overcome the pitfalls of energy drains as well as mobility issues. On the off chance that it thoroughly smoothen the hello packets through the Algorithm 1.

The main issue found was: how would one know the limitations of link breakage? Mostly ad hoc networks communicate in peer-to-peer fashion by exchanging the hello packets in a fixed period or when the speed-based UAVs fly, where reasonable intervals are decided based on the distance covered by the UAV with the velocity pretending to be flexible enough to suppress the hello interval. Therefore, as more descent is the subject of motion, the time is computed by the distance covered with some speed, but that is good only for constant acceleration, whereas it is unexpected in UAVs where, due to various mission-related information like airspace,

Algorithm 1: proposed Deep Energy Efficient Hello Packet Scheduling (DEEHPS)

Input:  $T_x, V_m, U_{acc}, V$  be transmission range, allowed airvolume. no of uavs, velocities

Output:  $T_{hello}$ , hello interval

Initialize:  $\Theta, \emptyset_{i=1, \dots, n}$  with  $F \leftarrow FU(st, st+1), \emptyset_{target,i} \leftarrow \emptyset_i$

For  $i=1, 2, \dots, n$

New state  $st+1$

For topology G

Initialize : n with network condition  $V_m * V_{max} / U_{acc} * T_x * T_x * V_{min}$

For  $i=1, 2, \dots, n$

Update  $\emptyset$  with descent time hello

Initialize the target networks with variable  $\emptyset_{target,i}$

Policy parameters for network conditions  $g$ , network density

$\gamma = \alpha / T_x$

$\alpha = \Theta * V_{max} / g * V_{min}$

update hello interval

$T_{hello} = \gamma / \emptyset_{avg}$

transmission ranges, the density of UAVs, etc., their flights unexpectedly decline with time. Such time is computed in a smart way using the deep learning method of SPSS as given in the proposed DEEHPS algorithm, where declining velocities are computed with double biasing of the current updates of the exponentially weighted moving average of speeds covering the distances that also keep changing as seen in the algorithm. Hence this way the hello time interval is seed in routing which is to be computed by equation (7):

$$\text{Hello time interval} = \frac{\text{distance travelled}}{VEWMA} \quad (7)$$

One such adaptation is given by Imtiaz *et al.*,<sup>[44]</sup> but it does not consider the mobility and speed differentials, which are more scaled in the proposed method, and the computation of the beacon time interval is enhanced by the deep processing of velocities based on current biasing differentials, which has a great impact on network metrics. The author<sup>[16]</sup> suggested standardizing computation with an exponential weighted moving average (EWMA), as shown in equation (8):

$$V_{EWMA(n)} = (1-\beta) * V_{EWMA(n-1)} + \beta * V_{EWMA(n)} \quad (8)$$

The newly extended EWMA can be recalculated by the given equation (9) where the biasing factor of previous and current velocity also consider:

$$V'_{EWMA(n)} = (1-\beta) * V_{EWMA(n-1)} + \beta * V_{EWMA(n)} + (V_{EWMA(n)} - V_{EWMA(n-1)}) \quad (9)$$

From the equations (5), (7) and (9) the modified hello intervals can be derived as given in equation (10):

$$T\text{-hello} = \frac{\text{distanctavelled}}{Vewma} = \frac{9 * \delta * X * Y * Z * Vmax}{4 * \pi * Um * r * r * V'ewma} \quad (10)$$

## 2.6 Simulation Environment

NS-3 is an integrated simulator with many existing real-routing

protocols that can be directly used with mobility models and fetch the network performance by varying parameters. In this paper, NS3.27 is used as a discrete event-driven network simulation. It yields a similar sense of real-time application for MANET, which has the same sense for AANETS. The experiment is carried out with the speed constraints and various parameters considered for the fixed-wing UAVs projected at 600\*600\*150. Table 1 represents the detailed considerations for simulating the scenario, where about 50 independent simulations need to be carried out. Consequences of the beacons owed by examining the proposed model of coordination with AODV for AANET environments where topologies are changing frequently.

Table 1. Considerations for simulation.

Parameter	Consideration
Mission area size	600 m × 600 m
Allowed airspace size	600 m × 600 m × 150 m
UAV's intelligence	Avoid collisions by themselves
UAV's speed	[5 – {10, 15, 20, 25, 30, 35, 40, 45, 50}] m/s
Transmission range of a UAV	150 m
Mobility model	Gauss-Markov-3D mobility model
Maximum change in horizontal angle	6.3°
Maximum change in vertical angle	3.15°
Available information to each UAV	Size of allowed airspace, Number of participating UAVs in a mission, UAVs speed, UAVs transmission range

Table 2 includes the parameters, like the number of UAVs, which need to be varied from 20 to 40 as per consideration of the high and low densities, respectively, for simulation. Another parameterized source and sink pair is 5 for low-density networks and 10 for high-density networks. For simulation, UAVs are considered to be communicated in the same line of sight (LoS), for which an omnidirectional antenna is parameterized with a constant bit rate model (CBR) with each packet transmission of 512 bytes.

## 2.6 Performance Metrics

The modified AODV encompassing AANET is tested with given parameters and results in the performance metrics of packet delivery ratio, end-to-end delay, and throughput.

**Packet Delivery Ratio (PDR):** It gives the analysis for the efficient delivery of the packets. It addresses the differentiation of the flow in the channel. It is the successful delivery of the total packets sent, which are computed using the formula where Packets<sub>r</sub> denotes packets received at the

destination and Packets<sub>s</sub> are the total packets ingressed.

$$PDR = \frac{|\text{Packets}_r|}{|\text{Packets}_s|}$$

**End-to-End Delay(E2ED):** It is the computation of determining the rate at which the packets are delivered within the given bandwidth. These services predict the delivery using a store-and-forward scheme and help in analyzing whether the packets need to be discarded or not if it takes a long time.

$$E2ED = \frac{(\text{Packets Arrival Time} - \text{Packets Sent Time})}{\text{transmission rate}}$$

**Throughput:** It is the overall performance of the UAV delivering the packets in a particular timeframe.

$$\text{Throughput} = \frac{(\text{Packets Delivered})}{\text{Time}}, \text{ where time is the period of destination.}$$

**Table 2.** Parameters for Simulation.

Parameter	Value
Number of UAVs	20, 40
Mobility model – degree of randomness (alpha)	0.5
Mobility model – Update interval	0.5 s
Source/destination pairs	5, 10
Packet size	512 bytes
Source packet rate	4 packets/s
Traffic model	Constant bit rate model
Loss model	Friss propagation loss model
Channel capacity	1 Mbps
Antenna type	Omnidirectional
Routing protocol	AODV
PHY/MAC protocol	802.11b
Simulation time	300

### 3. Results and discussions

In this paper, a smart hello interval scheme is implemented in

the AODV. With the experimentation of NS3.27, the AANET scenario is designed to fit into the mission area according to Tables 1 and scenario is designed to fit into the mission area according to Tables 1 and Table 2. The author<sup>[6]</sup> used one such scenario that works on all surfaces, including water and aerial networks, based on the same strategy as the proposed scenario. To simulate the proposed model, communication is considered with an omnidirectional antenna with a tolerance rate of 5% randomness for drifting velocity, as deployed in actual hardware implementation as given in Table 2. The next strong computation is its collision avoidance with the smart horizontal direction, which is equal to twice the vertical direction. This is implemented without any modification to the architecture. Further, the model is excited to adapt the hello intervals as AANET movement changes. The model also integrated the smart feedback mechanism to update the hello interval based on deep learning moving average velocities. The experiment results in Table 3 show that the proposed model has good output packet delivery in dense networks, which proves its success in the field of AANET research.

Using Table 1 and Table 2, a real-time simulation was done whose performance is compared in Tables 3, 4 and 5 and observes the QoS metrics in terms of PDR, E2ED, and throughput, where the proposed DEEHPS outperforms in dense networks with high speeds, which is seen for the first time. Most critical is the energy drainage problem, which this proposed smart design solves by saving about 12–54 joules in 30 minutes, which is a 28–36% reduction in consumption life, which is very impressive. Figure 9 implicates that the proposed Deep energy-efficient hello packet scheduling (DEEHPS) is better at delivering the packets compared to the previous AODV-EWMA and the original AODV. It demonstrates that the higher the throughput, the better the QoS.

**Table 3.** Packet Delivery for 40 UAVS.

Routing protocol	Speed in m/s								
	5-10	5-15	5-20	5-25	5-30	5-35	5-40	5-45	5-50
AODV	0.8298519	0.796534	0.792239	0.800255	0.798087	0.843428	0.841944	0.787678	0.804924
AODV-imitiaz	0.99636099	0.968281	0.998602	0.996905	.967777	0.997537	0.998582	0.999875	0.999253
Proposed DEEHPS	0.980998	0.995607	0.999511	0.999511	0.998701	0.99986	0.999624	0.998406	0.999627

**Table 4.** End to End Delay For 40 UAV.

Routing protocol	Speed in m/s								
	5-10	5-15	5-20	5-25	5-30	5-35	5-40	5-45	5-50
AODV	556267609	748535399	100919573	43275765	380615567	55170184	590201087	713424393	67741457
AODV-imitiaz	447671786	816166648	191342006	11702373	161839256	62183755	475642136	592566629	77792935
Proposed-DEEHPS	523709765	613436679	420384605	49499311	161406966	10817092	4609490354	105911048	67142965

**Table 5.** Throughput for the 40 UAV.

Routing protocol	Speed in m/s								
	5-10	5-15	5-20	5-25	5-30	5-35	5-40	5-45	5-50
AODV	0.138165	0.137694	0.137733	0.135362	0.138743	0.145994	0.138776	0.177967	0.138356
AODV-imitiaz	1.94626	1.9283	3.09517	3.73022	3.41242	3.34437	4.36039	3.94365	5.56419
Proposed-DEEHPS	3.79922	3.79922	4.18332	4.03917	4.41015	3.93494	5.1593	5.74775	5.58335

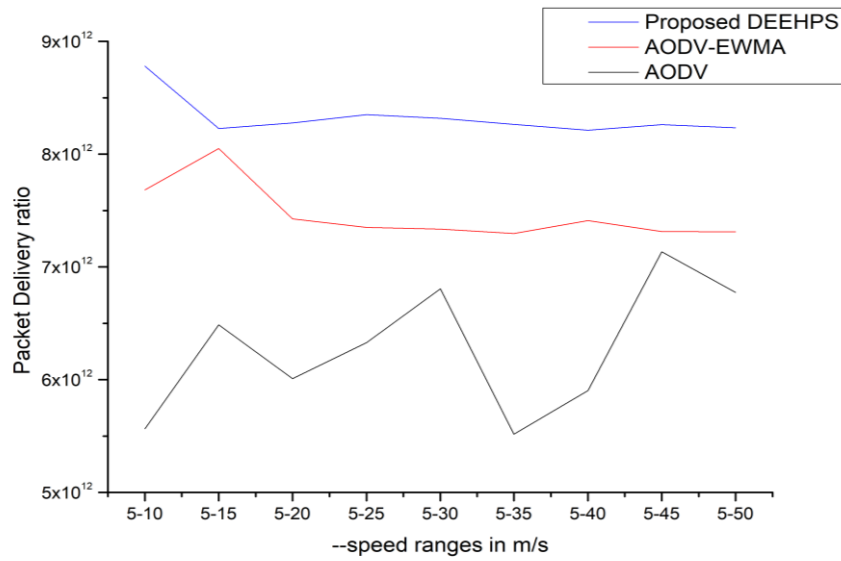


Fig. 9 Packet Delivery Ratio for high density 40 UAV.

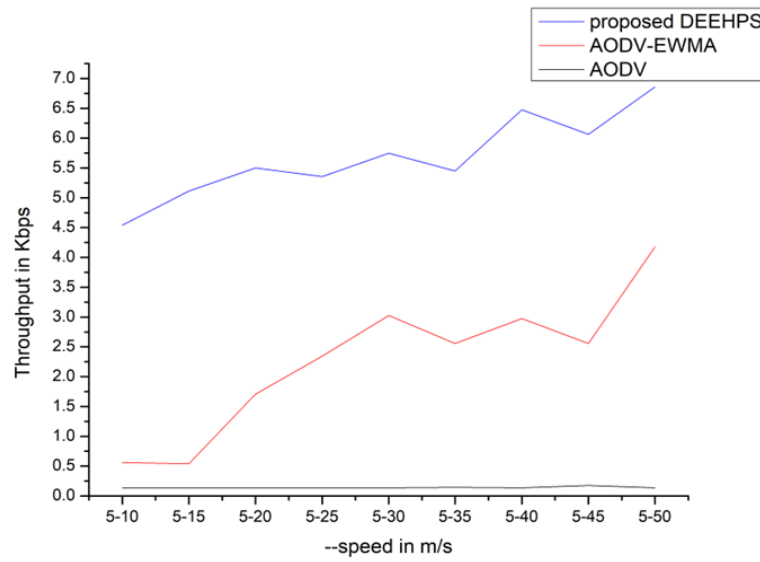


Fig. 10 Comparison of Throughput for high density-40 UAV.

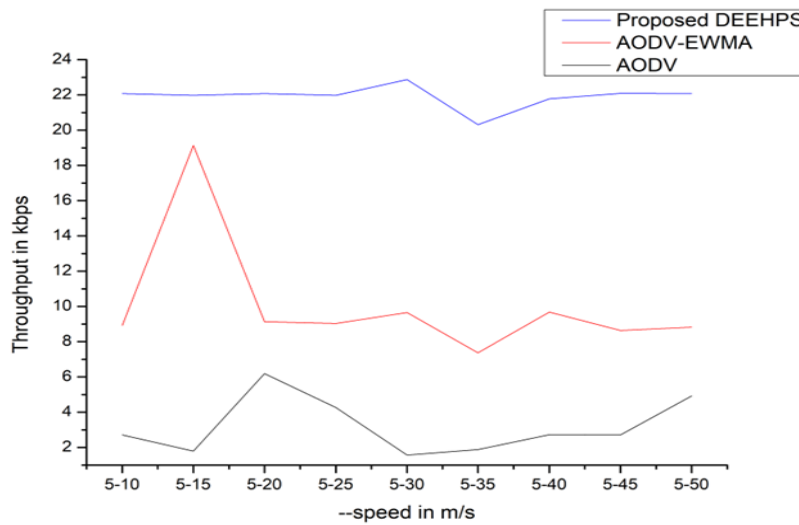


Fig. 11 Comparison of Throughput with low density -20UAV.

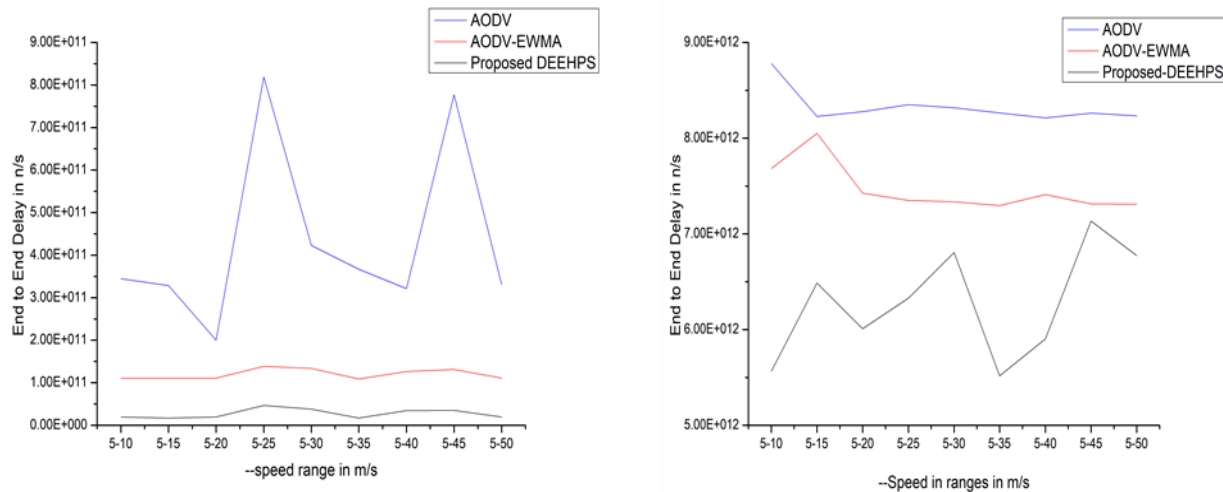


Fig. 12 End to End delay comparison analysis (a) with low density 20 UAV (b) with high density 40 UAV.

Next observation in Fig. 10 and Fig. 11 shows an 8%-89% increment in throughput with 5- to 50-m/s higher speeds, which is a good metric for the efficiency of AANET routing. In terms of the latency, Fig. 12 shows the proposed model has the lowest delay in the network, both in low-density as well as high-density networks. This way, from the given figures, the proposed DEEHPS outperforms well in terms of the throughput, delays, and PDR when compared with the z-direction scaling factor of the GMM.

**4. Conclusion**

The new era of the proposed smart model bridges the various gaps in wireless communications. In this proposed research, DEEHPS is independently implemented on AODV routing; there is no need to change the infrastructure. This smart design schedules hello packets with the higher velocities adapted with deep learning method moving averages and scaled by additionally supporting modified GMM, which thrills the flight in the z direction for the AANET movements. In simulation experiments, the proposed model was implemented into the AODV protocol. Here, AODV is selected due to its outperformance in yielding fast responses in simulations, which was seen in previous experiences. For comparing QoS network metrics like throughput, PDR, and E2ED, other schemes are implemented in the same AODV, whose results show that the proposed model gives better performance and attains a significant reduction in energy while aiding in the expansion of the flight, which is indirectly dependent on battery energy. In reenactment tests, consider the practical 3D set-up and measure the performance of the proposed novel DEEHPS model with trivial AODV and an adaptive imtiaz hello scheme, where the proposed novel DEEHPS excels in throughput with an enhancement of 8%–89% respectively at slow and high speeds and a significant reduction in energy consumption while saving 28–36% energy. Supplementary developed a method to find the optimised number of UAVs in the given mission, which persuaded the PDR and E2E delays and opened a way in cutting edge economics for future.

In future work, it is intended to implement the proposed model in delay-tolerant networks with a larger number of UAVs and other routing protocols like DSDV, DSR, and AOMDV, considering not only mission-critical scenarios but also various bio-inspired AANET scenarios. As future works adapt the various bioinspired mobility models, the mobility rate also learns the turns in dynamic nature, which are lacking in the proposed model. Furthermore, other mobility models can be explored and compared to our proposed method using new network scenarios from Industry 4.0.

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**Conflict of Interest**

There is no conflict of interest.

**Supporting Information**

Not applicable.

**Nomenclature**

$V_{ewma}$	Exponential weighted moving average velocity
$U_{acc}$	Accommodated UAVs
$V_m$	Allowed airvolume
$V_{max}, V_{min}$	Maximum and min velocity of UAV
pitch	Z direction angle in 3D
direction	Horizontal and vertical angle

x	Length of cuboids airspace
y	Width of cuboids airspace
z	Height of cuboid airspace
F	Functional unit
st	Current state
$T_x$	Transmission range of UAV
$T_{hello}$	Hello interval

### Greek symbols

$\beta$	constant parameter for the EWMA
$\alpha$	Distance $\alpha = \Theta * V_{max} / q * V_{min}$
$\delta$	density
$\gamma$	Network density $\gamma = \alpha / T_x$
$\emptyset$	Average target velocity
g	Network density
$\Theta$	tuning constant multiplied by ratio of $V_{max} / V_{min}$

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