Selection of parameters & assigning weight using fuzzy method for mobility management

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Abstract:
Today's wireless networks are equipped to deliver high-speed, secure services. It is essential that multiple types of networks based on diverse technologies be linked together in order to create a heterogeneous wireless environment where a user can move around freely while connected to the network that best suits their service and connection demands. As a result, wireless service providers will be able to provide users with the highest level of service and seamless connectivity.In such a setting, effective handoff is the primary necessity for enabling seamless connectivity and mobility. Appropriate parameters must be selected in order to make a successful handoff choice.In diverse wireless settings, smooth and competent handoff mechanisms are critical for achieving optimal network performance. The design and elements of the multi-attribute edge-computing framework for mobility management are covered in this paper. The suggested system selects a number of parameters and constructs their priority vectors using the Fuzzy Analytic Hierarchy Process (FAHP).
Keywords: Handoff; Handoff Parameters; Handoff Phases; RSSI, BER,BW.
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1. Introduction

The need for users to stay connected and to receive the highest quality services is rapidly increasing, so it is essential for service providers to work on the integration of heterogeneous wireless networks and develop the most efficient solutions to guarantee that the user is always best connected while on the move and enjoys the best services available[1]. Today, flawless network communications are necessary to provide high-quality services.This is only conceivable with the integration among several network access technologies, namely WLAN, WiMAX, third generation (3G), and fourth generation (4G) cellular networks, etc. In such a setting, handoff—the procedure by which a Mobile Node (MN) switches from one network to another—is crucial.[2]

Switching from one wireless cell to another by an MN is referred to as a handoff or handover. The two different handoff styles are horizontal and vertical.[3] A horizontal handoff occurs between BSs using the same type of wireless network interface, whereas a vertical handoff occurs between BSs using different wireless network interfaces. [4]Access points are the name given to the BSs in WLANs (APs). There are many variables that can be considered in order to maximize the success of the handoff, including throughput and grade of service (GoS). Determining when and how to execute this handoff is aided by the handoff policy. [5].With the use of MCDM approaches, numerous studies on network selection have been carried out over time. However, very few research took into account more than just parameters. This study makes a good effort to provide a model that selects the optimal network by considering a number of attributes.[6]

The requirements for the handoff method in heterogeneous networks should be considered when designing the algorithm, and they are as follows:

a) The handoff procedure should be dependable and effective;
b) The number of handoffs should be kept to a minimum as too many handoffs result in signal quality degradation, increased traffic dropping probability, and additional loads on the network;
c) The handoff procedure should be quick and its delay should be as short as possible;
d) The number of handoffs should be kept to a minimum as too many handoffs result in signal quality degradation, increased traffic dropping probability, and additional loads on the network. Fast MS should continue to be connected to CDMA because WLAN is designed for low-velocity MS and anticipates a small coverage area (100 m).

2. Handoff Process

Three stages of this process are handoff initiation, handoff decision, and handoff execution w— are used to describe the full handoff procedure .Figure 1 displays several phases and handoff characteristics, techniques and considerations for initiation and control.[7]

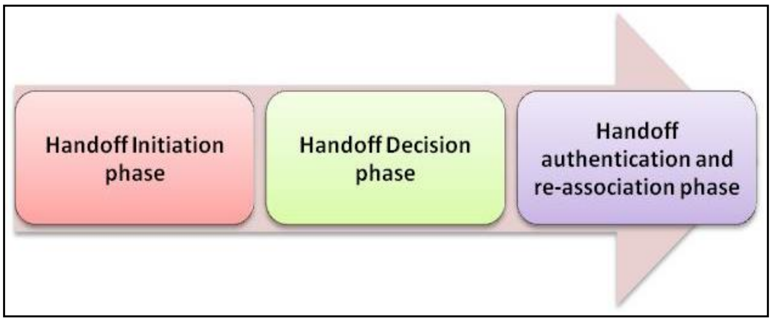

Figure 1: Handoff Process

Handoff Initiation Phase: During this phase, initial evaluation has been done whether handoff is required or not on the basis of detailed information of parameters like RSSI, network load, and power consumption,Bandwidth usage etc. which the researchers feels important.

Handoff Decision Phase: During this phase, the decision has to be made to switch to the new network if there are more than two networks are available.

Handoff authentication & re-association Phase: Following proper authentication and authorization, the mobile node is transferred to a new base station or network during this phase. It illustrates how data about surrounding network connectivity (including attributes like RSS, throughput, BER, CIR, etc.), the status of mobile devices (such as battery level, speed, etc.), and user preferences are acquired during the handoff (initiation) phase of a handoff (like budget and required services).

3. Parameters for selection

There are various parameters that are considered for handoff initiation and decision making in various categories:

Category	Parameters	Description
	RSSI	This criterion is most widely used. Especially in case of Line-of-sight (LOS) and limited interference systems, there the RSSI indicates the signal quality, and is accurate. As the distance between the increases, the RSSI value starts decreasing. As it falls below the minimum threshold, handoff is required.
	SINR	SINR is a metric associated with noise, interference, and signal strength. It is defined as the ration of signal to interference ratio. Its unit is also dBm but is different from RSSI. Lower value of SINR means low signal strength due to high interference.

Network Related	BER	The bit error rate is defined as the ratio between the number of bits in which error incurred during the transfer and the total number of transferring bits during a calculated time interval
	Retransmission	It is the process in which packets are retransmitted in case of lost frames, damaged frames or lost acknowledgement.
	Network Load	Network load is defined as the traffic or number of users connected to the network. If the load on the network is more; then it leads to overloading problems and hinders the performance of the network. It represents the ratio of allocated bandwidth of the total bandwidth.
	Network Coverage	The geographic area where the station can communicate
Quality of Service (QoS)	Bandwidth	Total capacity of the channel or frequency band available to or used by the communications channel.
	Packet Loss	Measures the average packet loss rate within the network.
	Delay	Interval between the packet arrival at the senders end and the packet reception time at the recipient.
	Latency	Time elapsed between the packets send and received during handoff, there are many messages which are exchanged among BS, MS and BSC which adds up to cause latency. It is the mean delay which is caused during handoff process.
	Throughput	The quantity of information or packets successfully transferred from a resource to a target is called throughput. It is measured in bps (bits per second.
Quality of Experience (QoE)	Cost per bit	Mobile users have become very smart and want full value for what they pay. They have their set of preferred qualities in a network related to quality, availability, reliability and maintainability. These sets of their preferences are called User preferences. For e.g. users preferred more secure network available at lower cost.
	Security	It is the process of protecting the network resources from unauthorized access to maintain confidentiality or integrity of the transmitted data. So during handoff network selection, priority may be given to a more secure network than the previous one.
	Battery Power	It is a sort of an electric power required for handoff process. Today in smart

		phones, if a mobile is running short of battery, then mobile can switch over to battery saver which consumes less battery. In case of handoff, a mobile user when running low for battery power, then it may switch to another network that would consume less battery
	User Experience	It means the experience of user in using different applications on the network.

4. Review of Literature

Various parameters have been considered by different researchers for their study. Following is the summary of previous work done

Author & Year	Method/Tool Adopted	Parameters considered	Critical Review		
			QoS	Real Time Scenario	Limitations
Guo et al. in [8][2020]	Ant Colony Optimization using Brute Force (BF) Algorithm	Cost Transmit Power Latency	X	X	More Intelligent schemes need to be incorporated.
Jha et al. in [9][2020]	Proposed IoTSim-Edge compared with other simulators	Network Communication Device Heterogeneity Device Movement Battery Features	X	X	Functionality of simulator needs to be tested in realistic environment.
Wan et al. in [10][2019]	Evolutionary Algorithms	Computation complexity Application Delay Power	X	√	Computational and storage constraints, scalability and security needs great attention.
Balasubramanian et al. in [11][2019]	Performance of a novel protocol "Connection Mode as a Service" (CMaaS)	Signalling cost Bandwidth efficiency	√	√	Availability of resources & its allocation needs better planning.

	is compared with DMM.				
Ryu et al. in [12] [2019]	Testbed of MEC servers using AWS services with wired & wireless backhaul.	No. of Mobile users Computational Overhead	X	X	Few topics were not explored like content storage and delivery Optimal planning and deployment of MEC Servers.
Fotouchi et al. in[13] [2019]	New architecture (MobiFog Handoff mechanism) is tested on Routing Protocol	Handoff delay Reliability	√	X	Update the parent list for optimum handoff is a challenge.
Lee et al. in [14][2019]	CloudSim and Edge CloudSim	No. of Mobile users Preference level	√	X	Add on Artificial Intelligence (AI) needs to be incorporated in case of frequent mobility of user node.
Zhang et al. in[15] [2019]	Simulating environment with experimentation in JAVA	Delay Handover Rate Movement of user	X	X	Further experimentation is required in realistic environment related to User' s path, behavior & prediction.

5. Proposed work

The previous research work done by experts shows that only a few parameters were considered for study and that too selected on random basis.[16] The algorithm proposed in this paper work in various phases to improve the quality of service to the mobile users and minimize the unnecessary handoffs.

Phase 1: Along with the previous work done by the researchers on various parameters, input from experts has also been sought to finalize the parameters. For this purpose, aQuestionnaire has been designed to get the input from 50 experts from the field of academia & industry to select theparameters from each domain i.e Network related, related with Quality of Service (QoS)and Quality of Experience (QoE).

S. No.	Parameters	Rating (1: Extremely Unimportant (EU), 2: Unimportant (UI), 3: Averagely Important (AI), 4: Important (IM), 5: Extremely Important (EI))				
		EU	UI	AI	IM	EI
Network Related						
1	RSSI (Received Signal Strength Indicator)					
2	SINR (Signal to Noise Ratio)					
3	BER (Bit Error Rate)					
4	Retransmission					
5	Network Load					
6	Network Coverage					
Quality of Service (QoS)						
1	Bandwidth					
2	Packet Loss					
3	Delay					
4	Latency					
5	Throughput					
Quality of Experience(QoE)						
1	Cost per bit					
2	Security					
3	Battery Power					
4	User Experience					

Table 1: Questionnaire to filled by experts

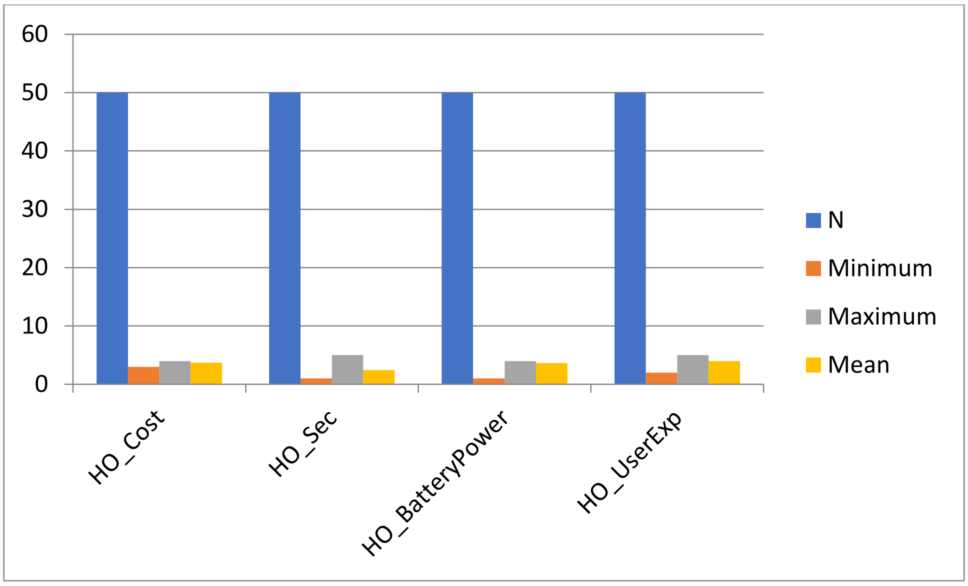

Figure 2:Network Related Parameters after expert Review

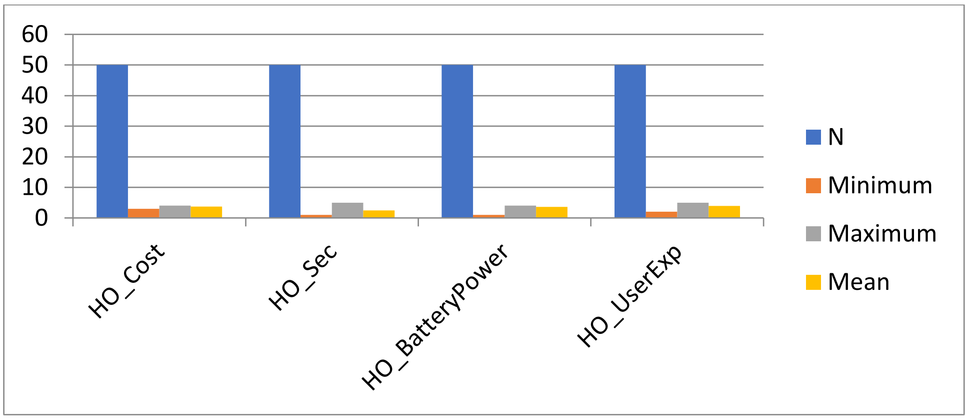

Figure 3:QoS based Parameters after expert Review

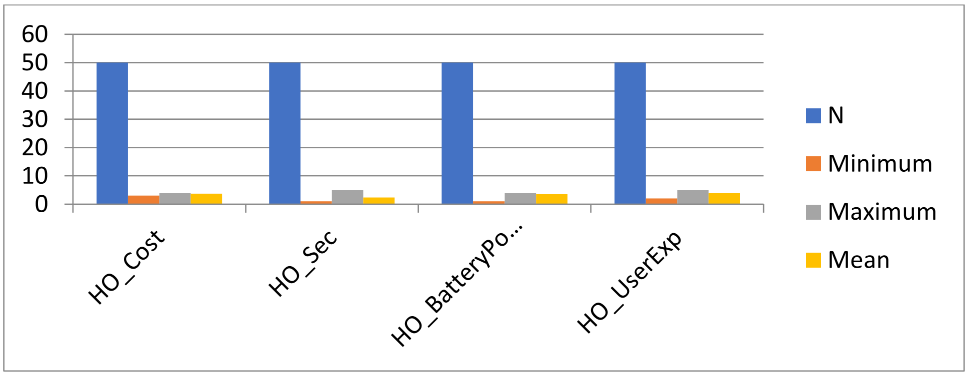

Figure 4 : QoE based Parameters after expert Review

Based on Likert scale ranking of importance, following parameters were shortlisted according to their mean score.

Network Related	RSSI & Network Load
Quality of Service (QoS)	Bandwidth & Packet Loss

Quality of Experience (QoE)	Cost & User Experience

Table 2: Selected Parameters after expert Review

Phase 2:Prioritize the Parameters according to Ranking

In this phaseMulti Criteria Decision Making (MCDM) approach has been used for decision making. MCDM refers to the process of choosing between options that have been determined based on a number of different available parameters. In this algorithm fuzzy based technique FAHP is used to determine the weights of all selected parameters.This technique is based on AHP (Analytic Hierarchy Process) which was developed by Thomas L. Saaty in early 1970s. It is a powerful tool based on 9-point scales and is used to assign weights to parameters selected for decision making[17]. This methodology eases decision makers to analyze the problem qualitatively and quantitatively in a simple hierarchical form.

Due to dynamic nature of real time scenario AHP becomes less effective and does not provide desired results. In this case, fuzzy systems are used to deal with ever changing values of all selected parameters. So a blended model of AHP &fuzzy set theory is used solve complex decision making problems. One of the method for FAHP was given by Buckley which use geometric mean method to calculate fuzzy weights. Table 3 depicts the triangular fuzzy numbers and the synthetic FAHP method.

Intensity of Importance	Definition	Explanation	Fuzzy triangular number (FTN)
1	Equal importance (EI)	Two activities contribute equally to the objective	1,1,1
3	Weak importance of one over another (WI)	Experience and judgment slightly favor one activity over other	2,3,4
5	Essential or strong importance (SI)	Experience and judgment slightly favor one activity over other	4,5,6
7	Demonstrated importance (VSI)	An activity is strongly favored and its dominance is demonstrated in practice	6,7,8
9	Absolute importance (EMI)	The evidence favoring one activity over another is of the highest possible order	9,9,9

Table 3: Definition and Fuzzy Triangular Number (FTN) of fuzzy scale

Following are the various steps for FAHP methodology:

Step 1: The language phrases presented in Table 2 are used by the decision maker to compare the criteria or alternatives. The linguistic definition displayed in Table 3 illustrates the relative strength of each dimension in relation to one another and assigns matching FTN to them. The FTN for one dimension will be (2,3,4) if the respondent rates it as being weakly more significant than the other dimension, and the FTN for the other dimension will be (1/4,1/3,1/2).

The pair-wise comparison matrix formed (eq. 1) where $a_i^k j$indicate the kthrespondentmakeschoice of it dimension over jth dimension.

$$\widetilde{A^k} = \begin{bmatrix} a_{11}^{\sim k} & \cdots & a_{1n}^{\sim k} \\ \vdots & \ddots & \vdots \\ a_{n1}^{\sim k} & \cdots & a_{nn}^{\sim k} \end{bmatrix} \quad (1)$$

Step 2: The pairwise matrix created in Eq. (1) describes each respondent's preference f pk ij, and these values (l, m, u) are aggregated to form pij, as shown in Eq (2)

$$\widetilde{a_{ij}} = \sum_{k=1}^{k} d_{ij}^{-k} / K \quad (2)$$

Step 3: Following the update of the pairwise values, an updated matrix P is generated, with each pij value regarded as a triplet.

$$\widetilde{A} = \begin{bmatrix} \widetilde{a_{11}} & \cdots & \widetilde{a_{1n}} \\ \vdots & \ddots & \vdots \\ \widetilde{a_{n1}} & \cdots & \widetilde{a_{nn}} \end{bmatrix} \quad (3)$$

Step 4: The geometric mean of a fuzzy evaluation matrix of each dimension is determined as follows:

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{a_{ij}}\right)^{1/n} \quad i=1,2,3............n \quad (4)$$

Step 5: Add the sums of the ri of the relevant dimensions.

Step 6: Find the inverse of the vector from and arrange the TFN in ascending order.

Step 7: To compute the fuzzy weight, multiply each ri by the reverse TFN value obtained in step 1.2.

$$\tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus .....\tilde{r}_n)^{-1} = (\mathrm{l}w_i, \mathrm{m}w_i, \ \mathrm{u}w_i) \quad (5)$$

Step 8: Using Eq, the de-fuzzy value of TFN is computed using the centre of area approach (6).

$$M_i = (lw_i + mw_i + uw_i)/3 \quad (6)$$

Step 9: Using Eq, normalise the non-fuzzy number.

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (7)$$

Applying FAHP on various Parameters

Following are the steps of calculating weight for each selected parameter:

Table 4 shows the pair-wise comparison matrix for network initiated handoff using fuzzy triangular numbers based on Saaty’ s scale.

Parameter	BW			RSSI			NL			PL			UE			Cost		
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
BW	1	1	1	2	3	4	4	5	6	1	1	1	6	7	8	1	1	1
RSSI	0.25	0.33	0.50	1	1	1	4	5	6	2	3	4	4	5	6	6	7	8
NL	0.17	0.20	0.25	0.17	0.2	0.25	1	1	1	1	1	1	2	3	4	1	1	1
PL	1.00	1.00	1.00	0.25	0.33	0.50	1	1	1	1	1	1	2	3	4	4	5	6
BP	0.13	0.14	0.17	0.17	0.20	0.25	0.25	0.33	0.50	0.25	0.33	0.50	1	1	1	2	3	4
BER	1.00	1.00	1.00	0.13	0.14	0.17	1.00	1.00	1.00	0.17	0.20	0.25	0.25	0.33	0.50	1	1	1

Table 4: Pair-wise comparison matrix

After applying the first three steps, we get the aggregated fuzzy evaluation matrix from the pair-wise comparison matrix. The geometric mean for each network parameter is computed by using eq. 5.4 and then geometric means of all parameters is computed and the summed and inverse of values is shown in Table 5.

Parameter	L	M	U	L	M	U
BW	1.906369	3.132603	3.464102	0.194348	0.371681	0.549985
RSSI	1.906369	2.365046	2.884499	0.194348	0.280611	0.457963
NL	0.778272	0.918386	1.069913	0.079342	0.108966	0.169867
PL	1.122462	1.30766	1.513086	0.114431	0.155153	0.240228
UE	0.370918	0.4604	0.588796	0.037814	0.054626	0.093481

Cost	0.21415	0.244118	0.288675	0.021832	0.028964	0.045832
Column Sum	**6.2985**	**8.4282**	**9.8091**			
Inverse Order	**0.1019**	**0.1186**	**0.1588**			

Table 5: Calculating Geometric mean

The computed fuzzy normalized weight for each parameter is given below in Table6.

Parameter	Fuzzy Nor. Weight
BW	0.348811
RSSI	0.291586
NL	0.111948
PL	0.159342
UE	0.058109
Cost	0.030201

Table 6: Normalized fuzzy weights

Now all these parameters with the above mentioned weights can be used to decide the best network amongst the given options available.

6. Conclusion

The goal of the next generation heterogeneous networks is to offer mobile nodes seamless connectivity while taking into account the requirements and preferences of the user. The most crucial component of heterogeneous networks is mobility management, which must address issues like preventing needless handoffs, which frequently waste network resources and result in excessive power consumption and an imbalance in the traffic loads of the associated networks. The authors of this paper have put forth an algorithm that can aid in resolving handoff-related problems and boosting system effectiveness. The amount of parameters that need to be compared has been significantly expanded, and the application-aware environment's throughput will significantly increase. With the use of FAHP, fuzzy based weights are applied to produce accurate handoff decisions.

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