Handover Using Fuzzy Analytic Hierarchy Process

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Abstract- The Next Generation Networks have heterogeneous nature and cover wide range of technologies such as Long-Term Evolution (LTE), Wireless Local Area Network (WLAN), Worldwide interoperability for Microwave Access (WiMAX) etc. with a variety of data rates and coverage. When a user travels at a certain speed and continuously changes the direction, good connectivity and reasonable Quality of Service (QoS) should be provided in order to manage the switch over between various networks.

Keywords- Handover, network selection, Quality of Service, efficiency, fuzzy weights, analytic hierarchy process.

I. INTRODUCTION

Although the researchers have been working arduously in the field of heterogeneous wireless networks, but to achieve seamless connectivity and an efficient handoff many issues and challenges have surfaced from time to time. With the advent of Next Generation Networks (NGN's) and advancement of technology related devices, services and applications have changed rapidly. User applications require real-time data and this imposes the challenge of delivery of data to be on time.

Thus, this indicates that focus on factors like throughput, packet loss, delay etc. is essential. Earlier studies and simulations have been based on single parameter (mainly RSS) study. With increasing load and improvement in heterogeneous environments, single criteria handover decision is no longer considered as an efficient method as it may result in inefficient handoff, unbalanced network load, and service interruption.This switchover, called handover, should be effective and efficient to avoid ping pong effect and unnecessary handovers. To perform different operations using applications like file transfer, video streaming, conferencing, messaging etc, the User Equipment (UE) has to be on the network with higher bit rate.

Therefore, UE in recent networks like 4G heterogeneous wireless network repeatedly use vertical along with horizontal handover as well. Thus, network selection becomes very important for better Quality of Service (QoS). The paper proposed here suggests selecting multiple handoff parameters and calculating their priority vectors and fuzzy weights using Analytic Hierarchy Process (AHP) and Fuzzy AHP (FAHP) respectively. Also, Fuzzy Inference System (FIS) is used to decide when the handover has to be taken place. Hence by using the proposed system, unnecessary handovers can be avoided which improves the efficiency of the system, thereby making the system more effective.

1. Hierarchy of Handoff:

Recent researches have shown that multiple parametric considerations are essential because for a heterogeneous wireless network there are more than one type of networks to be adhered to.

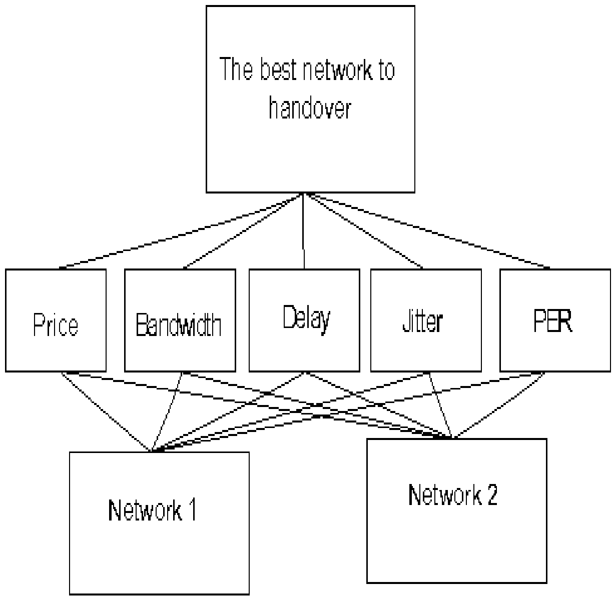

Fig 1. Handoff Hierarchy.

Multi criteria or multiple parametric consideration will help in minimizing handover delays and thereby benefitting the overall throughput of the system. So, it becomes reasonable to consider different parameters which may suit different environments as the decision alternative. Furthermore, multi criteria decision making provides flexibility along with its ability to make quantitative calculations convenient in order to decide the best network. A number of parameters related to various technical and performance issues in mobility management have been defined and discussed by various researchers.
The handoff decision depends upon various types of parameters namely Network related parameters, Terminal

related parameters, User related parameters and Service-related parameters. These parameters include Received Signal strength Indicator (RSSI), Signal-to-Noise interference Ratio (SINR), Bit-Error-Rate (BER), speed, bandwidth, delay, packet loss, throughput, battery power, cost etc.

2. Classification of Parameters:
Parameters can also be categorized into Static and Dynamic parameters where security, cost and power consumption are static parameters while bandwidth, throughput, velocity, received signal strength, bit error rate, reliability, direction etc. fall in the second category.Existing studies have been talking mainly about signal strength of a mobile node in terms of received signal strength indicator (RSSI). Path loss investigation has been an important part of signal strength because of various factors like distance between sender and receiver, interference of other signals, signal fading etc.

SINR, which includes noise and interference, has to be calculated with consideration of path loss. Speed and direction of the mobile node can be effective parameters as for a moving node the number of handoffs may increase thereby affecting its Quality of Service (QoS). While choosing different parameters for studying handoff, pairwise comparison of the parameters helps in analyzing the parameters in better way.

The vague values of the older systems have been taken over by the Fuzzy systems. Fuzzy AHP improves the handoff decision making process by providing intelligent interface for the imprecise data received. The proposed system model consists of a mobile node travelling through LTE and WiMAX overlapped systems. The mobile nodes can switch over to either of the networks Base Stations (BS).

2.1 Signal-to-Noise Interference Ratio (SINR): While implementing and designing any heterogeneous wireless network, path loss prediction is an important parameter to be taken care of. Path loss defines the energy budget of each mobile node. Path loss is the difference of signal strengths of antennas from transmitting station to the receiving station. It occurs due to the distance between the receiving and transmitting nodes, diffraction, reflection, and scattering, absorption of signals by objects on the path and variations of transmitter and receiver antenna heights. SINR which is signal to interference and noise ratio, can be given as

SINR = Signal / (Noise + Interference)
= Gain × (Transmitting Power Thermal Noise + Interference)

Where Gain is assumed to be masthead amplifier gain, thermal noise, interference and transmitting power can be calculated separately for uplink and downlink differently.

The other two parameters of the study are speed and direction which are assumed to be measured by any suitable method.

2.2 Speed: Here distance can be calculated from Mobile Node (MN) to Base Station (BS). As MN sends data to neighboring cell, it stores distances and if one subtracts current measured distance with previously measured distance, it can be seen how close the MN came to the BS or went away from the BS. Dividing this difference by elapsed time between these two measurements will provide the speed and the positive or negative sign will indicate the direction whether the MN is coming close or going away from BS.

2.3 Direction: It is important to note that these parameters suitably affect the number of handoffs performed by the network. If the mobile node is moving at a medium speed and is travelling towards the direction of its point of attachment (PoA), no handoff will be required as sooner or later it will reach in the area of PoA. But if the mobile node is moving far from PoA, it will have to reconsider the idea of handoff as it would be leaving the area of the signal connectivity. In such a scenario, a handoff will be performed as the current SINR will also be weak and connect to another Base Station with a stronger SINR.

II. PROPOSED SYSTEM MODEL

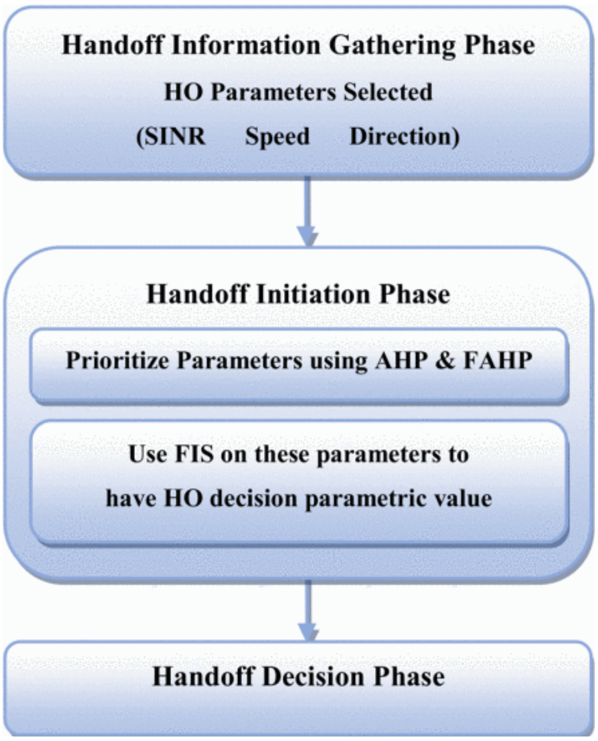

Fig 2.1. Proposed System model.

The study here is concentrated to (a) choosing multiple parameters for an efficient handoff (b) studying weights of these parameters (using AHP and FAHP) so as to prioritize them accordingly (c) using fuzzy logic system to input these chosen parameters to finally get handoff decision parameter.

III. ANALYTIC HIERARCHY PROCESS (AHP)

AHP is one of the Multi-Criteria Decision-Making (MCDM) methods that was developed by Prof. Thomas L. Saaty1970s and has been extensively studied and refined since then. It is a structured technique that organizes and analyzes complex decisions, based on simple mathematics and psychological approach. It is a method of deriving ratio scales from paired comparisons.

The input is obtained from actual measurement or from subjective opinions. The AHP decision making divides the problem into hierarchical order and simplifies the given problem. At each hierarchical level, the weights of the elements are calculated. The final decision is made on the basis of these weights.

Table 1: Numerical rating in AHP

Scale	Meaning
1	Equal importance
3	Moderate importance
5	Strong importance
7	Demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

In the present study, three different criteria are chosen and they are given priorities according to the judgement done from literature study by the authors. To reduce number of unnecessary handoffs and for an efficient handoff decision, higher weights are given to SINR. AHP Pair-wise comparison matrices are given in table 2 and table 3.

Table 2: AHP Pair-wise Comparison matrix

	Speed	SINR	Direction
Speed	1	1/5	1/3
SINR	5	1	5
Direction	3	1/5	1

Table 3: AHP Normalized Pair-wise comparison matrix.

	Speed	SINR	Direction
Speed	0.111	0.142	0.052
SINR	0.555	0.714	0.789
Direction	0.333	0.142	0.157

Table 4: Critical Weights Calculations.

	Speed	SINR	Direction	Weighted sum values	Criteria Weights/Priority Vector
Speed	0.111	0.142	0.052	0.306	0.101
SINR	0.555	0.714	0.789	2.230	0.686
Direction	0.333	0.142	0.157	0.646	0.210

IV. DRAWBACKS OF AHP

In the conventional AHP, the pair wise comparisons for each level with respect to the goal of the best alternative selection are conducted using a nine-point scale. So, the application of Saaty's AHP has some shortcomings as follows

- The AHP method is mainly used in nearly crisp decision applications
- The AHP method creates and deals with a very unbalanced scale of judgment
- The AHP method does not take into account the uncertainty associated with the mapping of one's judgment to a number
- The subjective judgment, selection and preference of decision-makers have great influence on the AHP results.

In addition, a decision-maker's requirements on evaluating alternatives always contain ambiguity and multiplicity of meaning. Furthermore, it is also recognized that human assessment on qualitative attributes is always subjective and thus imprecise.

Therefore, conventional AHP seems inadequate to capture decision maker's requirements explicitly. In order to model this kind of uncertainty in human preference, fuzzy sets could be incorporated with the pairwise comparison as an extension of AHP. A variant of AHP, called Fuzzy AHP, comes into implementation in order to overcome the compensatory approach and the inability of the AHP in handling linguistic variables. The fuzzy AHP approach allows a more accurate description of the decision-making process.

FAHP overcomes these disadvantages and models uncertainty in human preference by using fuzzy logics. Fuzzy AHP (an extension of AHP) uses linguistic variables approach to make decision making process more accurate and precise. The study here extends AHP factors further into fuzzy AHP and uses geometric mean method given by Buckley.

V. FUZZY AHP

In general, FAHP comprises of components like Fuzzifier, and Defuzzifier.

Table 2 shows the input parameters chosen for the SINR of the network available, speed of the mobile node and direction of the mobile node. Each of the input parameters has been assigned three membership functions (mf). The fuzzifier transforms the real-time measurements into fuzzy sets by mapping these measurements on to the values of the membership functions and weights are calculated.

Table 6: FAHP Pair-wise Comparison matrix.

Weighted sum values/critical weights	
0.309/0.100	3.09
2.15/0.697	3.08
0.646/0.203	3.18

Table 7: FAHP weights and Critical weights

	Speed	SINR	Direction
Speed	1,1,1	1/6,1/5,1/4	1/4,1/3,1/2
SINR	4,5,6	1,1,1	4,5,6
Direction	2,3,4	1/6,1/5,1/4	1,1,1

Table 8: Ratio of Weighted sum values and critical weights.

	Fuzzy Weights $w\sim_i$	Weights w_i
Speed	(.072, .097, .14)	0.100
SINR	(.525, .701, .927)	0.697
Direction	(.144, .202, .281)	0.203

The weights wi in table 7 shows that SINR is having highest priority as compared to the other two. Amongst speed and direction, direction has the higher priority.

The comparison of AHP and FAHP result values of the parameters is shown in figure 2.1. It shows that FAHP is better in cases of vague values as input as compared to AHP.

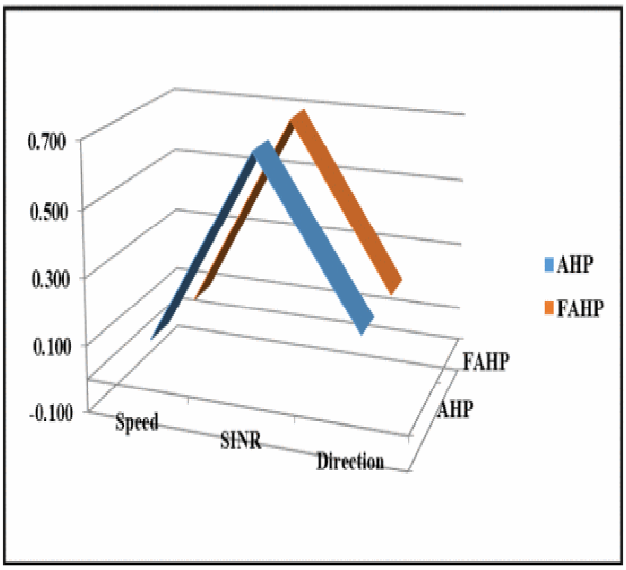

Fig. 1 AHP & FAHP comparison.

SINR, which indicates the radio signal quality, has been assigned Low for poor signal quality, Med for medium signal quality and High for comparatively better signal quality. Similarly, speed has been assigned Low, Medium High for low, medium and high speed of the node respectively.

The direction parameter has been assigned Towards mf so as to indicate that the mobile node is moving towards the Base Station, Med mf to indicate it is at some medium distance from the Base Station and Far mf to indicate that the mobile node is moving far from the Base Station.

The final handoff Initiation making parameter is predicted by the defuzzifier output.
If the defuzzifier output (Handoff Initiation Making parameter) > 0.5, then the handoff will be initiated else there will be no handoff.
To determine consistency, firstly λmax is to be calculated.

$$\boldsymbol{\lambda max = (3.09+3.08+3.18)/3}$$

$$= 3.116$$

Calculating Consistence Index (CI):

$$\mathbf{CI= \lambda max-n/(n-1)}$$

$$= (3.116-3)/2$$

$$CI = 0.058$$

The appropriate consistency index is called Random consistency Index (RI). The Random consistency index for number of parameters compared in the matrix is given below.

Table 9: Random consistency index.

Matrix size	Random consistency index (RI)
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Here, as we have considered 3 parameters, RI = 0.58

Consistency Ratio (CR) = CI/RI

=0.058/0.58

= 0.1

It can be analyzed that CR ratio is 0.1<=0.1. Thus, we can say that the weights are consistent under FAHP method.

- The final handoff Initiation making parameter is predicted by the defuzzifier output.
- If the defuzzifier output (Handoff Initiation Making parameter) > 0.5, then the handoff will be initiated else there will be no handoff.
- Defuzzifier output (SINR) = 0.697, therefore handoff can be initiated.

VI. ADVANTAGES AND DISADVANTAGES

Handoff using FAHP helps in reducing the ping pong effect and maintains the continuity of service effectively throughout.Fuzzy AHP is a highly complex methodology and requires more numerical calculations in assessing composite priorities than the traditional AHP and hence it increases the effort.

VII. CONCLUSION AND

New Generation Networks can roam freely across different wireless system by doing horizontal and vertical handover. In such environment, the selection of network from the available wireless system is difficult in nature. To select the best network from the wireless system and to achieve QoS, AHP and FAHP are implemented. According to the proposed scheme, weights are assigned to different criteria and obtained the results using which a decision is taken whether handoff is to be initiated or not.

VIII. FUTURE SCOPE

As a future work, better ranking method can be used to rank various handoff parameters. Also, for a better QoS standard, user-related handoff parameters (cost, security etc.) can be considered in addition to these network and terminal related parameters.

REFERENCES

[1] Ismail, B. H. Roh, "Adaptive handover in heterogenous networks using fuzzy MADM", IEEE international conference on mobile IT convergence, pp. 99-104, 2011.
[2] Sgora, D.D. Vergados, "Handoff prioritization and decision schemes in wireless cellular networks: a survey", IEEE Communication Survey Tutorial, vol. 11, no. 4, pp. 57-77, 2009.
[3] E. Lee, C. Choi, P. Kim, "Intelligent handover scheme for fuzzy inference systems", IEEE Access, vol. 5, no. c, pp. 13712-13719, 2017.
[4] P. Dhand, S. Mittal, "Adaptive Threshold and Hysteresis for Handoff Initiation in Next Generation Networks from Path Loss Model", International Journal of Applied Research on Information Technology and Computing, vol. 6, no. 1, pp. 10-17, 2015.
[5] P. Dhand, S. Mittal, "Adaptive Threshold and Hysteresis for Handoff Initiation in Next Generation Networks from Path Loss Model", International Journal of Applied Research on Information Technology and Computing, vol. 6, no. 1, pp. 10-17, 2015.