A Handover Decision Model for Unmanned Vehicles for Ubiquitous Communication in Wireless Networks

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***Abstract*—Drone technology also referred to as Unmanned Aerial Vehicles (UAVs) provides many benefits to wireless communication systems. In the coming years, the linked drones will be commonly used in different fields such as delivery methods, monitoring services, and defense networks etc. However, security and logical characterization of handover probability in drone systems is still a big problem. Various fuzzy based methods were proposed by a number of researchers to resolve these issues, but the problem with conventional methods was that they considered only limited dependency factors. However, there are some other dependency factors as well that affect the performance of the drones. In this research, a fuzzy based decision model is proposed. The proposed fuzzy system uses five dependency factors such as coverage, speed limit, cost, connection time and security as inputs. To process these inputs 160 rules are defined in the given fuzzy system in order to produce an output in terms of handover probability. The performance analysis of the traditional and proposed model is analyzed in the MATLAB software when they were moving in random and straight directions, in terms of estimation level, PDR, throughput and delay. The simulation results showed that the proposed model is efficient and stable as compared to traditional fuzzy system.**

***Index Terms*—Intelligence in wireless communication, Unmanned aerial vehicles, Fuzzy logics, Soft computing in WSN, FANETS, etc.**

I. Introduction

With the advancement of wireless network technologies, our day-to-day lives have changed dramatically in every aspect. One of the fastest and rapidly growing technology of wireless networks is Internet of Things (IoT) [1]. With the introduction of IoT, it is possible to connect a large number of devices together in the real world for the betterment of humans. In return, the need for communication over different places at any time especially in busiest areas is rapidly increasing [2].

Therefore, the present framework of internet is experiencing exponential rise in bandwidth demand. The concept of aerial networks using Unmanned Aerial Vehicles (UAV) was being suggested as optimistic solution to reduce the bandwidth problems [3]. Recently, popular uses of drones have lured deep interests in broad areas such as area-inspection, Closed-circuit television (CCTV) surveillance [4].

Unmanned Aerial Vehicles (UAVs) popularly known as drones needs connectivity in order to perform the given tasks [5].

Nowadays, drones are paving their path into number of fields which are automatically raising their existence in the consumer market [6]. A cellular network provides universal coverage which serves as a baseline that not only offers a broad area for communication but also ensures the connectivity of drones over ocular sight. With the help of drone's humans are able to communicate to vast remote sensing areas. Due to their significance, drones are usually used in crucial tasks like rescue operations, surveillance, transportation as well as agriculture, forestry, environmental protection, and security [7].

In order to make this technology fully automatic, there are few challenges that need to be addressed. The biggest challenge for experts is to design a drone that is safe, secure and can perform its operation effectively even in adverse weather conditions. Also, due to the limited capacity and the fact that Wi-Fi network technology is typically lighter than LTE (Long Term Evolution), current drones can be utilized as Wi-Fi access points (AP) [8]. Moreover, a conventional Wi-Fi network provides limited communication scope and quite long handover time so it is quite complicated to execute stable handover [9]. Over the years, a large number of methods were proposed by researchers to improve the performance of drones. Some of them are discussed in the following section of this paper.

II. Litertaure Review

The mobility of Drone Base Stations (DBSs) derived various efforts in the literature but there were only small number of works that can be considered for handover in drone's networks. The related work on handover in drones' network is explained below.

Eunji Lee *et al*. [10], defined the various communicating parameters of drones including speed limit and coverage that interact in 3-D space. By

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considering these parameters as input to handover decision module a fuzzy interface method was proposed. The number of handover decisions computed indicated that considering terminal-related and network-related parameters into account had a favorable impact on handover decision. Navuday Sharma *et al*. [11] proposed a system to achieve speedy handover and efficient management. For taking handover decisions, Exchange to Exchange (E2E) delay, handover latent-time, signaling overheads were taken into account. This mechanism will be useful to intellect the effect of handover methods in the incoming 5G. It can be concluded from the study that combination of UAVs and small cells will have better performance than only small cells. K. Park *et al*. [12] developed a coverage decision algorithm capable of achieving smooth and continuous handover in an entirely connected aerial network. The chances of positive results and failure of handover initiation of this interrupt free handover were computed. It was concluded that the suggested scheme can be considered as a best way to proceed for handover in an aerial network. Amin Azari [13] suggested logical framework for the key Performance Indicators (KPIs) which states the Handover and Radio Resources Management (H-RRM) optimization issues. This model consists of interface over cellular network and communication delay. When these issues turn into machine learning problems, deep reinforcement learning methods were introduced to sort-out H-RRM problems. It can be concluded from the results that the optimal H-RRM strategy in network is formed with the velocity and height of drones and tolerable level of interface. For different altitudes and velocities of drone's, heat-maps of handover decisions were introduced that helps in reviewing of the legacy handover methods and reshape the limits of cells in the sky.

A. Other Related Works

Yucel Aydin *et al*. [14] addressed the problem of terrestrial BS (Base station) authentication of UxNB (define the abbreviation). By lowering the number of communications among BSs, the lack of a credential exchange phase preserves resources. Furthermore, the suggested approach completes several UE handover procedures in a short amount of time. To enable connectivity and mobility of robust wireless for drone-UEs, Yun Chen *et al*. [15] proposed a unique HO (Handover) method for a cellular-connected drone system. In comparison with the baseline HO method, the results reveal that the suggested methodology can drastically minimize the amount of HOs while preserving connectivity. Man Hon Cheung [16] attempted to reduce AoI (Age of Information) in both handover and network access. The simulation outcome revealed that the load-aware handover of the DBA scheme results in a lower AoI cost when compared with the two benchmark methods. In MIMO (Multiple Input Multiple Output) system, Zhengjia Xu *et al*. [17] defined and calculated the multi-parametric objective function for proactive handoff with QoS (Quality of Service) constraints. When authors compared handoff technique performance with standard selection techniques, it was discovered that the handoff technique outperforms the standard selection approach in terms of an average utilization ratio. The outcome suggested that by adopting a broader bandwidth and loosening the QoS criteria, the utilization ratio of the spectrum can indeed be doubled. To permit dynamic task allocation through information dissemination, Samira Hayat *et al*. [18] added communication into the multi-UAV path planning issue for rescue and search operations. By effectively including communication into the path design, additional tasks can be completed in the allotted mission time. In terms of connectivity, researchers also noticed the improvement of resultant paths.

Although these works provide useful guidance, the issues of logical characterization of handover probability in drone networks still remains a big problem. This paper mainly focuses on this open problem. Only few studies are available for handover in drones that are based on fuzzy logics. The reason why fuzzy logics is recommended over other systems is its property of processing concepts similarly as per human thoughts. Secondly it let the designer to model the system's input and output relationship without considering their physical impact. The current available methods are focusing on considering QoS factors as Received signal strength (RSS), data rate, cost, [19], as an improvement a system was proposed by introducing the concept of coverage and speed limit [10]. These systems work effectively but other than these factors, we have considered security and connection time for handover decision in drones in this paper.

III. Overview of Proposed Scheme

This section provides a brief overview of the the proposed scheme in which a fuzzy decision model is designed for handover in drone systems. This system was created by analyzing the present network requirements as well as connection-based characteristics. As for now only factors as signal strength, data rates are not enough for current drone systems, security and privacy of the data and connection link are also important. Therefore, the proposed scheme is comprised of increased dependency factors for decision modeling for drone handover. The architecture of the proposed scheme is shown below in Fig. 1. The proposed system is considering 5 decision factors as network coverage, speed limit of drone to consider the mobility factors, cost, connecting time and security that represents how secured the connection will be.

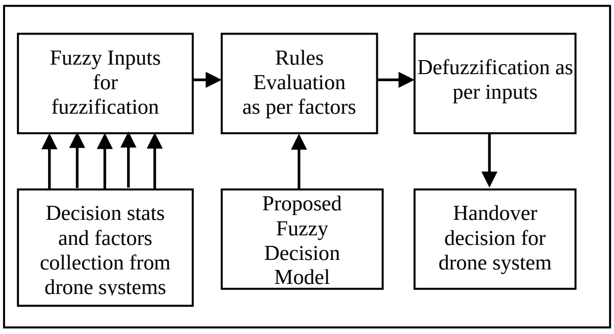

Fig. 1. Proposed handover decision model.

The proposed handover decision model consists of 3 modules, in module one the fuzzy based proposed decision system is designed by defining the input factors, rules for Mamdani type of fuzzification and output handover decision parameters after defuzzification. The system diagram is shown below in Fig. 2. The second module of proposed scheme is collecting the required parameters from the information gathering layer of communication protocol. This information includes speed, location, security and requests, connection time etc. These factors are further processed by the algorithm and filtered the required parameters as input for fuzzy decision system.

The input layer of the fuzzy decision system further converts the information to membership function for the fuzzification process, which are further evaluated by fuzzy rules. At final layer of fuzzy decision system, the defuzzification of these inputs produce a handover decision for the drone. This whole process is done for single time to get the handover estimation level.

A. Proposed Handover Decision System

The proposed handover system consists of 3 sections, fuzzification, rules evaluation and defuzzification. This section provides a detail information of each section with the normalization ranges of the input variable, defined rules in proposed system and their linguistic variables.

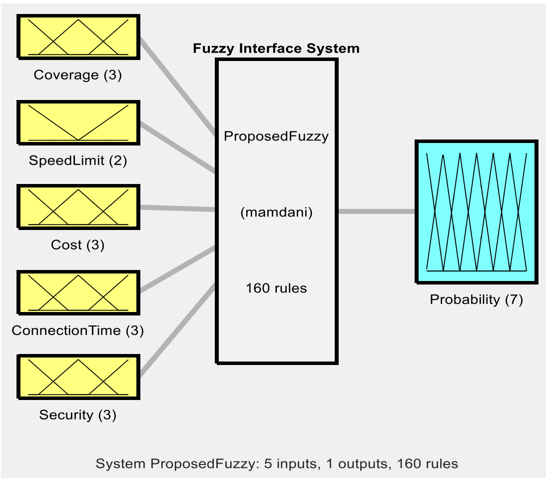

Fig. 2. Proposed fuzzy decision model for drone's handover decisioning.

TABLE I: INPUT MEMBERSHIP VARIABLE & FUNCTIONS

Fuzzy Input Variables	Normalized range	Linguistic Variable
Coverage	0<*x*<0.4 0.1<*x*<0.9 0.6<*x*<1	Low Average High
Speed limit	0<*x*<0.5 0.5<*x*<1	Low High
Cost	0<*x*<0.4 0.1<*x*<0.9 0.6<*x*<1	Low Medium High
Connection Time	0<*x*<0.4 0.1<*x*<0.9 0.6<*x*<1	Low Medium High
Security	0<*x*<0.4 0.1<*x*<0.9 0.6<*x*<1	Low Medium High

TABLE II: SAMPLE INFERENCE RULES OF PROPOSED FUZZY SYSTEM

Sr No.	Sample Rules
1	If coverage is low and speed limit is low and cost is low and connection time is low and security is low then probability is very Low
2	If coverage is low and speed limit is low and cost is low and connection time is low and security is medium then probability is very low
3	If coverage is low and speed limit is low and cost is low and connection time is low and security is high then probability is medium low

TABLE III: OUTPUT MEMBERSHIP FUNCTION

Fuzzy Output Variable	Normalized range	Linguistic Variable
Probability	0<*x* <0.16 0<*x* <0.33 0.16<*x*<0.5 0.33<*x*<0.6 0.5<*x* <0.83 0.6<*x* <1 0.83<*x* <1	Very Low Medium Low Low Medium High Medium High Very High

Above Fig. 2 represents the different layers of proposed fuzzy decision system. At input layer, 5 different membership variables are considered as input those are coverage, speed limit, cost, connection time and security. Each of this variable is further divided to different number of membership functions as 3 for coverage, 2 for speed limit, and for cost, connection time and security these are 3. The detail of individual membership variable with its normalized range and linguistic variable name is given in Table I.

Once the membership variable and their functions are defined, next section is to define the inference rules, those are designed based on the decision parameters for handover in drones. In proposed system a total of 160 rules are defined. An example set of proposed fuzzy rules are given below in Table II.

The final section of the proposed fuzzy system is to defuzzification, which converts the fuzzy output into a crisp value that would help for decisioning of handover by drones. The output membership variable of the proposed scheme is termed as handover probability. The range of the crisp values to be generated after defuzzification over probability value are given below in Table III.

IV. SIMULATION RESULTS AND DISCUSSIONS

In this section the simulation results of the proposed fuzzy based system with increased dependency factors are given and discussed. The whole simulation is conducted by using the MATLAB tool. The first step for processing the systems is to design the fuzzy decision system which is done by using the MATLAB's in-built fuzzy toolbox. The major contribution of the proposed scheme is that the system is considering different factors including mobility and security of the drone and network for making decision for handover. The simulation results are calculated in terms of estimation level, packet delivery ratio, throughput and delay. Initially a conventional fuzzy based handover decision system [10], in which only 2 decision factors coverage and speed limit were considered for making the decision regarding handover. After implementing the current system an analytical study is conducted that helped to propose an improved system in this paper. Finally, a comparison is done to prove the efficiency and effectiveness proposed decision model.

The performance of the proposed model while moving in two directions i.e., randomly and straight, is evaluated in terms of their estimation level as shown in Fig. 3. The blue-colored bar represents the conventional fuzzy model while as the orange-colored bar demonstrates the performance of the proposed-fuzzy system. From the graph, it is observed that the estimation level in the proposed system in both random and straight cases is around 0.6035 and 1.3946 respectively. While as in traditional fuzzy system the estimation level value while moving randomly and straight is 0.7717 and 2.5000 respectively. Thus, estimation level value in proposed system is much lower than conventional systems.

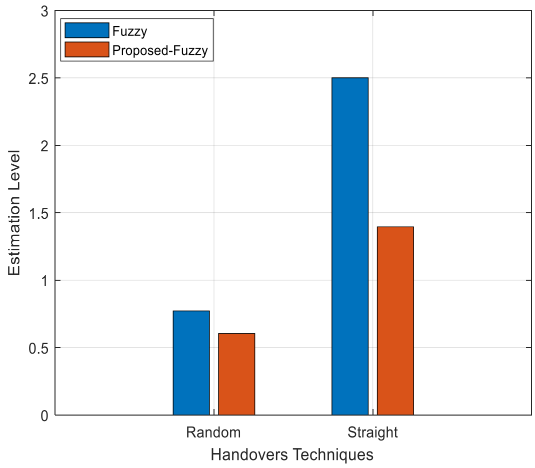

Fig. 3. Comparison of traditional and proposed fuzzy model in terms of estimation level.

Moreover, the performance of the proposed model is also analyzed and compared to the traditional fuzzy model in terms of their packet delivery ratio and is shown in Fig. 4. The performance of the proposed fuzzy system is demonstrated by the orange colored bar. On the other hand, the performance of the traditional fuzzy model is represented by the blue colored bar. From the graph, it is observed that the PDR percentage in the traditional model in random direction is 76.4160% while as its 77.8320% while moving in straight direction. While as in case of the proposed fuzzy approach the packet delivering ratio is 87.8320% and 87.6563% while moving in random and straight directions respectively.

Fig. 5, Illustrates the comparison graph of the proposed and traditional model in terms of their throughput values while moving in two directions i.e., randomly and straight. The performance of the traditional approach is depicted by the blue colored bar wile as the performance of the proposed fuzzy model is depicted by the orange colored bar. After examining the graph, it is observed that the throughput value in proposed fuzzy approach while moving in random direction came out to be 89.940 whereas it came out to be 89.760 when moving in straight direction. On the other hand, the throughput value in traditional fuzzy system is only 77.057 and 62.312 while moving randomly and straight. This, makes the proposed system more efficient and reliable.

Finally, the performance analysis of the proposed and conventional model is done in terms of delay as well and is shown in Fig. 6. The delay in proposed system while moving in random and straight directions is only 0.00017 and 0.000138 while as, in traditional fuzzy model the value of delay is 0.000383 in random and 0.000690 in straight directions. The specific values of these parameters are given in Table IV.

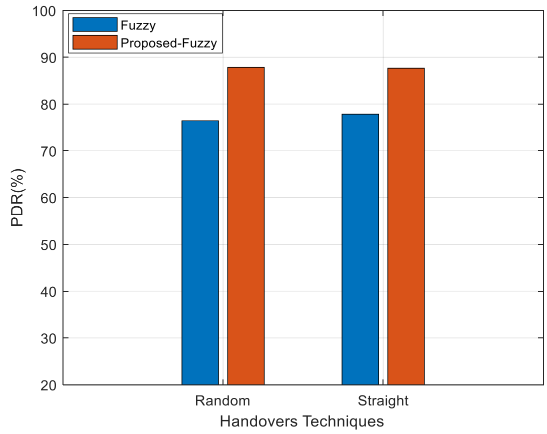

Fig. 4. Comparison graph in terms of PDR.

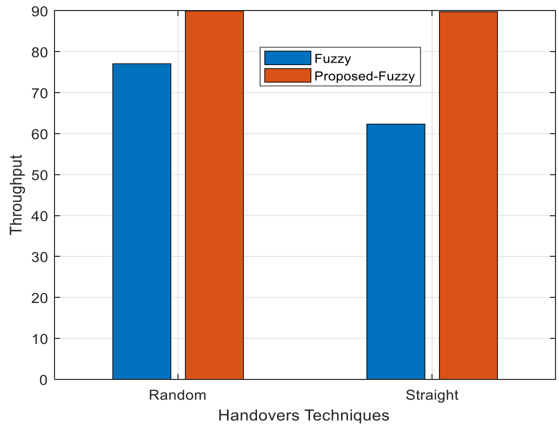

Fig. 5. Throughput value in traditional and proposed models.

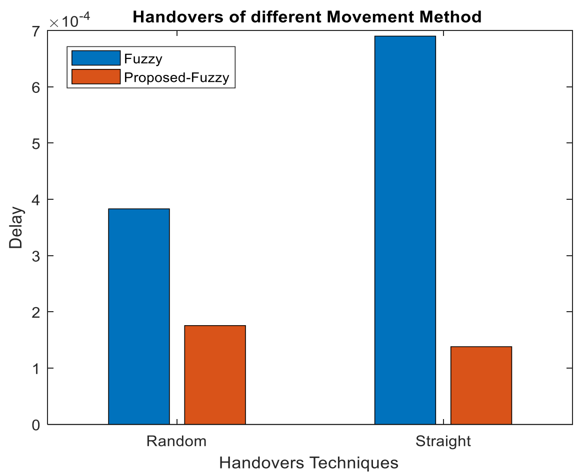

Fig. 6 Comparison of traditional and conventional model in terms of delay.

TABLE IV: COMPARATIVE ANALYSIS OF PROPOSED SCHEME

Parameter	Traditional (Random Movement	Traditional (Straight Movement)	Proposed Fuzzy System (Random Movement)	Proposed Fuzzy System (Straight Movement)
Estimation Level	0.7717	2.5000	0.6035	1.3946
PDR (%age)	76.4160	77.8320	87.8320	87.6563
Throughput (%age)	77.057	62.312	89.940	89.760
Delay	0.000383	0.000690	0.00017	0.000138
Parameter	Traditional (Random Movement	Traditional (Straight Movement)	Proposed Fuzzy System (Random Movement)	Proposed Fuzzy System (Straight Movement)

From the graphs and table, it is observed that the estimation level in the proposed fuzzy system is reduced by 0.1682 when moving randomly and 1.1054 when moving in straight direction. Moreover, the PDR value in the proposed system is also increased by 11.416 and 9.8243 when movement is random and straight respectively. Furthermore, the throughput value of the proposed system is near to maximum value in both movements. There is an improvement of 12.883% when moving randomly and 27.448% when moving straight. Additionally, the delay is also reduced in the proposed fuzzy system by 0.000213 and 0.000552 in random and straight directions.

V. CONCLUSION

Handovers play a significant role in Unmanned Aerial vehicles or drones. The proposed system used a fuzzy based system to perform handovers effectively in which multiple dependency factors i.e., estimation level, packet delivery ratio, throughput and delay were taken as inputs. The performance analysis of the proposed system is also compared with the traditional fuzzy model in which only 2 dependency factors were taken as inputs. The proposed model is simulated and analyzed in the MATLAB software. The simulation results were obtained in terms of estimation level, packet delivery ratio, throughput and delay when drones were moving randomly and in straight directions. The estimation level in the proposed model is minimized up to 0.1682 and 1.1054 while moving in random and straight directions respectively. The packet delivery ratio is also enhanced in the proposed system by 11.416 and 9.8243 when movement is random and straight respectively. The effectiveness and superiority of the proposed fuzzy model is also depicted by its increased throughput value while moving randomly and straight by 12.8835 and 27.448%. In addition to this, the delay in the traditional systems was around 0.000383 (randomly) and 0.00690 (straight) which is reduced up to 0.00017 (random) and 0.000138 (straight) in the proposed fuzzy model. Thus, the proposed system outperforms the traditional model in all parameters which proves that the proposed model is efficient, reliable and secure.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Sonika Singh conceptualized the topic, analyzed data and wrote the paper. She also conducted the research, collected data and validated the results. Mandeep Kaur Sandhu guided Sonika Singh in different phases of research. All authors had approved the final version.

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