Network Selection in Heterogeneous Wireless Environment using Computationally Reduced Fuzzy Rule Base System

P. Aruna Kumari, I. Santi Prabha

Abstract--- ***The number of mobile subscribers has been increasing at a faster pace every year. This has imparted the need on the part of network operators to provide continuous and seamless mobility with the aim "Anywhere, Anytime" services to the users. Designing a proper handoff mechanism and its implementation is the important factor to provide ubiquitous data services. A new network selection algorithm in case of heterogeneous network environment for taking handoff decision has been proposed and implemented using Fuzzy Logic. The limitation of using Fuzzy Logic for increased network metrics consideration has also overcome by using Dominant Rule Determination. Fuzzy Rule Base system with reduced complexity is developed and evaluated. The network with highest handoff score value obtained from the fuzzy system output is chosen for executing better Quality of Service (QoS) handoff.***

Keywords—heterogeneous; handoff decision; Fuzzy Logic; Fuzzy Rule Base; handoff score; QOS.

1. INTRODUCTION

The last few years have witnessed a phenomenal growth in the wireless industry, both in terms of mobile technology and its subscribers. The integration of cellular and wireless networks is the growing trend in next generation networks. This is made possible using handoff techniques for providing seamless mobile connection, despite the location and mobility of users. The acquaintance to such techniques and the proposal of a better way to implement them are necessary to ensure Quality of mobile communication. The objective of mobile communications is to provide a truly *Anytime, Anywhere* communication. Today mobile is providing voice, messaging and a number of data services to users like real time TV, online payments of utility bills, m-commerce, news, entertainments etc. Both the mobile network operators and vendors have felt the importance of efficient networks with equally efficient design. This resulted in network planning and optimization related services coming in to sharp focus. Next generation networks with 5G technology are envisaged as a multitude of heterogeneous systems interacting through an IP-centric architecture.

Vertical handoff or heterogeneous handoff is defined between two points of access of two networks with different access technologies [1]. To perform good quality handoff, a handoff algorithm requires consideration of multiple network metrics as mentioned in [2], [3]. Selection metrics corresponding to each network in heterogeneous environment includes Received Signal Strength, Signal to Interference noise ratio, Available bit rate, Cost of the network, Throughput and Bit Error Rate, Jitter and many more. Handoff algorithms with very less decision times leads to repetitive handoffs and with delayed decision times may result in call terminations before handoff is executed. So, in the complete handoff process, handoff decision is an important phase and decision algorithms are developed using these network selection metrics.

2. Related Work

A review study on decision making algorithms is proposed in [4], for vertical handoff process. Network selection mechanism for vertical handoff in heterogeneous networks using dynamic weight setting is proposed in The scheme utilized Multi-Attribute Decision making method for determining handoff cost function. In Conventional approach, the imprecision in the attributes for handover decision cannot be handled by analytic network processes. Incorporating fuzzy logic with multiple attributes decision making algorithm handles these attributes by converting them to linguistic variables.

Numerous studies considered selection of the best network using vertical handoff decision function based on fuzzy as mentioned herein. Fuzzy logic-based implementations help in generating the outputs as per user requirements by providing a scope to give linguistic rules. The base for adopting a Fuzzy rule-based algorithm for optimum network selection taking into consideration the QoS parameters has been explained in [5]. Selection algorithm based on hierarchy analysis and fuzzy evaluation presented in obtained handoff score value to select the access network. Fuzzy logic with two metrics - RSS indication and relative direction of mobile node is implemented to achieve handover latency reduction in [6].

In decision making, fuzzy logic method uses multi attributes decision making or multi criteria method out of which TOPSISs [7] has several advantages. Though fuzzy logic has many advantages over other algorithms, the complexity of such a fuzzy system increases when the number of parameters considered for handoff increases. The idea for reducing such a larger fuzzy rule base to normalized rules by considering active rules has been mentioned in [8].

Revised Manuscript Received on February 11, 2019.

Ms. P. Aruna Kumari, Electronics and Communication Engineering, Asst. Professor, GVPCE(A), Research Scholar, JNTUK, Kakinada, India. (hiaruna4u@gmail.com)

Dr. I. Santi Prabha, Electronics and Communication Engineering, Professor and Rector, Jawaharlal Nehru Technological University, Kakinada, India. (santi.prabha@yahoomail.com)

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

In this paper, selection metrics considered corresponding to each network in heterogeneous environment are Received Signal Strength (RSS), Bandwidth (BW), Available bit rate (ABR), Bit Error Rate (BER) and Jitter. These Metrics serves as indicators to determine an alternate network when handoff is initiated.

Remaining sections of the paper is organized as follows. Section.3 gives handoff mechanism using fuzzy logic – original and compressed rule mechanisms. Section.4 projects actual implementation of the proposed mechanism – Handoff score evaluation for original and compressed Fuzzy Rule Base. Section.5 presents results and performance evaluation using surface view plots and finally Section.6 concludes the overall work presented in the paper.

3. HANDOFF MECHANISM USING FUZZY LOGIC

3.1. Proposed Network Selection Criteria

Since the capability of dealing with imprecise data and modeling nonlinear functions is built in as property, Fuzzy logic-based handoff algorithm is preferred in the network selection proposal. The advantages of using the proposed algorithm of selecting the optimum network using Fuzzy Tool box also ensures QoS aware handoff decisions [9] maintaining the prescribed quality of communication. The Fuzzy logic used here for taking handoff decision is a simple technique that involves decision taking accurately in case of imprecise data base available in real time scenarios. Fig.1 shows the proposed fuzzy based network decision system with reduced rule complexity using dominant rule determination.

At the time, the mobile node (MN) connected to any of the ith network in a heterogeneous wireless environment observes signal degradation, it has to chose an alternate network to handover the ongoing service. In scenario consisting of n-available networks, choosing which network to handover is a crucial task. Fuzzy system with fuzzy rule base is used for taking handoff decision. Efficiency of handoff decision depends on multiple attributes of the network.

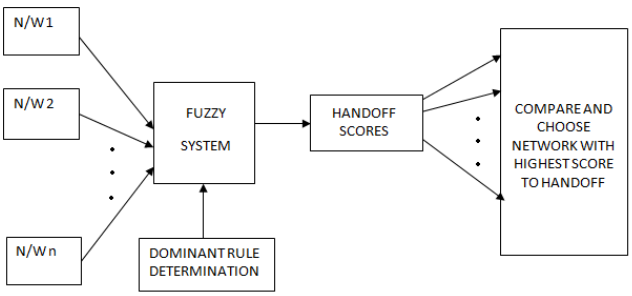


Fig.1. Fuzzy based network selection with dominant rule determination.

But increased number of attributes requires more fuzzy rule combinations which increases the fuzzy system complexity. Dominant rule reduction mechanism applied to fuzzy rule base reduces the complexity of the system in finding out the handoff score to each available network. Finally, handoff is executed to the jth network which scores maximum value.

3.2. Handoff Mechanism using Fuzzy Rule Base

The proposed FRB algorithm uses Fuzzy Inference system created using MATLAB for taking handoff decisions. Five QoS parameters have been considered namely Bandwidth, RSS, E2E delay, Jitter, BER as inputs to the Fuzzy Inference System. The handoff score is taken as output of the FIS. The FIS uses membership functions of values low, medium and high. So, depending upon the input combinations, the handoff score is calculated for the given network. This is done with the help of If-Then rules given to the FIS which mention the outputs for different input combinations. This is called Fuzzy Rule base.

Three networks namely, Cellular, Wi-Fi, WIMAX are considered for vertical handoff. So, for three networks, the three handoff scores are calculated using Fuzzy Tool box in MATLAB. Hence the mobile selects the best network with the highest handoff score value and switches to it.

It is important to note that the rule base differs for different applications. The algorithm has been extended to take vertical handoff decision to select the optimum network depending on the application like voice or data. This is because, for example, BER and bandwidth for conversational application need not be low. However, the E2E delay and jitter should be always low and RSS should be high. Whereas for data-based applications, jitter should be low, E2E delay may be medium, Bandwidth should be high. So, the rule base differs for different kind of applications.

3.3. Fuzzy Rule Reduction using Dominant Rule determination

The main limitation of using FRB systems is that the complexity of the system increases when the rules increase. Generally, handoff is a dynamic process which involves many parameters. That is, in order to take an efficient handoff decision, a greater number of parameters should be considered. But as the number of input parameters increase, the number of rules in the rule base also increases. Such a large rule base makes the Fuzzy system complex to understand, interpret and debug.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

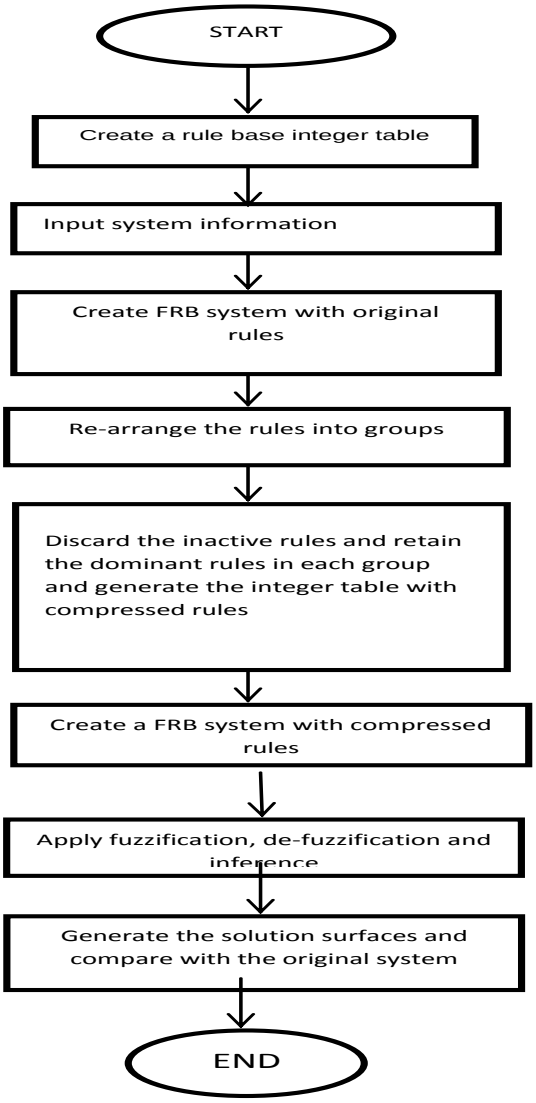


Fig.2. Fuzzy rule reduction using Dominant rule determination

This method compresses fuzzy system, with large number of rules into a smaller fuzzy system by removing the redundant rules in the fuzzy rule base. To overcome this limitation, a method for rule reduction has been proposed and implemented. This is named as Dominant Rule Determination method. This reduces the complexity of the Fuzzy system in case of a greater number of input parameters. The proposed algorithm in order to design an optimum network for QoS aware handoff decision is implemented in stage 1. Stage 2 is used to reduce the rule base so that an effective decision can be taken with a compressed rule base system. Total number of rules in FRB system = m^k for 'm' number of linguistic variables considered for each parameter and 'k' number of input parameters considered. In the system, five input and one output parameters are considered.

3.4. Stage 1 Implementation: Hanoff scores evaluation using Fuzzy Rule Base

Five input and one output parameters are considered. For every parameter, membership functions are created with three variables – Low, Medium and High. So, the total rules will be 3^5=243. However, bandwidth can be low even in the conversational application. So, BW is given none value and the remaining 81 rules are given in order to get the output score value depending upon the input parameters given in the rule viewer. Finally, for a given set of inputs measured at mobile node as mentioned in TABLE I, the handoff scores for all the three networks are obtained in TABLE II. Optimum network is selected for conversational application depending upon the highest score value.

Table I. Input parameters measured at mobile node – conversational class

BW	RSS	E2E ELAY	BER	JITTER
2Mbps	-50 dBm	57ms	0.06	5µs

Table II. Evaluated Handoff Scores for Three Networks

Network	CN	Wi-Fi	WIMAX
Handoff Score	50	77.3	81

For conversational application, the handoff score is highest for WIMAX for the given input values. So, the optimum network for the measured input values at the sampling interval is WIMAX. Though theoretically, cellular network is best suited for conversational, the availability of all the optimum parameters measured from the mobile node at a particular instant and location, take WIMAX as the best network in this case.

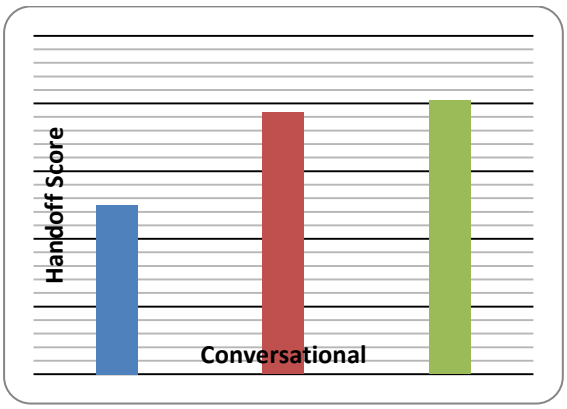


Fig.3. Handoff score value for 3 Networks for conversational application.

3.5. Stage 2 Implementation: Hanoff scores evaluation using Reduced Fuzzy Rule Base

The effectiveness of taking handoff decision increases if the number of parameters considered is more. But the complexity of a fuzzy system increases with number of parameters. Dominant rule determination used to remove inactive rules in a rule base reduces fuzzy system complexity and minimizes handoff decision time. The following steps are used to determine dominant rules as active rules in FRB.

1. There are 81 rules considered in the original system. These rules are grouped as monotonic rules (rules with same output value). So, we get 3 rule groups - Low, Medium and High handoff scores – shown in TABLE III.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

2. For every rule, firing strength is calculated using eq.1.

$$fs_i = \prod_{p=1}^{k} g_{pi} \quad (1)$$

Where fs_i = firing strength of ith rule

g_{pi} = membership grade for each parameter considered in i[th] rule.

3. Membership grade is determined using eq.2.

$$g_{pi} = \frac{v_{pi}}{v_{j\max(p)} - v_{i\min(p)}} \quad (2)$$

Where v_{pi} = input parameter value in i[th] rule. $v_{j\max(p)} - v_{i\min(p)}$ = range in the membership location mentioned in the rule for that parameter.

Sample rule base with calculated firing strengths is depicted in TABLE IV.

4. Rules having firing strength greater than the specified threshold are considered as active rules and remaining are discarded. This gives a new compressed rule base – depicted in TABLE V.

Active rules in each group

$$R_a = (R \in f_{si} \succ f_T) \quad (3)$$

Where f_T = firing threshold.

5. Comparison between output surfaces of original rule base and compressed rule base is performed for varying firing thresholds to evaluate the rule reduction technique. Depending upon the required degree of accuracy firing threshold can be fixed.

4. Results – Performance evaulation

Following are the obtained integer tables of original and compressed rule base systems based on their calculated firing strength values.

Table III. Integer Table with 81 Original Rules

Low	2,3,5,6,8,911,12,14,15,17,18,19,20,21,22,23,24,25,26,27,30,33,35,36,38,39,41,42,43,44,45,46,47,48,49,50,51,52,53,54,66,69,72,74,75,77,78,79,80,81
Medium	1,4,7,10,13,16,28,29,31,32,34,37,40,60,63,68,70,71,73,76
High	55,56,57,58,59,61,62,64,65,67

Table IV. Sample Rule base with calculated firing strengths

Rule No.	BW	RSS	ABR	Jitter	BER	Handoff score	fs_i
6	L	L	L	M	H	L	19.98
81	L	H	H	H	H	L	2.02
1	L	L	L	L	L	M	31.4
34	L	M	L	H	L	M	1.44
59	L	H	L	M	M	H	12.86
64	L	H	M	L	L	H	27.48

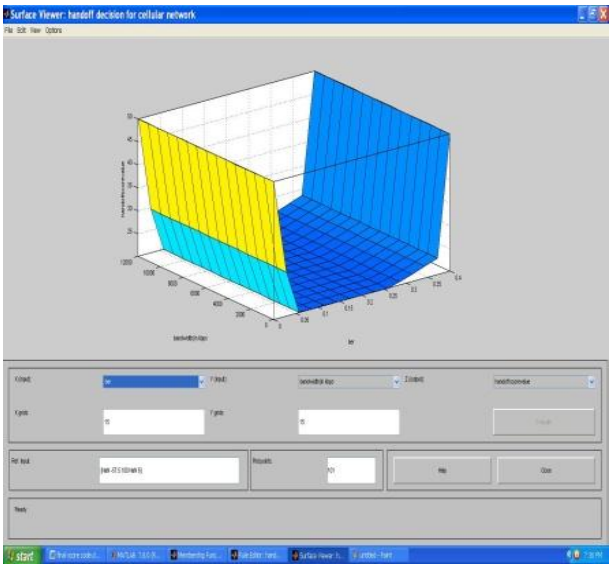
Table V. Integer Table With 55 Compressed Rules

Low	2,3,5,6,11,12,14,15,19,20,21,22,23,24,30,33,38,39,41,42,45,46,47,48,49,50,51,66,68,69,74,75,77,78
Medium	1,4,10,13,28,29,31,32,37,40,60,73,76
High	55,56,57,58,59,64,65,67

Fig.4 and Fig.5. depicts surface views generated for conversational application with 81 rules and 55 rules. These are used to evaluate the proposed rule reduction technique that generates the compressed rule base with the original rule base. Threshold of 10 generated 55 rules as active rules in the compressed FRB system with surfaces similar to original surface and the networks scoring similar handoff score values.

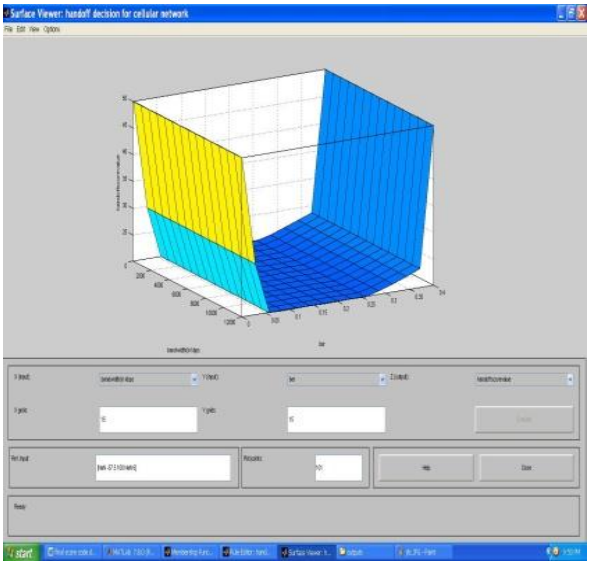
The algorithm is also implemented for data-based application i.e. for streaming. Bandwidth is now considered as active parameter, and hence the total rules in the original rule base are 243. Using dominant rule determination technique, the rules are reduced to 103. Network parameters are chosen at an instant as per 3GPP standards [10], [11] for the three networks and handoff scores are evaluated using the compressed fuzzy rule base obtained.

Handoff scores resulted for CN = 17.7, Wi-Fi = 41.7 and WiMAX = 23. Wi-Fi network is observed to have the highest score value for the input values measured at that instant at the mobile node and selected as alternative network to handoff from the current network. So, it should be noted that the optimum network is decided at any instant for handoff depending on the network parameters measured at that instant.



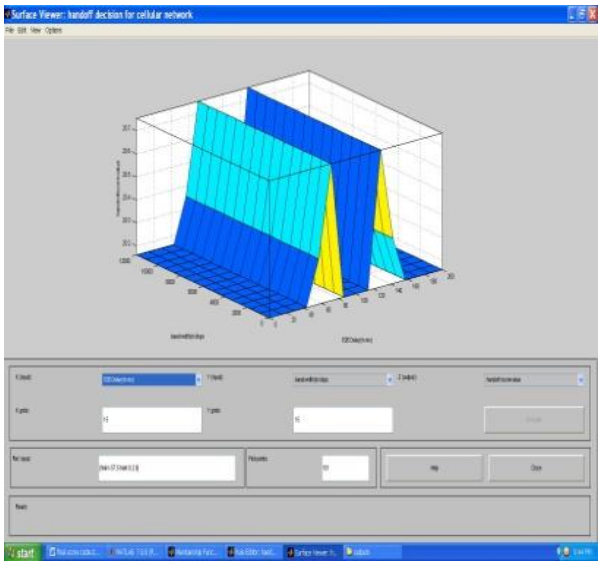
4.(a)

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

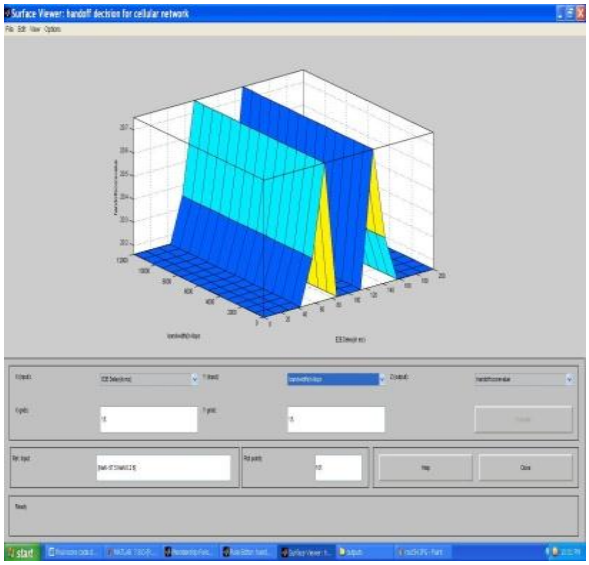


4.(b)

Fig.4.Surface view for original and compressed rule base – BER, BW and Handoff Score

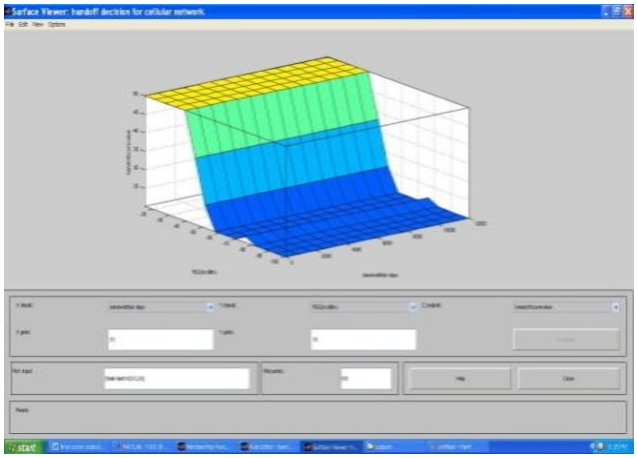


5.(a)

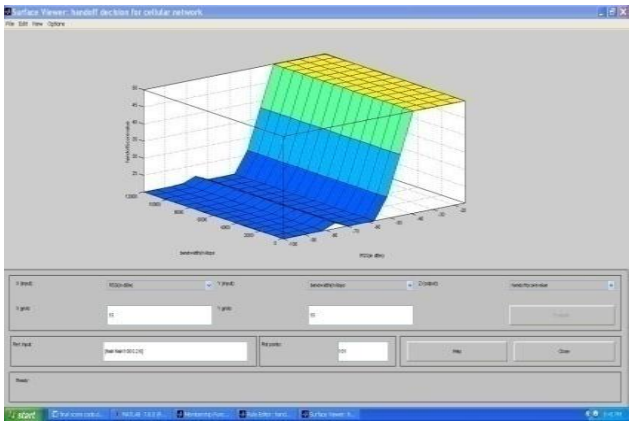


5.(b)

Fig.5.Surface view for original and compressed rule base – Jitter, BW and Handoff Score



6.(a)



6.(b)

Fig.6.Surface view for original and compressed rule base –RSS, BW and Handoff Score

5. CONCLUSIONS

In this paper a QoS aware handoff decision making to select an optimum network for heterogeneous handoff scenario has been implemented using Fuzzy Logic with reduced FRB system. QoS parameters considered for handoff decision includes BW, RSS, E2E Delay, Jitter, and BER. Three networks namely, Cellular, Wi-Fi and WIMAX have been considered as the available networks. Handoff is executed to the network with highest handoff score value. The increase in fuzzy system complexity considering more network metrics has been overcome by dominant rue reduction technique to reduce the number of rules. By using this technique, handoff to the available network is achieved in less handoff decision time. The method proposed to reduce rules is also evaluated for its correctness and validity by comparing the surfaces of the original system and compressed system. Thus, good QOS and continuity is achieved in heterogeneous wireless environment.

REFERENCES

1. Goyal, Pramod, D. K. Lobiyal, and C. P. Katti. "Vertical handoff in heterogeneous wireless networks: a tutorial." In Computing, Communication and Automation (ICCCA), 2017 International Conference on, pp. 551-566. IEEE, 2017.

2. Shen, Yulong, Ning Xi, Qingqi Pei, and Jianfeng Ma. "The QoS-Ensured Vertical Handoff Decision in Heterogeneous Wireless Networks." Journal of Information Science and Engineering 30, no. 3 (2014): 875-893.
3. Mahardhika, Gita, Mahamod Ismail, and Rosdiadee Nordin. "Vertical Handover Decision Algorithm Using Multicriteria Metrics in Heterogeneous Wireless Network." Journal of Computer Networks and Communications 2015 (2015).
4. Kassar, Meriem, Brigitte Kervella, and Guy Pujolle. "An overview of vertical handover decision strategies in heterogeneous wireless networks." Computer Communications 31, no. 10 (2008): 2607-2620.
5. KantubuktaVasu, SumitMaheshwari, SudiptaMahapatra and Cheruvu Siva Kumar "QoS-aware fuzzy rule-based vertical handoff decision algorithm incorporating a new evaluation model for wireless heterogeneous Networks",EURASIP Journal on Wireless Communications and networking 2012.
6. Sadiq, Ali Safa, and Kamalrulnizam Abu Bakar. "A fuzzy logic approach for reducing handover latency in wireless networks." Network Protocols and Algorithms 2, no. 4 (2011): 61-87.
7. M. M. Alkhawlani, K. A. Alsalem, and A. A. Hussein, "Multi-criteria vertical handover by TOPSIS and fuzzy logic," in Proceedings of the International Conference on Communications and Information Technology (ICCIT '11), pp. 96–102, 2011
8. Yaochu Jin, Member, IEEE, "Fuzzy Modeling of High-Dimensional Systems:Complexity Reduction and Interpretability Improvement"IEEE TRANSACTIONS ON FUZZY SYSTEMS, VOL. 8, NO. 2, APRIL 2000.
9. Rajiv Chechi, Dr.RajeshKhannaI "QoS Support in Wi-Fi, WiMAX& UMTS Technologies" IJECT Vol. 2, Issue 3, Sept. 2011.
10. 3rd Generation Partnership Project (3GPP)," http://www.3gpp.org/. 8.
11. 3rd Generation Partnership Project 2 (3GPP2)," http://www.3gpp2.org/

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication