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Review

A Fuzzy Based Handover Decision Scheme for Mobile Devices Using Predictive Model

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Abstract: Handover usually deals with the mobility of the end users in a mobile network to assure about the ongoing session of a user. It is observed that frequent handover results in call dropping due to latency. In order to overcome this issue, a fuzzy based handover decision scheme for mobile devices using a predictive model is proposed. First, an MFNN (Multi-layer Feed Forward Network) is used to determine the next cell of the user along with best hand off time. To obtain the best access network, multiple-attribute Access Network Selection Function (ANSF) is used. The fuzzy rule is applied by considering the parameter data rate, reliability, signal strength, battery power and mobility as input and the output obtained is the optimal network. The proposed scheme selects the best access network and enhances the quality of services.

Keywords: MFNN; handover; mobility prediction; ANSF

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1. Introduction

4G is the extreme network provided rate of data (100 Mb/s), expands multimedia services and gives about 2.8 GHz frequency. 4G is a collection of technologies and protocols which generate packet-switched networks which are optimized for data [1]. The fourth generation (4G) wireless networks possess specific characteristics like higher usability anywhere, anytime and with any kind of technology and they also assist services intelligently at making the transmission cost low [2]. It has a wide area of applications in extensive wireless multimedia services, full-motion video applications and wireless teleconferencing [3]. The numerous measures of voice traffic in 3G harden the undertaking of roaming and interoperating while 4G gives worldwide portability and service portability by its advanced packet network. The inabilities and downsides of 3G propel the deploying of 4G [3]. The network architecture has a core component of system integration [2]. The existing wireless technologies are coherently integrated in 4G and this provides fast and extensive access and service for the cellular user. By combining mobility and networking, it can develop a new class of amazing applications [4].

5G enables a variety of connections such as the Internet of Things (IoT), Machine to Machine (M2M), Device to Device (D2D), Vehicle to Everything (V2X) and Bluetooth. Collectively, they influence corporate governance and interaction with customers in the physical world [5,6]. Connections have grown dramatically over time as the benefits of connecting devices have been recognized in Internet access by customers, businesses and governments. Over the next decade, these aforementioned services will become a key element of the larger market of devices in the world [7]. The 5G networks connected simultaneously by the hundreds of thousands that are considered essential for the massive deployment of these services. These different types of connected services require more system capacity and higher data rates, but some of them require lower latency. All this led to the development of 5G systems.

Recently, several studies have been carried out in terms of mobility prediction, autonomous vertical handoff, security, software-defined network (SDN), software-defined network virtualization (SDNV), network function virtualization (NFV) and battery consumption patterns. mobility management issues [8,9]. In addition, a survey based on actual measurement data conducted shows how the LTE-A (Long-Term Evolution-Advanced) network works during user mobility compared to the first phase of the LTE version. This study analyzed turnaround times, coverage and transfer times [10]. However, each survey provided a different perspective. Therefore, an investigation is needed to uncover the challenges, problems, mobility solutions and determinants of the future direction of the network in mobility.

Handover considers the end user's mobility in a mobile network and assures the continuity of the wireless services if the mobile user varies its position across the cellular boundaries. The moving of a mobile's association starting with one base station then onto the next is called handover. Handover provides the following:

- Continuity of call
- Optimum radio link selection
- Traffic distribution

The main aim of 3GPP-WLAN internetworking is coherent mobility that can reduce data loss and latency (i.e., the time spent in handover) during the handover. 3G access procedures consist of two procedures: namely, a context activation packet data protocol procedure with allocation of IP address and a service request process along with authentication of the subscriber. Handover latency is increased when the procedure takes a long time to complete. This may cause service failure. The prediction of handover for triggering a link is very important for coherent mobility; because previously, when the link layer predicts WLAN signal loss and when the 3G network connection was made before the link interruption, the break time of the link was reduced and services were continued with no disruption.

In a wireless network, there are two forms of handover: horizontal handover and vertical handover. Horizontal handover is a handover process (within the device handover) that happens between the same network's access points and base stations. It occurs between the homogeneous cells of a wireless access system at the end of the day. Vertical handover (outside framework handover) is characterized as a handover instrument that happens between the various purposes of connection of various networks. In any case, it might influence the connection, network and transport layers [11]. The three phases of the vertical handover process are network exploration, handover judgement and handover execution. During the handover decision stage, access focuses can choose when to play out the vertical handover, and it can locate the best handover competitor access network. Contingent upon serving of base station, the handover is grouped into soft and hard handover.

Hard handover implies that all old radio connections are ended before setting up new radio connections. Hard handover can be either coherent or non-coherent. Coherent hard handover isn't noticeable to the client and requires a difference in the bearer frequency (between frequency handover) [12], whereas in soft handover, radio links are joined and removed in a radio link and this is performed with the help of macro diversity when several radio links are active concurrently. If the cells operating in the same frequency change, soft handover can be preferred.

Requirements of handover mechanisms are network cost, handover latency, energy consumption, velocity, bandwidth, network throughput, load-balancing, security, received signal strength, etc. [12].

However, handover management in a 3G network has several challenges.

The vertical handover among different wireless communication systems is very hard to understand while satisfying QoS requirements.

The major challenge of handover with high user mobility is call dropping, which occurs due to frequent handover, and the resources are not available in the target base station [13]. If handover latency is long, the packets could be disconnected or lost during the handover [14].

Mobility Rate: The important criterion to be considered in research on the mobility of wireless networks is mobility rate. Many UEs may have different speeds and have different effects on the received signal strength during UE mobility, which may have different effects on the stability of the communication. The maximum user speeds supported by wireless communications systems with mobility capabilities vary. For example, 4G in, the maximum supported speed per hour 350 km [15] It was the case, the 5G cellular system per hour 500 km can support up to [16]. As the maximum speed increases, not only the required transfer process, but also the decision making of high-speed transfer becomes an essential requirement.

2. Related Work

An adaptive multiple attribute vertical handover decision algorithm has been developed by Yaw and Agbinya. This algorithm allows for the selection of a wireless access network at a mobile terminal using fuzzy logic and a genetic algorithm. The vertical handover decision algorithm will be used to choose the best access network when a handover is needed. The chosen network can be tailored to network conditions including QoS specifications, mobile terminal state, service cost, and customer expectations [17].

Toni Janevski and Kire Jakimoski [18] have proposed a solution for improving the QoS during vertical handovers between UMTS and WiMAX networks for real time video applications. The analyses had shown that performance parameters, such as delay and throughput, are strongly dependent upon the speed of the mobile terminals, showing higher delays and bigger throughput gap as the velocity increases. The proposed optimized solution for vertical handovers between WiMAX and UMTS networks for video traffic has been tested for different video traffic types. This approach will increase the control and signaling traffic in the wireless networks.

In [19], a fuzzy based handover algorithm is proposed to improve the capacity as well as QoS of the network using the ratio of declination of normal signal loss to the actual signal loss. The problem is supported by the analytical solution which is based on a fuzzy network.

Various systems are formulated based on these mobility models, but the majority of them suffer from high packet loss, repeated handovers, too early and late handovers, insufficient network selection, and so on. To address these issues, a generalized vertical handover control system for heterogeneous wireless networks is introduced in [20].

In paper [21], the research initiatives are described under Mechanism of vertical handover decision for heterogeneous networks with cellular, with a good mix of unconventional and conventional. Recent approaches have been developed to assist in the decision-making process for vertical handover.

The authors of paper [22] increased the network performance in terms of the number of handovers and the handover delay by using an LTE-SDN architecture and a novel handover decision algorithm focused on predicting the potential locations of a moving car. The suggested algorithm divides the handover process into two stages: preparation and implementation.

Paper [23] proposes fuzzy logic-based vertical handover decision making to solve the smooth vertical handover problem. The paper uses the network simulator ns-3 and the fuzzylite library to conduct the required performance evaluation and facilitate the development of real-time scenarios. The suggested solution is quicker than the average rank for the setup in question, eliminates ping pong handovers, and boosts overall performance.

For handover optimization, article [24] introduces an intelligent mobility management system based on the Enhanced Multi-Objective Optimization Method by Ratio Analysis (E-MOORA) and the Q-learning method. The E-MOORA approach incorporates vector normalization by combining the modified entropy weighting methodology with the Multi-Objective Optimization Method by Ratio Analysis (MOORA). When selecting a HO target cell, the suggested E-MOORA technique judiciously utilizes the performance factors and thereby decreases ranking abnormality. The best triggering locations are selected using a Q-learning technique to reduce the effect of frequent unwanted handovers while meeting user QoS requirements.

The article [25] proposes a 5G Ultra-Dense Networks handover decision solution for connected cars (5G-UDN). Its main goal is to treat high vehicular mobility and provide performance gains in vehicle handover, because cellular network densification causes difficulties in cell selection, a higher number of failed and unnecessary handovers (ping-pong effect), longer delays and energy consumption, and high packet losses, despite the expected capacity gain. Virtual Cells are the foundation of the solution (V-Cells). To build a V-Cell, sophisticated network metrics, as well as additional factors such as signal intensity, distance, and speed, are used to choose the optimal cells.

Based on Q-learning frameworks and subtractive clustering approaches, article [26] offers an intelligent handover triggering system for UE. Subtractive clustering is used to transform the input measurements to state vectors, which can increase the training process's efficiency and efficacy. Following that, the Q-learning framework learns from the environment the best handover triggering policy. To start the handover procedure, the trained Q table is deployed to UE.

The authors of [27] paper has discussed about the mobility management in 5G Networks. In 5G technology, the use of millimeter waves [28,29] is a major factor affecting mobility. This is due to high path loss when millimeter wave frequency bands are used, which reduces cell coverage. This greatly increases the probability of transfer and increases mobility issues such as high transfer failures, transfer ping-pong effects, and wireless link failures. In addition, new types of mobile connectivity systems are expected to be implemented in future networks. The implementation of these systems also contributes to increasing mobility problems. These issues will lead to a future increase in mobile data traffic. This rapid growth also contributes to the high probability of transfer rates.

3. Problem Statement

There are some of the issues in the existing works of Handover management in 4G networks. Handover management technique [13] is used to reduce handover delay and call dropping. Here, the prediction component of the MFNN (Multi-layer Feed Forward Network) is used to record the mobility pattern of the user. The data cleaning component of the PTSMA (Prefix Tree Sequence Mining Algorithm) filters only relevant patterns from the predictive model. Handover may fail, though, when prediction of the target base station is not in the neighbor of the source base station. If the predicted cell is not suitable for the user requirements, then it will degrade the quality of service (QoS).

In [17], the primary downside of expanding the lifetime of the Mobile Terminal inside the WLAN is expanding the packet delay coming about because of channel condition corruption. For the decision creation of a network, the fuzzy based decision making is clever; however, increasingly, a number of fuzzy standard sets ought to be framed. In QoS based VHO decision algorithm [10], the frequent vertical handover can cause wastage of network resources. Additionally, this is suitable only for soft vertical handover.

The Vehicular Handover Decision (VHD) algorithm [30] increases the dropping rate to choose the good network from the present network. The drawback of the HNE (Handover Necessity Estimation) [31] is that the throughput metrics for the mobility management technique were not considered. In [32], if the speed will increase, the number of packets dropped will also increase. A new location in which the mobile does not receive packets from the old base station is the settling time in which packet loss occurs.

4. Proposed Methodology

4.1. Overview

In this paper, a Vertical Handover Decision Algorithm based on Fuzzy is proposed along with mobility prediction. MFNN (Multi-layer Feed Forward Network) is used for user mobility prediction. Once the mobility of the user is predicted and the next cell is determined; mobile terminal conditions, network conditions are checked against the user preferences and application requirements. If the predicted cell does not fulfill the preferences and requirements, then the best access network has to be selected. To do so, a multi-attribute Access Network Selection Function (ANSF) [33] is used to select the best access network. It is efficient for utilizing radio resources and improves quality of service. The parameters included are Data rate, reliability, signal strength, battery power and mobility. The parameters are input for the Fuzzy logic-based decision making and as an output, the best network is selected.

Figure 1 represents the proposed block diagram. First, mobility prediction is done using Multi-layer Feed Forward Network (MFNN) to obtain the next cell along with network condition. In case the predicted cell does not fulfill the requirement, then the best network selection is selected by applying the Multiple-attribute Access Network Selection Function. The attribute data rate, reliability, signal strength, battery power and mobility are taken as input for the fuzzy logic decision making engine and the output is taken as best network.

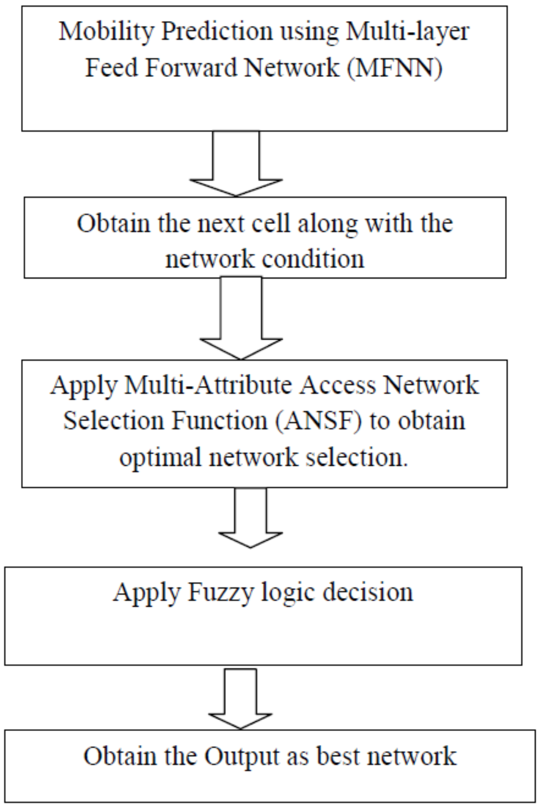

Figure 1. Block Diagram of Proposed System.

4.2. Generation of Input Data for Mobility Prediction

Mobility profiles are generated by collecting input data and reducing the size by removing the outliers. The reduced data are transmitted to each base station which in turn predicts the next cell.

4.3. Collection of Input Data

Mobility management entity maintains the records of entry. Additionally, exit times of each user entity (UE) are maintained at Base Station (BS). At each cell, UE's dwell time T_i is computed.

$$T_i = ExitTime_{cell-m} - EntryTime_{cell-m} \tag{1}$$

The format of the input data is given in Table 1 which contains the information of all visited base stations (BSs) at a given time interval.

Table 1. Format of Collected Data.

UEID1	Cell ID_1	Dwell $Time_1$	Cell ID_2	Dwell $Time_2$	Cell ID_3	Dwell $Time_3$

Assume the mobility pattern as $X_m = \{x_1, x_2 \ldots x_m\}$ recorded for a user entity (UE). The movement of a UE is denoted by x_i during a time interval t_i during which a call is made by UE. The mobility pattern X_m is defined as the cell number and the time duration spent in that particular cell.

X_i represents a combination of u_i, t_i. Here, u_i represents the cell number and t_i represents the duration of time spent.

For example, a mobility pattern is recorded for m = 3: i.e., transition from cell 1 to cell 3. The time spent is 10, 20, and 12 min in each cell, respectively. The mobility pattern may be written as:

$$\begin{aligned} X_3 &= \{x_1, x_2, x_3\} = \{(u_1, t_1), (u_2, t_2), (u_3, t_3)\} \\ &= \{(1, 10), (2, 20), (3, 12)\} \end{aligned} \tag{2}$$

4.4. MFNN Model

For mobility prediction, the Multi-layer Feed Forward Network (MFNN) model is acknowledged. It contains input, hidden, and output layers. The sub pattern is a training data pair with cell number and time spent as input and the next cell location with time as a desired output. In Table 2, for example, the training sub pattern x_1, x_2, … , x_k represents input, whereas x_k + 1 is the intended output. The prediction order, k, is determined by the UE's movement characteristics as well as the magnitude of the recorded mobility patterns. In other words, the intended output is assigned to the final element of the sequence. Table 2 assumes that the number of node movement examined in the input training data is four: i.e., z = 4, and X_j—each movement requires 2 quantities for representing User entity's cell number and time.

Table 2. Movement of Input Training Data.

Sub-Pattern	Input Training Data 1	Input Training Data 2	Input Training Data 3	Input Training Data 4	Desired Output
1	x_1	x_2	x_3	x_4	x_5
2	x_2	x_3	x_4	x_5	x_6
3	x_3	x_4	x_5	x_6	x_7

In the proposed technique, one neuron contains the cell number and time. As a result, there are four neurons in the input layer and three in the hidden layer. The neuron's no. at hidden layer is equal to the pattern's no. used for training and length of the sub-pattern. At output layer, neuron's no. depends on two parameters: cell number and time.

On the basis of trial and error, the value of each parameter can be decided. In the case of designed MFNN, the learning parameters are set as 0.8 and 0.008 from input layer to hidden layer and hidden layer to output layer, respectively. Tanh is used as an activation function. The number of iterations is selected as 20,000 to avoid jam for MFNN at local minima.

4.5. Prediction Based Model

The way toward anticipating UE's next cell area is depicted with a model that is given as follows.

Consider an array of seven cells with mobile network topology depicted in Figure 2. The BS-1 is at the center which is surrounded by 6 BSs from BS2 to BS-7.

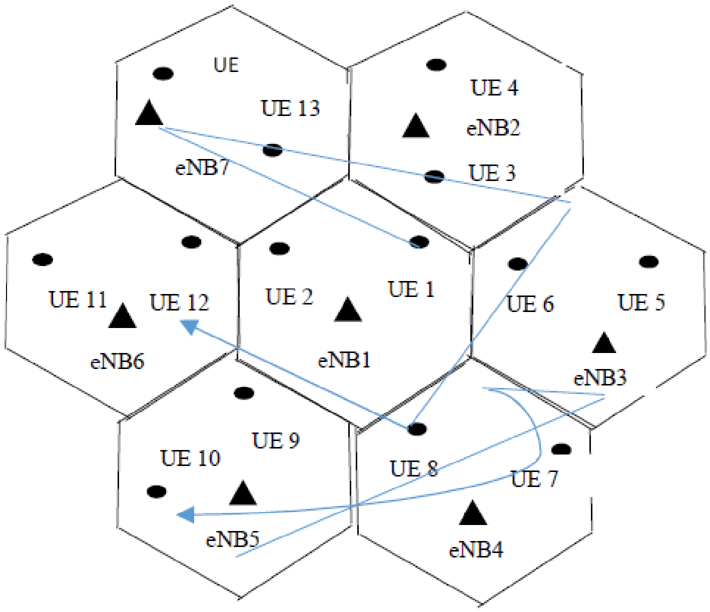

Figure 2. Representation of Mobility Prediction Model.

For each handoff, the cell number and time spent in that cell are considered. UE advancements are recorded and pre-executed to get the case of portability. According to cell-based portability structure, the model for UE1 and UE10 is induced for desire as follows:

The mobility pattern is given as below for UE 3:

$$X_i = \{(1, t_1), (7, t_2), (2, t_3), (3, t_4), (4, t_5), (5, t_6), (6, t_7)\} \quad (3)$$

with seven hands-off.

For UE13, the mobility pattern is

$$X_i = \{(5, t_1), (4, t_2), (3, t_3), (4, t_4), (5, t_5)\} \quad (4)$$

with five hands-offs.

The corresponding sub-patterns are achieved by monitoring each user's pattern which is recorded for a certain period. The obtained sub-patterns are used to train the mobility prediction model. The example of portability of UE 1 is masterminded as in Table 2, which is fitting for training the prescient model. This training informational collection is then taken care of to the predictive model. In the proposed example, consider Pattern 1 and Pattern 2 that represent the training pattern, whereas Pattern 3 represents the test pattern. P_1 to P_4 are given as input to the predictive model, whereas P_5 will be considered as the required output. We accept that over three examples happen for various occasions in the recorded versatility history of UE1. For prediction of mobility, the network is tried on the testing information.

4.6. Optimal Network Selection Algorithm

In case the predicted cell is unable to satisfy the requirement, then the best access network is selected by applying Access Network Selection Function (ANSF) as shown in Figure 3.

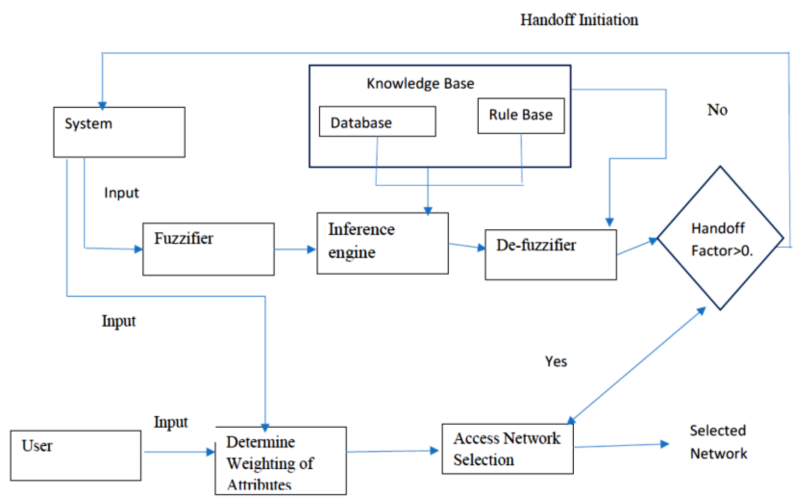

Figure 3. Representation of Block Diagram for Selection of best Network.

ANSF is a neutral function used to compute the efficiency of using a radio resource. It enhances QoS of mobile users acquired by performing handover to a particular network. It represented all elective objective connectivity networks that could serve a mobile client's coverage area. The network with the highest ANSF value would be deemed the best choice for transitioning from the current access network.

The following events occur during the initiation of ANSF:

- Initiation of new service request.
- The MT discover the availability of new network
- A user alters his preferences
- Critical signal degradation or complete signal loss of current radio link

The network selection calculation requires input information from client and framework both. An ideal wireless access network is chosen for excellent service that can fulfill the accompanying targets:

- Strong signal quality implies the accessibility of a network. Accessible network is identified if its signal quality is strong.
- If a network with high optimal data rate is selected, it will reduce time of service delivery of non-real time system and improves the QoS of real-time system.
- A network with high reliability does not have an error and offers a high level of performance.
- Handover should be performed to a network where the battery power requirement is low.

Mobile clients are associated with the upper layers and get favorable position of more prominent coverage region.

4.7. Fuzzy Logic Technique

This section describes the fuzzy logic technique to determine the best network. The fuzzy rules and attributes used in fuzzy logic are convenient to modify. Users can easily modify the fuzzy member function as well as the fuzzy rules to obtain the most suitable output for the considered network environment.

The basic steps of the fuzzy logic technique are:

- The burst inputs are taken from chosen attributes and degree to which inputs of info have a place with each appropriate fuzzy set is resolved. This process is called fuzzification.
- At that point, this fuzzified input is taken and applied to the predecessor of the fuzzy principle and applied to ensuing part work.
- Aggregation is the step in which all the inputs are considered and merged.
- The output of the joined fuzzy set might be taken as input for defuzzification, and a single burst number is acquired as yield.

To start with, the fuzzy logic engine analyzes routing layer to determine the best network. The information is collected and is stored in the LSPs packet in the format shown in Table 3: Network Condition.

Table 3. Network Condition.

Layer	Signal Strength	Reliability	Battery Power	Mobile Terminal Velocity	Data Rate
Routing layer	T	R	B	U	V

4.8. Fuzzification

In fuzzification, input variables like signal strength (T), Reliability (R), Battery power (B), Mobile terminal velocity (U), Data Rate (V) are given a degree of suitable fuzzy sets. The burst inputs are a combination of T, R, B, U and V.

The different possibilities for each attribute are given as below:

- Signal Strength: (Good, Medium, Bad)
- Reliability: (High, Medium, Low)
- Battery Power: (Good, Medium, Bad)
- Mobile Terminal Velocity: (Good, Medium, Bad)
- Data rate: (Very fast, fast, slow)

To input and output variables, Figures 4–9 represent member function. For efficient computation, triangulation functions are used to design member function that gives excellent result.

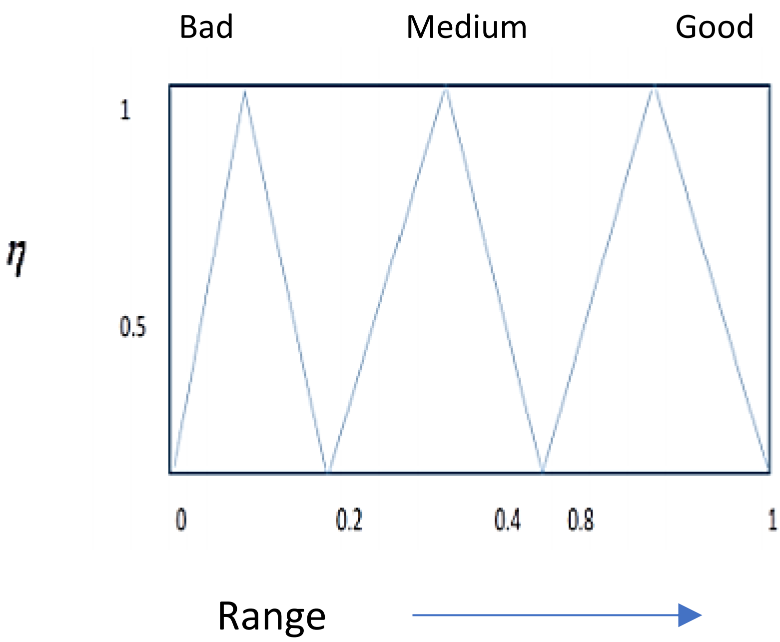

Figure 4. Signal Strength.

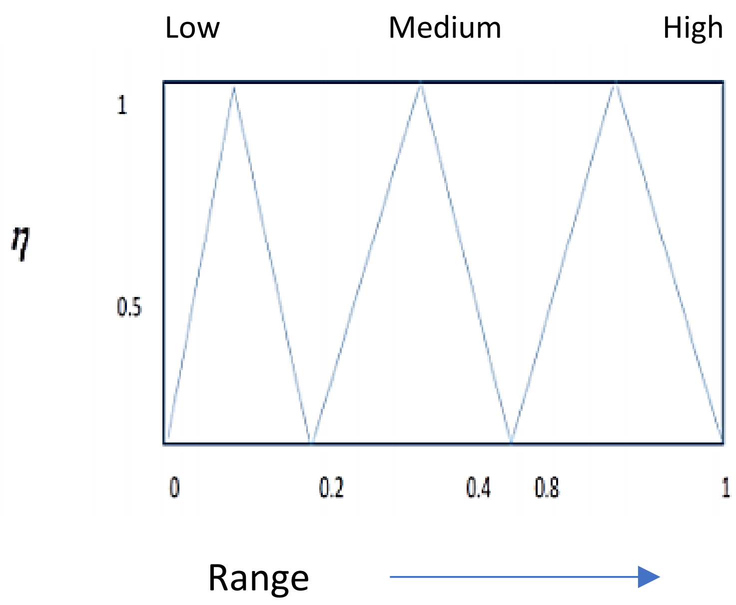

Figure 5. Reliability's Degree Member Function.

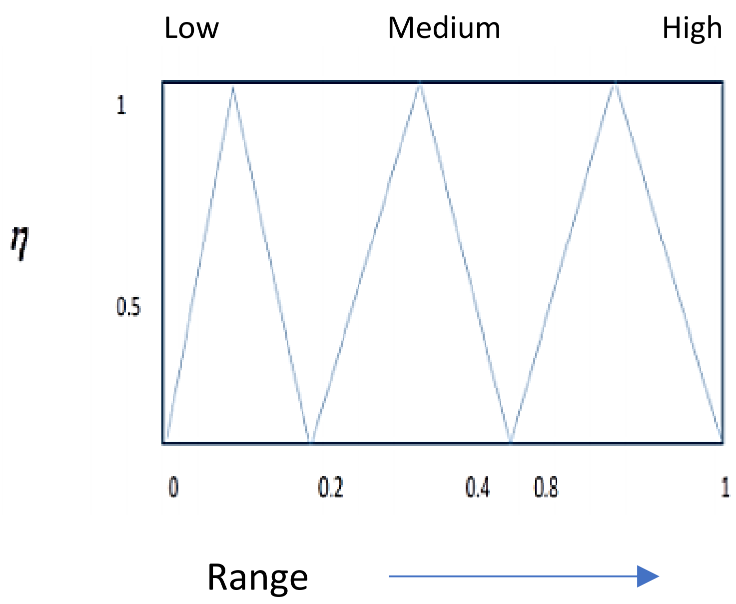

Figure 6. Battery Power's Degree Member Function.

In Table 4, T, R, B, U and V are taken as input and the output represents best network in the routing layer. The following are the fuzzy sets with combination as depicted in Table 4:

- Signal strength (T)
- Reliability (R)
- Battery Power (B)
- Mobile terminal velocity (U)
- Data Rate (V)

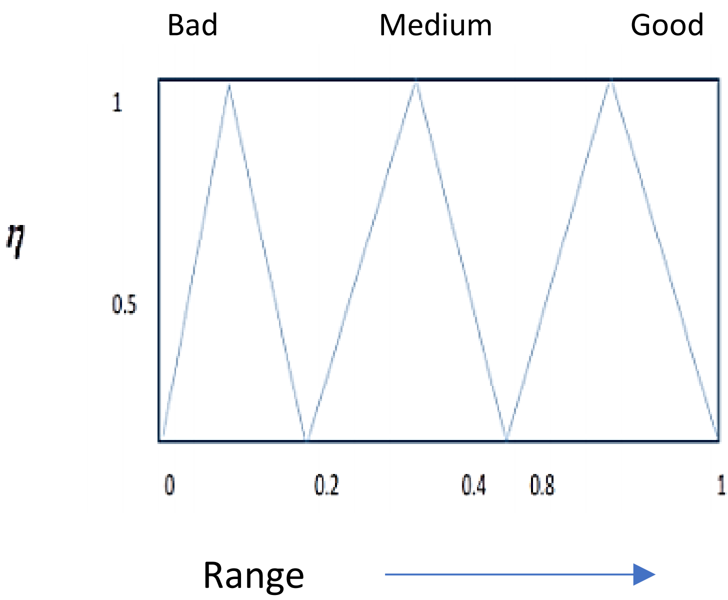

Figure 7. Mobile terminal velocity's Degree Member Function.

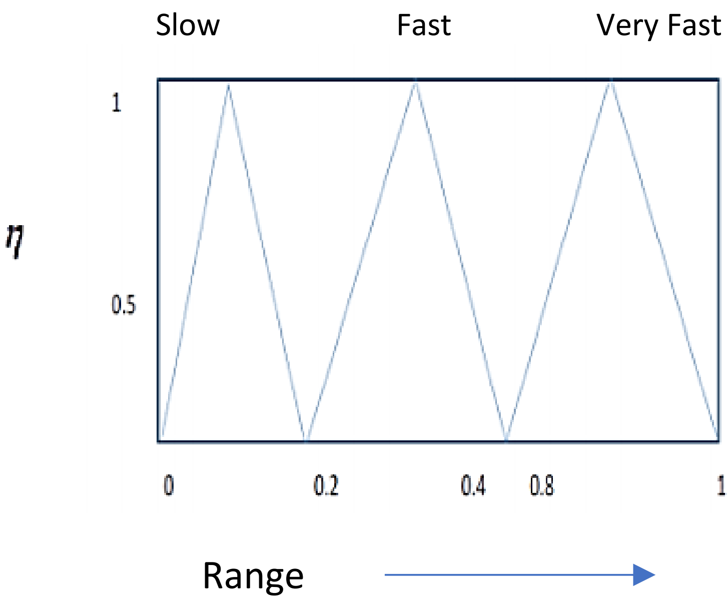

Figure 8. Data rate's Degree Member Function.

If all the conditions satisfy, then it gives the best network.

If any one condition is low, or medium, then the result gives a fair network.

If any one condition satisfies, but the remaining is low or medium, then it gives the result as a bad network.

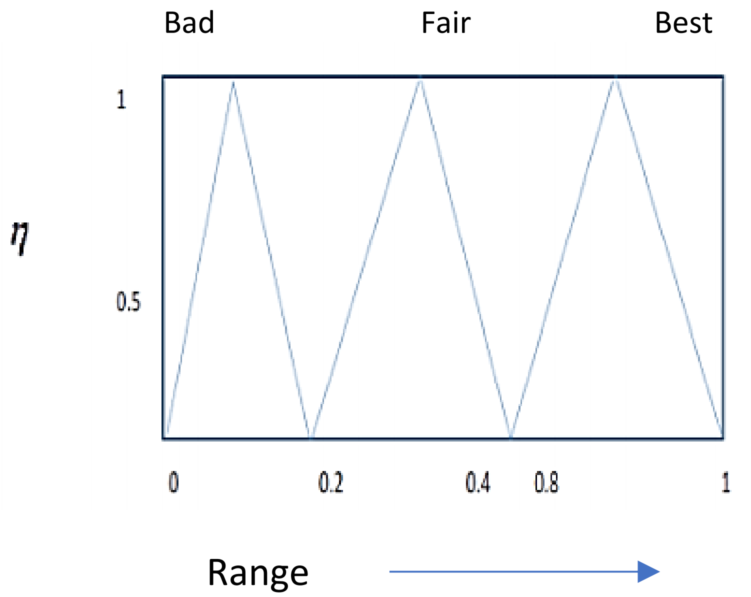

Figure 9. Output Member Function.

Table 4. Fuzzy Rule Base.

Rule	T	R	B	U	V	N (o/P)
1	Good	Medium	Low	Bad	Slow	Bad
2	Medium	Medium	Low	Bad	Slow	Bad
3	Bad	Low	High	Bad	Slow	Bad
4	Medium	Medium	High	Medium	Fast	Fair
5	Medium	Medium	Low	Medium	Fast	Fair
6	Good	Medium	Medium	Medium	Fast	Fair
7	Good	Medium	Medium	Medium	Slow	Fair
8	Medium	Medium	High	Good	Fast	Fair
9	Medium	High	High	Medium	Fast	Fair
10	Medium	High	Low	Medium	Very fast	Fair
11	Medium	Medium	High	Medium	Fast	Fair
12	Good	High	Low	Medium	Fast	Fair
13	Bad	High	Low	Bad	Slow	Bad
14	Bad	Low	Low	Bad	Slow	Bad
15	Bad	Low	Medium	Medium	Fast	Fair
16	Medium	Low	High	Good	Very fast	Fair
17	Medium	Medium	Medium	Medium	Fast	Fair
18	Good	Medium	Low	Bad	Bad	Bad
19	Good	Medium	Medium	Good	Fast	Fair
20	Good	High	High	Good	Very Fast	Best

4.9. Defuzzification

The method of obtaining a numerical result based on a defined fuzzy set and on an output member function is called defuzzification. The output member function is shown in Figure 6. The center of gravity technique is considered to defuzzify the fuzzy result. The following formula describes the defuzzifier technique:

$$Fuzzy\_Cost = [\sum_{all\ rules} R_i * \eta(R_i)] / [\sum_{all\ rules} \eta(k_i)] \quad (5)$$

where *Fuzzy_Cost* represents the degree of deciding factor R_i denotes all fuzzy rules and variables and $\eta(R_i)$ its member function. The output of the *Fuzzy_Cost* function is changed to numerical result based on the above described defuzzification method.

4.10. The Overall Algorithm

1. Function Mobility_Prediction ()
2. Initially, collection of Input data is done
3. Apply sequence mining technique
4. Collect training data set
5. Determine the next cell
6. If predicted cell is unable to satisfy requirement
7. Then
8. Apply function Multiple-attribute Access Network Selection ()
9. consider values of parameters attribute, signal strength, reliability, battery power, mobility terminal velocity and data rate
10. Apply function fuzzy logic decision () to decide the network
11. Return the best network

5. Performance Evaluation

5.1. Experiment Setup

The evaluation of execution of Fuzzy based Vertical Handover Decision Algorithm (FVHDA) is done by Network simulator (NS-2) [34]. Consider a zone of 1000 × 1000 m of irregular network conveyed. The administration demand is fluctuated as 50 Kb/s, 100 Kb/s, 150 Kb/s, 200 Kb/s and 250 Kb/s. IEEE-Distributed Coordination Function (DCF) is utilized as the MAC layer convention for wireless LANs. The reenacted traffic is CBR with UDP source and sink. Figure 10 shows the simulation topology and Table 5 summarizes the simulation parameters used. In the topology, BS1 to BS4 belongs to the WiMAX network and BS5 and BS6 belongs to UMTS networks.

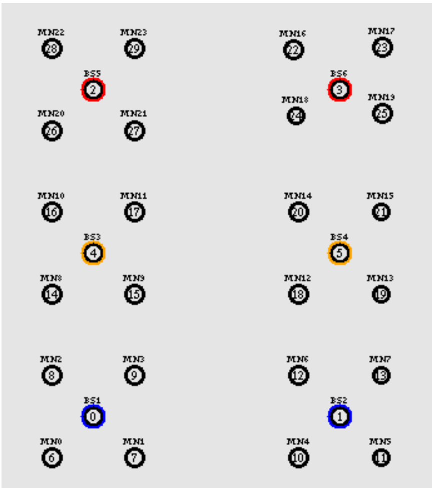

Figure 10. Simulation Topology.

Table 5. Used Parameters.

Mobile Nodes No.	**30**
Network Size	1000 × 1000
Mac standard	IEEE 802.11
Time	35 sec
Simulation Traffic	CBR
Packet Size	100
Rate	50 Kb/s, 100 Kb/s, 150 Kb/s, 200 Kb/s and 250 Kb/s.
Propagation Model	TwoRayGround
Antenna type	OmniAntenna

5.2. Metrics for Performance Analysis

In the performance analysis, the metrics of FVHDA are compared with vertical handover decision algorithm (VHDA) [21–23]. The metrics for performance analysis is evaluated according to the following metrics.

Average Handover Delay: Average of end-to-end delay from the origin to the destinations for all remaining data packets.

Average Packet Delivery Ratio: The average packet delivery ratio is calculated by dividing the number of successfully received packets by the total number of packets sent.

6. Experimental Results

The experiments are conducted for two scenarios. In scenario 1, handover from WiMAX network to UMTS network is considered, and in scenario 2, handover from UMTS network to WiMAX network is considered. In both scenarios, the number of service request is varied as 50, 100, 150, 200, and 250, and the performance metrics are evaluated for both the techniques.

6.1. Scenario 1 (WiMAX to UMTS)

Figures 11–13 depict the results of handover_delay, delivery ratio, and bandwidth utilization for the service request 50, 100, 150, 200, and 250 in FVHDA and VHDA protocols. The performance of the two protocols is compared. From that comparison, we may infer that FVHDA executes better from VHDA by 14.2% in handover_delay, 18% in delivery ratio, and 17% bandwidth utilization.

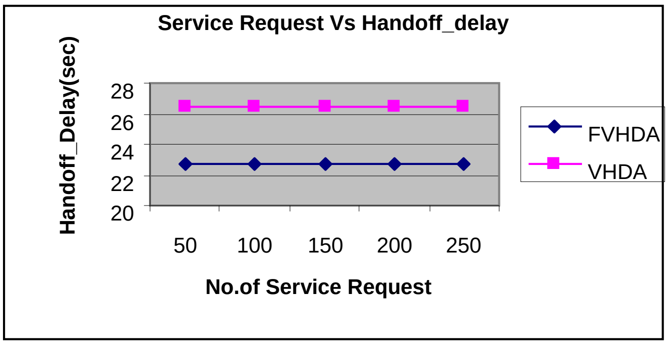

Figure 11. Service Request vs. Handover_Delay.

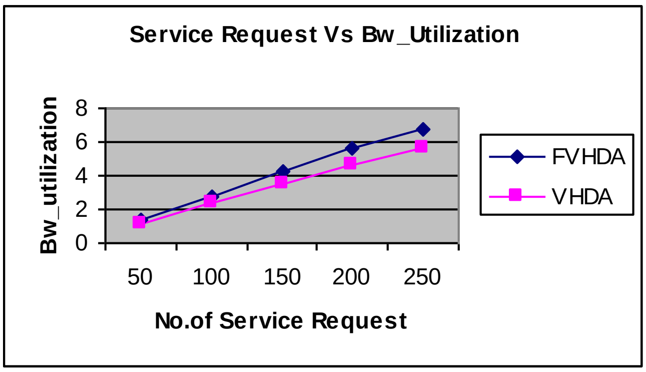

Figure 12. Service Request vs. Delivery Ratio.

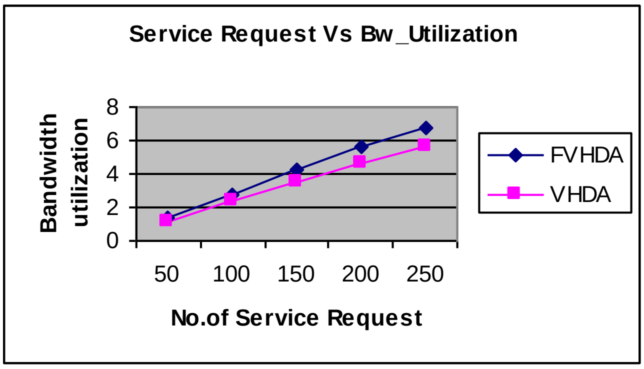

Figure 13. Service Request vs. Bw_Utilization.

6.2. Scenario 2 (UMTS to WiMAX)

Figures 14–16 depict the outcome of handover_delay, delivery ratio, and bandwidth utilization for the service request 50, 100, 150, 200, and 250 in FVHDA and VHDA protocols. The performance of the two protocols is compared. From that comparison, we may infer that FVHDA outperforms VHDA by 6.14% in handover_delay, 3.24% in delivery ratio, and 3.32% in bandwidth utilization.

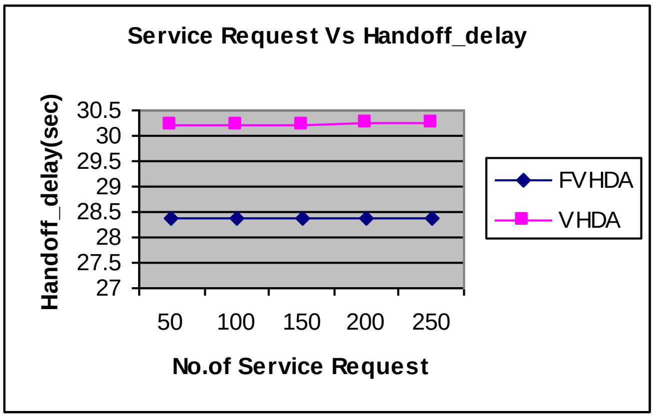

Figure 14. Service Request vs. Handover_Delay.

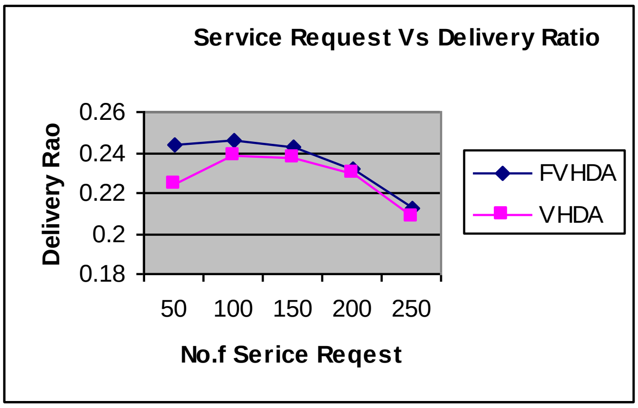

Figure 15. Service Request vs. Delivery Ratio.

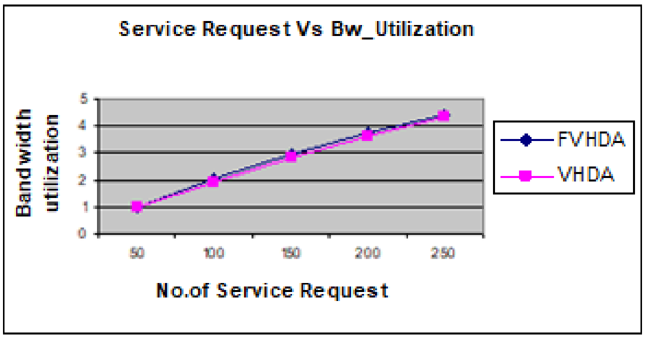

Figure 16. Service Request vs. Bw_Utilization.

7. Conclusions

A Fuzzy based Vertical Handover Decision Algorithm Using Predictive Model for Next Generation network is proposed by us in this paper. A MFNN (Multi-layer Feed Forward Network) technique has been used to determine the next cell of the user along with best hand off time. In the case that the predicted cell does not satisfy the requirement, then the multiple-attribute Access Network Selection Function (ANSF) is used to obtain a suitable access network. A fuzzy logic decision is used to obtain the best network and assure the user about the ongoing session.

In the case of handover from WiMAX network to UMTS network, FVHDA execute better from VHDA by 14.2% in handover_delay, 18% in delivery ratio, and 17% bandwidth utilization. In the case of handover from UMTS network to WiMAX network, FVHDA outperforms VHDA by 6.14% in handover_delay, 3.24% in delivery ratio, and 3.32% in bandwidth utilization. In both the cases of handover, FVHDA outperforms VHDA.

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