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Mobility Management in Heterogeneous wireless network using Adaptive Fuzzy Logic

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Abstract— Everyday brand new smart phones are produced for people to use . These devices have become lighter and smarter. There are several wireless networks in operation by different service providers. Most of these wireless networks can provide internet connectivity and they allow users to move around freely when they are connected. These networks have their area of strength and weakness which can be enhanced if they can be used interchangeably in order to have an efficient internetworking system. When users move from one network based station to another there is need for handover so that connection can be sustained. This calls for an efficient handover system which will not just transfer user's session to a new network base station but also select a network that will provide quality of service compared to the previous one. In this research work, a network assisted handover model was developed using fuzzy logic and a dynamic programming method called Technique Order of Preference with Similarity to Ideal Solution (TOPSIS). It is a multi-criteria decision model which can be used in the ranking of wireless networks based on their performance. The handover decision is modeled using fuzzy logic technique while the network selection is done using TOPSIS algorithm.

Index Terms—Fuzzy logic,TOPSIS,UMTS,Vertical Handover,WiFi,WiMAX, 4G LTE

1 Introduction

Ever increasing demands of users for services such as voice , data , video while roaming leads to the challenging issues like mobility management, quality of service (QoS), increase in coverage area, reduced datacost etc (Chandavarkar et al, 2011). In heterogeneous wireless network environment, several networks can operate independently. These networks can either be of IEEE standard (WiMAX, WiFi) or 3GPP standard (UMTS, 4G LTE, WCDMA). All these networks provide mobile users connection as they move freely within the network coverage area. According to (Bijwe et al, 2015) we have mobile nodes which have multiple transceivers that can connect to multiple wireless networks at the same time. This has open up a new area of research called seamless mobility in heterogeneous wireless network whereby mobile users can move from one network to another without any disconnection.Therefore, there is need for efficient mobility management system among heterogeneous wireless networks where several wireless networks can interoperate to provide users with goodQoS. However, the success of a good mobility framework largely depends on the capability of performing fast and seamless handovers irrespective of the deployed architectural scenario (Singh et al , 2013). The objective of this system is to provide continuous connection to users as they access various wireless network, also to connect withnetwork that provide the best service for the user.There are several wireless networks available to users based on their needs. In an heterogeneous network environment where users are authorized to make use of any of the accessible networks, there is need to disconnect from one access point(AP) and connect to another as the user moves.

The process of disconnecting from a serving AP to a new access point is called handover. According to Ashana et al, (2012) there are two types of handover namely horizontal handover operation (HHO) and vertical handover operation(VHO) . Horizontal handover operation occurs when a mobile user switches between networks with the same technology (WLAN to WLAN) , while vertical handover occurs when user switches between networks with different technology (UMTS to WLAN)).In the past, the conventional mode of handover uses only receive signal strength (RSS) as the only parameter for handover within networks of the same technology. RSS is not sufficient when handover involves multiple wireless network of different standards. Example of parameters used for vertical handover include Bit Error Rate(BER),Mobile velocity, Bandwidth, Jitter, Network coverage area, Data rate, Security etc (Ashima et al, 2014).

Vertical handover process can be categorized into three namely: System discovery, Vertical Handover Decision, Vertical Handoff Execution (Gita et al, 2015)
In this paper an effective vertical handover model was developed using fuzzy logic and TOPSIS algorithm.

2 RELATED WORKS

Malathy E and Muthuswamy V.(2015) worked on vertical handover in heterogeneous wireless network using knapsack-TOPSIS technique. In their work , they proposed a network controlled handoff model two wireless networks WLAN andWiMAX are considered. Some of the network

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metrics used include RSS, traffic in the candidate networks. Their result showed a reduction in unnecessary handover by 24%. This proposed scheme did not consider the security of the candidate network duringhandover through authentication and efficient distribution of nodes on the network to avoid congestion.

Verma et al, (2013) proposed a fuzzy based concept to design a handover algorithm for the integration of UMTS and WiMAX wireless network. Network parameters used are RSS and data rate, coverage area, perceived QoS. These four parameters were fuzzified into appropriate fuzzy set. Then the IF-THEN rules were used to specify what should be done when some conditions were met. The result from the simulation showed that the system could make handover decision between UMTS and WiMAX and manage network resources. The system design does not consider the type of service (voice or streaming) being accessed by the user before a handover is intiated.

Gita Mahardhikaet al (2015) worked on vertical decision algorithm using multi-criteria metrics in heterogeneous wireless network. In their work three wireless networks are considered WLAN, WiMAX and 3G network. The proposed model was simulated using MATLAB. Network metrics used include RSS, Mobile velocity, Traffic class, Network occupancy. They compared equal priority multi-criteria, mobile priority multi-criteria and network-priority multi-criteria. Their result showed that network priority multi-criteria method has the best performance in terms of balance index and average blocking probability compared to equal priority and mobile priority. *The work did not compare TOPSIS ranking approach with other multi-criteria method to know the reliability of TOPSIS method.

MsAshimaet al(2014) worked on fuzzy rule based vertical handoff decision strategies for heterogeneous wireless networks. In their work , an intelligent wireless selection model was designed using fuzzy logic. Wireless network used include UMTS, WiMAX and WLAN. The model used TOPSIS algorithm technique for ranking the wireless networks and analytic hierarchy process to assign weight to each criteria Network parameter used include bandwidth, end to end delay, jitter, Bit Error Rate(BER). From their result the proposed scheme showed better performance in terms of minimized handovers.

Asthana et al(2012) worked on vertical handoff operation in fourth generation wireless networks. A fuzzy logic based vertical handoff was designed for handover decision between UMTS and WLAN network. Network selection decision process was designed as a multi attribute decision model for UMTS and WLAN. The wireless network selection function(WNSF) was used to generate performance evaluation value (PEV) for each of the networks. Parameters used for wireless network selection function (WNSF) include RSS, Data Rate, Service Cost, Reliability , Battery power, security, Mobile velocity, network latency. This work did not consider situations where more than two wireless networks of different standards are present in an environment.

3. SIMULATION METHODOLOGY

To obtain performance results, the handover model was simulated using MATLAB. There are four stages involved in the simulation (i) Collection of network parameter which include the RSS , Data Rate, Network Coverage Area and the Mobile velocity (ii) This parameters are supplied into fuzzy logic system which gives crisp output or handover value which helps to decide when the mobile nodes needs to handover(iii) The use of TOPSIS multi-criteria decision is to rank the wireless networks based on the network metrics(RSS, MV, Data Rate, Coverage area) supplied to it. (iv) The system is evaluated s based on time of handover and Performance evaluation value of each network . The wireless networks considered in this work are WLAN, and 3G (UMTS), WiMAX, 4G LTE .

The handover simulation is divided into three parts (i) Network Discovery (ii) Handover Decision (iii) Handover Execution.

3.1 Network discovery

In the process of network discovery the mobile device searches for all reachable wireless networks (WLAN, UMTS, WiMAX, 4G-LTE) in the environmentand obtain their current data rate, received signal strength, coverage area. All these parameters are supplied into the fuzzy logic system along with the device's mobile velocity. .

3.2 Handover Decision

The handover decision is done using fuzzy logic and the four parameters used as crisp input are receive signal strength of the current network, Data Rate, Coverage Area and mobile velocity of the mobile terminal. These four parameters are fuzzified using triangular membership function to obtain the required fuzzy set (Low , medium and high). The final crisp output is a called the handover factor which is used to decide when there is need to handover from the current network to a new network.

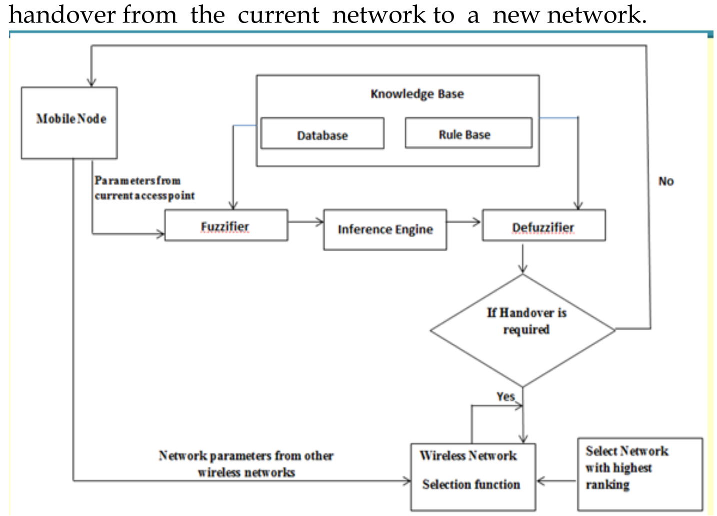

Fig 3.1: Block diagram for vertical handover:AdaptedfromAsthanaet al.(2012)

The above diagram shows the vertical handover decision model using fuzzy logic. In homogeneous network when a mobile user is on the move, the RSS either decreases or increases. When it increases there is no need for handover because the signal power is enough to carry out transmission successfully. But in an heterogeneous wireless network more parameters need to be considered such as data rate, coverage area of network, mobile velocity before a handover decision is taken. In order to prevent disconnection from base station, an intelligent vertical handover decision model was designed using fuzzy logic.

Fuzzificiation: The four parameters used to design the handover model are received signal strength (RSS), Data Rate(DR), Coverage Area (CA) and mobile velocity (MV). These four parameters are fuzzified using a triangular membership function. These values are imprecise and they vary depending on the condition of the wireless networks.These crisp inputs can also be called linguistic variables, where C_i represents the fuzzy sets used for the networksN_i, a represents the range of values for each network parameter and $\mu_{Ci}(a)$ denotes the membership function of a in the set C_i. The input values of network parameters N_i are mapped to values within [0,1] with fuzzy setC_i by using a triangular membership function

$$F(C_i, x, y, z) \quad (1)$$

In heterogeneous wireless networks, multiple wireless networks are represented by N_i where i = 1,2,…n

$C_i = \{C_i, \mu_{Ci}(a)) \mid \mu_{Ci}(a) \in [0,1]\}$ where i = 1,2,…m

$C_i$represents the fuzzy set used for the networks

a represent range of values for each network parameter

$\mu_{Ci}(a)$denotes the membership function of a in the set C_i

The values of network parameters $C_i$are mapped to values within [0, 1] with a triangular membership function F(C_i, x, y, z).

where x is the minimum and z is the maximum of the linguistic parameters and y is the core value of the fuzzy set C_i. Each of these parameters is described with one of the following linguistic terms: x is low, y is medium and z is high.

$$F(C_i; x, y, z) = \left\{\max(\min\left(\frac{C_i - x}{y - x}, \frac{z - C_i}{z - y}\right), 0)\right\} \quad (2)$$

Inference Engine: The fuzzy sets are fed into a fuzzy inference engine where a set of IF-THEN rules is applied to obtain fuzzy decision sets. The outputsof fuzzy decision sets are sent into defuzzier for defuzzification. Then values are converted into crisp outputs which is referred to as handoff factor.

3.3 Fuzzy Rules Used For the HandoverDecision

There are four input variables, Receive Signal Strength, Data Rate, Mobile Velocity and Coverage Area. Three fuzzy sets are described for each fuzzy variables, the maximum possible number of rules in the rule base for handover decision is 3^4= 81. The fuzzy rule base contains IF-THEN rules such as:

(1) If RSS is low and Mobile velocity is low and Coverage Area is Low and Data Rate is Low Then Handover factor is high

(2) If RSS is low and Mobile velocity is low and Coverage Area is Medium and Data Rate is Low Then handover factor is high

(3) If RSS is low and Mobile velocity is low Coverage Area is High and Data Rate isLow Then handover factor is high

(4) If RSS is Low and Mobile velocity is Medium and Coverage Area is Low and Data Rate is Low Then handover factor is high.

(5) If RSS is high and Mobile velocity is medium and Coverage Area is Medium and Data Rate is high then handover factor is medium.

3.4 SampleFuzzySetusedformodelingNetworks

TheMembershipfunctionfor“3GRSS”

$$Low(x) = \begin{cases} \frac{-(0.29x+24.8)}{10}, & -120 < x < -85 \\ 0, & x \geq 0 \end{cases} \quad (3)$$

$$Medium(x) = \begin{cases} 0, & x < 0 \\ \frac{(0.36x + 32.4)}{5}, & -90 \leq x \leq -85 \\ 1, & x \leq 76 \\ \frac{-0.45x - 29.25}{5}, & -76 < x < -65 \\ 0, & x > 0 \end{cases} \quad (4)$$

$$High(x) = \begin{cases} \frac{0.25x+17.5}{5}, & -70 \leq x \leq -51 \\ 0, & x > -51 \end{cases} \quad (5)$$

TheMembershipfunctionfor“WLANRSS”

$$Low(x) = \begin{cases} \frac{-(0.33x+29.7)}{5}, & -90 < x < -75 \\ 0 & , \quad x < -90 \end{cases} \quad (6)$$

$$Medium(x) = \begin{cases} 0, & x < 0 \\ \frac{(0.25x+20)}{5}, & -80 \leq x \leq -75 \\ 1, & x \leq -60 \\ \frac{-(29.7+0.66x)}{10}, & -55 < x < -45 \\ 0 & , \quad x > 0 \end{cases} \quad (6)$$

$$High(x) = \begin{cases} \frac{0.2x+11}{5}, & -55 \leq x \leq -30 \\ 0 & , \quad x > -30 \end{cases} \quad (7)$$

The Membershipfunction for "4G LTE RSS"(-150)-(-90)db

$$Low(x) = \begin{cases} \frac{-(0.25x-32.5)}{5}, & -150 < x < -130 \\ 0 & , \quad x < -150 \end{cases} \quad (8)$$

$$Medium(x) = \begin{cases} 0, & x < 0 \\ \frac{(0.5x+60)}{5}, & -120 \leq x \leq -115 \\ 1, & x \leq -110 \\ \frac{-0.5x-50}{5}, & -105 < x < -100 \\ 0 & , \quad x > 0 \end{cases} \quad (9)$$

$$High(x) = \begin{cases} \frac{0.27x+30.24}{6}, & -112 \leq x \leq -90 \\ 0 & , \quad x > -90 \end{cases} \quad (10)$$

The Membership function for "Wimax Receive Signal Strenght" (-90)-(-50) db

$$Low(x) = \begin{cases} \frac{(-0.25x-17.5)}{5}, & -90 < x < -70 \\ 0 & , \quad x \leq -90 \end{cases} \quad (11)$$

$$Medium(x) = \begin{cases} 0 & , \quad x < 0 \\ \frac{(0.6x-45)}{3}, & -75 \leq x \leq -72 \\ 1, & x \leq -70 \\ \frac{-0.6x+39}{3}, & -68 < x < -65 \\ 0 & , \quad x > 0 \end{cases} \quad (12)$$

$$High(x) = \begin{cases} \frac{0.6x-27}{15}, & -60 \leq x \leq -50 \\ 0 & , \quad x > -50 \end{cases} \quad (13)$$

Defuzzification: The fuzzy decision sets are converted into a single crisp output or handover factor with the use of centroid function is given as follows

$$Z = \frac{\sum_{i=1}^{n}(\alpha_i, y_i)}{\sum_{i=1}^{n}\alpha_i} \quad (14)$$

where Z is the crisp value and can be used for decision making, n represents the number of rules, α_i is the fuzzy antecedence of each rule and y_i is the consequent of each rule.

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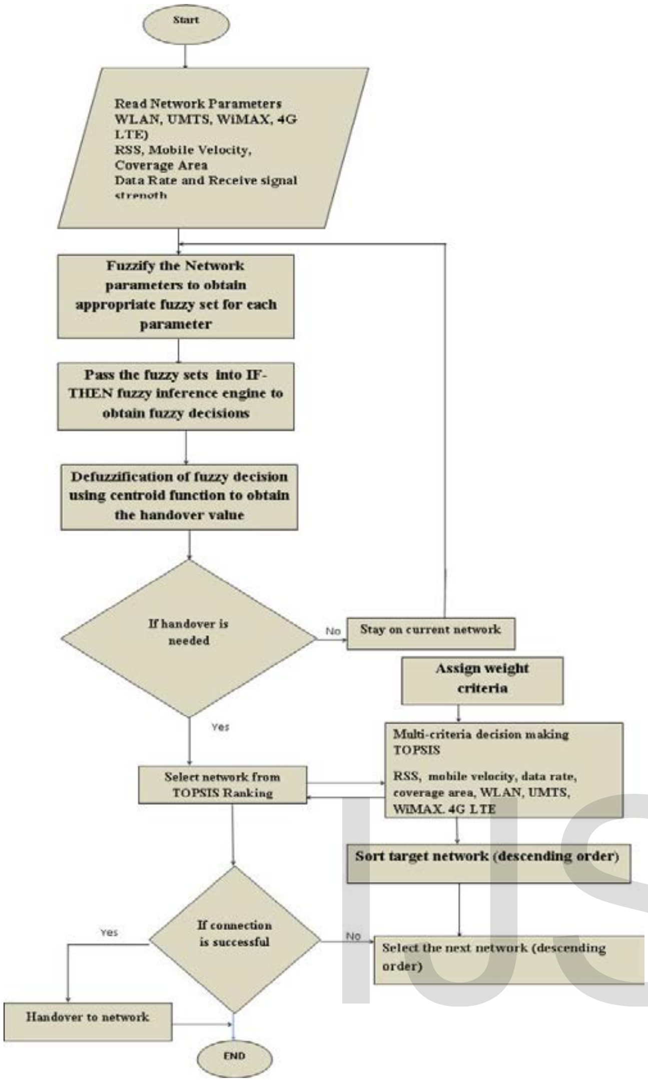

Figure 3.1: Handoff Decision Flow Chart

3.5 Network Selection Process

Step1

For each wireless network criteria value d_{ij} is generated. The criteria used include Received signal strength, mobile velocity, coverage area and data rate of each wireless network these values are arranged in matrix form. D_{ij} represents the matrix generated from the values received from the networks N_i with respect to the different criteria C_i.

$$D_{ij} = \begin{array}{c} \\ N_1 \\ N_2 \\ \vdots \\ N_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_m \end{array} \\ \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1m} \\ d_{21} & d_{22} & \cdots & d_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{nm} \end{bmatrix} \end{array} \quad (15)$$

N_1, N_2,...,N_1 represents the available wireless networks in that environment.

Step 2

The weight assigned to criteria depend on how much importance is attached to them. This helps to form a weighted decision matrix by multiplying each decision value in D_{ij} with the associated weight.

$$U_{ij} = D_{ij}(.)W_i \quad (16)$$

The sum of the weight should be equal to one

Step 3

This decision matrix is then normalized to form a normalized decision matrix. The normalization is done by each dividing each value in the matrix by the sum of square of values in its column. This helps to bring the various criteria scale into a comparable scale.

$$U_{norm} = \frac{d_{ij}}{\sqrt{\sum_1^n d_{ij}^{\;2}}} \quad (17)$$

Step 4

The normalized weighted decision matrix is further processed to obtain positive ideal solution. The maximum positive value in each column is selected and grouped to form a set of positive ideal solutions.

$$\{U^+\}_j = (U_1^+, U_2^+, \ldots, U_n^+) \text{ where } U_j^+ = \max(U_{ij}),\ j = 1,2,\ldots n \quad (18)$$

Also the normalized weighted decision matrix is further processed to obtain negative ideal solution. The maximum negative value in each column is selected and grouped to form a set of negative ideal solutions.

(19)

$\{U^-\}_j = (U_1^-, U_2^-, \ldots, U_n^-)$ where $U_j^- = \min(U_{ij})$, j = 1,2,…n

Step 5

The distance of each alternative from positive ideal solutionis obtained with this formula

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(U_{ij} - U_j^{+})^2} \quad (20)$$

While the distance of each alternative from negative ideal solution is obtained with this formula

$$d_i^- = \sqrt{\sum_{j=1}^{n}(U_{ij} - U_j^{-})^2} \quad (21)$$

Step 6

The network ranking is done by using the value of closeness coefficient CC_i. This closeness coefficient is obtained from the values generated in step 5 using this formula.

$$CC_i = \frac{d_i^-}{d_i^- + d_j^+} \quad (22)$$

4.0 Result and Discussion of the Simulation

1. Handover Time
2. Number of Handover Nodes

Table 4.1 : Wireless Network Parameters

Wireless Networks	Received Signal Strength(dB)	Mobile Velocity (m/s)	Coverage Area	Data Rate
WLAN	(-90) – (-30)	0.01- 5.00	5 - 32 Meters	2 - 55 Mbps
3G (UMTS)	(-120) – (-50)	10 – 160	10 - 35 Km	60-2000Kbps
WiMAX	(-85)-(-50)	10-60	10 -45Km	5- 70Mbps
4G LTE	(-120-(-90)	10-160	10 - 50km	3- 100Mbps

Table 4.1: shows the parameters used for this simulation. This include received signal strength, mobile velocity, coverage area, data rate with their respective values. The networks involved are 3G Network (UMTS), WiFi, 4G LTE, WiMAX. In this research work a handover decision model was developed using fuzzy logic and network selection was developed using TOPSIS algorithm.

Table4.2: Rule Base for Fuzzy Decision

	RSS`	Data Rate	Mobile Velocity	Coverage Area	THEN	HANDOVER FACTOR RANGE {0, 1}	DECISION
1	L	L	L	L	THEN	Handover Factor = High	HANDOVER
2	L	L	L	M	THEN	Handover Factor = HIGH	HANDOVER
3	L	L	L	H	THEN	Handover Factor = HIGH	HANDOVER
36	M	M	H	M	THEN	Handover Factor = MEDIUM	Stay on Network
37	M	M	L	M	THEN	Handover Factor = MEDIUM	Stay on Network
36	M	H	L	M	THEN	Handover Factor = MEDIUM	Stay on Network
80	H	H	H	M	THEN	Handover Factor = LOW	Stay on Network
81	H	H	H	H	THEN	Handover Factor = LOW	Stay on Network

Table 4.2 show the fuzzy rule based used to design the handover decision model. The total rule used for the model is 81. The fuzzy set is 3 while the input parameters are 4. 3^4 = 81 rules.

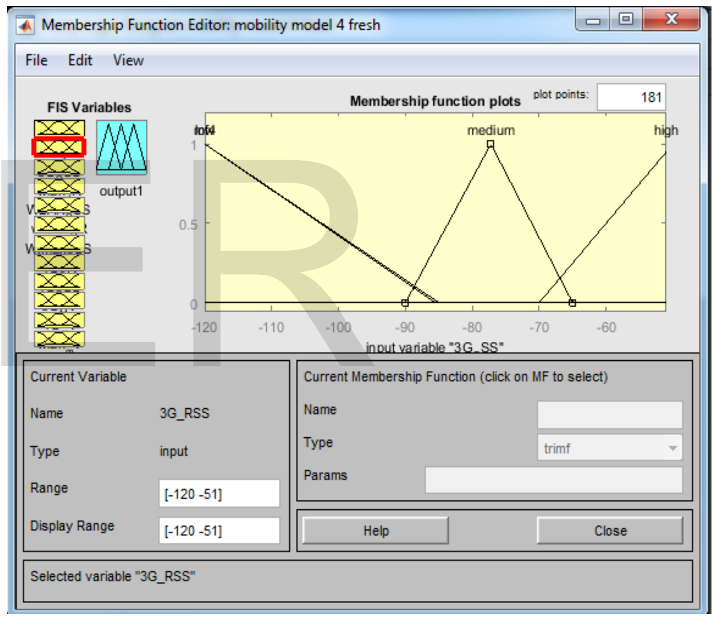

Fig 4.1: Fuzzy Input and output Membership Function

Fig4.1 shows a pictorial representation for the membership function of 3G received signal strength

Table 4.3: Handover Result for 500 Nodes

Wireless Network	Number of handover Nodes	Average TOPSIS Value	Average Handover Time
UMTS	22	0.3942	0.00362
WIFI	14	0.3599	0.00360
4G	63	0.4998	0.00364
WIMAX	20	0.3629	0.00369
Total Number of handover	119		

Table 4.3 shows the first simulation. The number of nodes used was 500 to test the algorithm and 119 nodes handed

over to different networks as shown in the table. The result shows that 4G LTE has thehighest number of nodes whileWiFi has the least number of nodes after handover. This is due to the small coverage area of WiFi and it does not support users moving at high velocity.

Table 4.4: Handover Result for 1000 Nodes

Wireless Network	Number of handover Nodes	Average TOPSIS Value	Average Handover Time
UMTS	34	0.3484	0.00368
WIFI	23	0.3400	0.00362
4G	57	0.4080	0.00367
WIMAX	97	0.5064	0.00370
Total Number of handover	211		

From Table 4.4: The number of nodes used to test the algorithm is 1000 and 211 nodes handed over to different networks as shown in the table . The table shows increase in average handover time with respect to increase in the number of handover nodes.

Table 4.5: Handover Result for 2000 Nodes

Wireless Network Selected	Number of handover Nodes	Average TOPSIS Value	Average Handover Time
UMTS	73	0.4030	0.003683
WIFI	51	0.3469	0.003632
4G	94	0.3558	0.003690
WIMAX	232	0.4848	0.003720
Total Number of handover	452		

From Table 4.5: The number of nodes used to test the algorithm was 2000 nodes and 452 nodes handed over to different networks as shown in the table. The average handover time increases with increase in the number of nodes but the average TOPSIS value varies depending on the condition of the network at the point of handover. WiMAX, 4G LTE, 3G (UMTS) have more nodes after handover because of their wide coverage area which supports users moving at high or low velocity.

Table 4.6: Handover Result for 5000 Nodes

Wireless Network Selected	Number of handover Nodes	Average TOPSIS Value	Average Handover Time
UMTS	232	0.3959	0.003686
WIFI	140	0.3559	0.003650
4G	493	0.4863	0.003710
WIMAX	229	0.3645	0.003740
Total Number of handover	1094		

From Table 4.6: The number of nodes used to test the algorithm was 5000 nodes and 1094 nodes handed over to different networks as shown in table 4.6. 4G LTE has the highest number of nodes after handover followed by WiMAX and the least is WiFi.

Table 4.7 : Handover Result for 10000 Nodes

Wireless Network Selected	Number of handover Nodes	Average TOPSIS Value	Average Handover Time
UMTS	437	0.3925	0.00371
WIFI	200	0.3471	0.00368
4G	541	0.3622	0.003736
WIMAX	1024	0.4879	0.003800
Total Number of handover	2202		

From Table 4.7: The number of nodes used to test the algorithm was 10000 nodes and 2202 nodes handed over to different networks as shown in the table. WiMAX has the highest number of nodes after handover followed by 4G LTE and WiFi has the least.

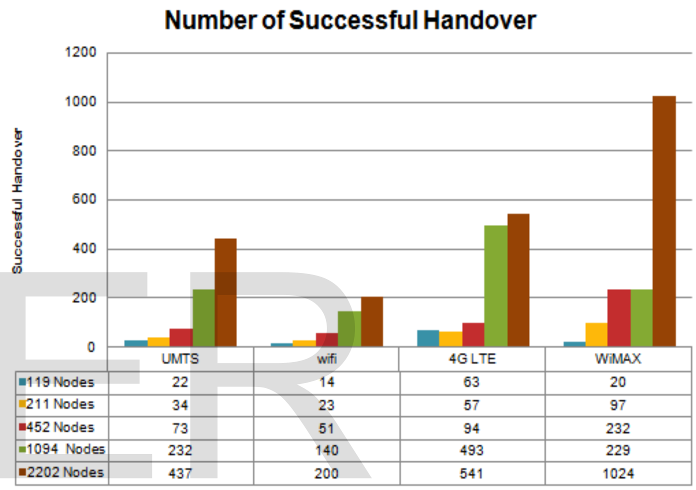

Fig4.2 : Successful Handover

The result in fig 4.2 shows that with increase in number of nodes increase also leads to increase in number of handover. The handover is done base on network capacity in terms of coverage area, data rate, RSS and mobile velocity of the nodes.

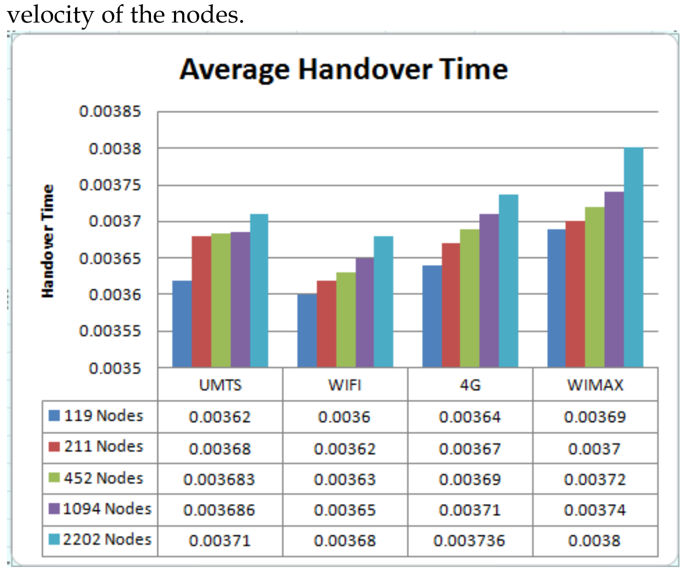

Fig 4.3: Average Handover Time

The result for average handover time for simulation with different number of nodes. The handover time is the time taken to connect to a new access point.

4 CONCLUSION

The simulation results show better performance for the handover model in terms minimized handover time and the selection of network with the best performance evaluation value when handover is needed. The fuzzy logic decision model was able to initiate handover when it is needed and the TOPSIS algorithm was able to select network with the best performance during the simulation. This will helpin the interoperability of wireless networks of different standards.

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