Fuzzy Logic Based Handoff Controller for Microcellular Mobile Networks

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Abstract
In mobile cellular systems the handoff is a very important process, which refers to a mechanism that transfers an ongoing call from one Base Station (BS) to another. The performance of the handover mechanism is very important to maintain the desired Quality of Service (QoS). The conventional handoff decisions are normally signal strength based, which are not suitable for modern small sized microcellular networks. In order to maintain reliable communication in microcellular mobile systems, new and better handoff algorithms must be needed to keep QoS, as high as possible. The purpose of this research work is to design an intelligent handoff controller, using fuzzy logic. Fuzzy logic toolbox of MATLAB 7.6.0 is used for designing FIS.

Keywords: *Handoff, Cellular networks, Fuzzy Logic, QoS, Signal strength.*

1. Introduction

During the last few years wireless networks have been a very active research area [1]. In cellular networks it is required to perform handoff successfully and as fast as possible to provide reasonable Quality of service (QoS) levels to the end users.

Handoff in the older generation systems was not difficult to achieve efficiently as the cell size in those systems taken large enough, but in modern cellular systems the cell size is kept small to accommodate maximum users by implementing frequency reuse concept .In the case of the smaller cell size-with increased probability of the mobile system (MS) crossing a cell boundary, the handoff decision becomes more challenging. This problem becomes further complicated by the fact that there is an overlap of the signals from different base stations in the vicinity of the cell boundary. Therefore Soft Computing approaches based on Genetic Algorithm (GA), Fuzzy Logic (FL), and Artificial Neural Networks (ANN) can prove to be efficient for next generation wireless networks.

Fuzzy techniques are becoming an attractive approach to handle uncertain, imprecise, or unmodeled data in solving control and intelligent decision-making problems [2]. So it can be used in the handoff decision making, as the input parameters used for handoff decisions are also uncertain and time variable.

2. Conventional Handoff Algorithms

Conventionally signal strength based handoff decisions are considered. The conventional handoff decision compares the Received signal strength (RSS) from the serving base station with that from one of the target base station, using a constant handoff threshold [3]. The conventional RSS based handoff method selects the Base station (BS) with strongest received signal at all times. However the fluctuations of signal strength causes ping-pong effect. Some of the main signal strength metrics used to support handoff decisions are: Relative signal strength, Relative signal strength with threshold, Relative signal strength with hysteresis, Relative signal strength with threshold and hysteresis.

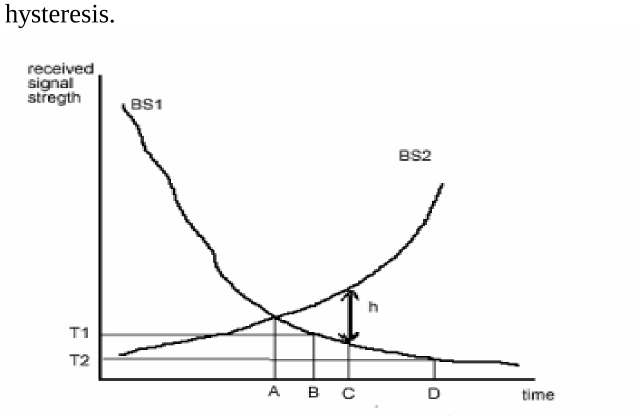

Figure 1. Conventional handoff based on RSS [3]

All the above techniques initiate handoff before point D, which is called “Receiver Threshold” [3]. Receiver threshold is the minimum acceptable RSS for call continuation [T2 in figure 1]. If RSS is dropped below receiver threshold the ongoing call is dropped. This method is observed many unnecessary handoffs even when the signal strength of the current BS is still at an acceptable level, which results poor quality of service (QOS) of the cellular system.

3. Proposed Fuzzy Logic Based Handoff Algorithm

Figure 2 shows the structure of proposed fuzzy Logic based handoff mechanism. The basic fuzzy logic concept and description of proposed fuzzy logic based system is described here.

3.1. Fuzzy Logic Concept

During the sixties, Professor Lotfi Zadah, of the University of California at Berkeley, proposed a mathematical way of looking at the intrinsic vagueness of the human language, he called his approach "Fuzzy Logic"[4] and presented as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership.

Fuzzy logic starts with the concept of a "fuzzy set". A fuzzy set is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership. A classical set is a set that wholly includes or wholly excludes any given element.

Fuzzy set theory allows the gradual transition from full membership of a set to full non-membership (though not simultaneously) [5]. Thus fuzzy set theory is a generalization of classical set theory. In fuzzy set an element is related to a set by a membership function μ. As an example, consider a fuzzy set A and an element x, the membership function $\mu_A(x)$, specifies the relationship of x to A. The membership function usually takes on a value between 0 and 1, i.e., μ [0,1] where 1 is for full membership, 0 for the null-membership, while values in between give the degree of membership. Fuzzy logic uses linguistic variables to map the input fuzzy variables to the output fuzzy variable(s) by using fuzzy IF-THEN rules.

3.2. Designing of Fuzzy Inference System (FIS)

In order to design a fuzzy Inference system the following steps are used:

(i) Identify the inputs and outputs using linguistic variables. In this step we have to define the number of inputs and output terms linguistically.
(ii) Assign membership functions to the variables. In this step we will assign membership functions to the input and output variables.
(iii) Build a rule base. In this step we will build a rule base between input and output variables. The rule base in a fuzzy system takes the form of IF---AND---OR, THEN with the operations AND, OR, etc.

3.3 Description of Proposed System

As shown in figure 2, the main parts of the proposed system are: Input parameters, Fuzzifier, Fuzzy Inference Engine, Rule Base and Defuzzifier.

The three input parameters, which we have considered, are:

(i) Distance between Base station (BS) & Mobile station (MS),
(ii) Received Signal Strength (RSS)
(iii) Network Load.

The only output parameter of the fuzzy inference system is Handoff Decision.

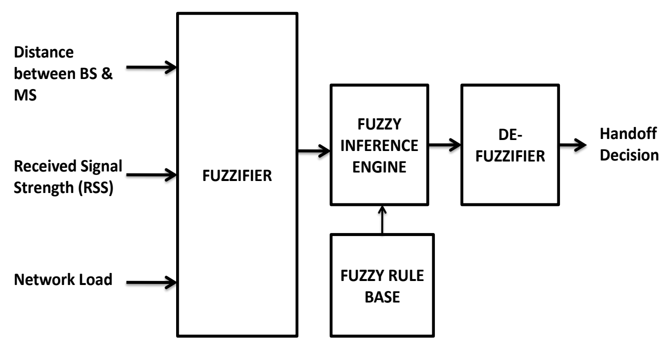

Figure 2. Block diagram Proposed fuzzy logic based handoff mechanism

Data to the fuzzy system is first applied to the fuzzifier, which takes the inputs and fuzzified the information .The fuzzified information is then passed to the fuzzy Inference Engine. The Inference Engine will take the fuzzified input and perform operations on it according to the Fuzzy Rules. These operations will produce output fuzzy sets for each fired rule. The Output of Inference Engine will be passed to the Defuzzifier. The Defuzzifier will compute a crisp value, i.e., converts the fuzzy domain back to the real world domain. There are several methods for defuzzification such as left max operation, right max operation, Centroid algorithm etc. The Centroid algorithm is mostly used method for defuzzification [4,5]. The output crisp value using centroid method is given as:

$$\text{Crisp Handoff Decision} = \sum M_i \times W_i / \sum Mi$$

Where M_i is the degree of membership in output singleton i, and W_i is the weightage value for the output singleton i.

In our proposed model the range for distance between base station and mobile station is taken 0 to 8 km., the range for received signal strength is taken 0 to 10 mW and the range for network load i.e. number of users in the cell is taken 0 to 15.

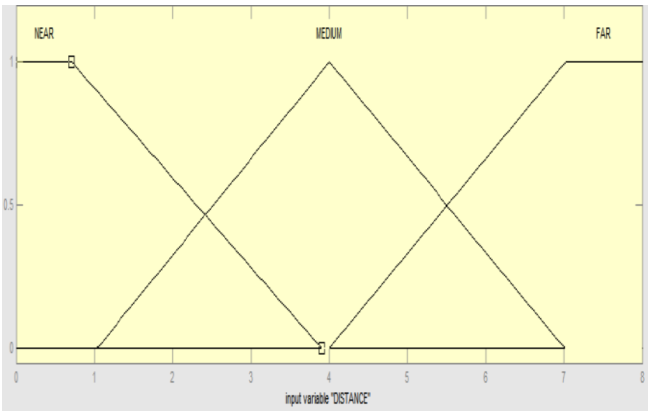

Figure 3. Membership functions of Distance between BS & MS

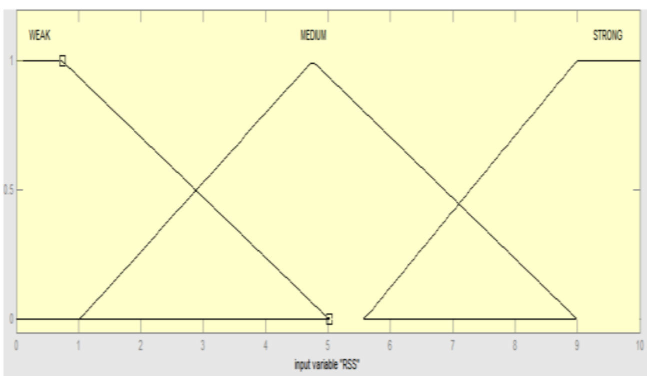

Figure 4. Membership functions of Received Signal Strength (RSS)

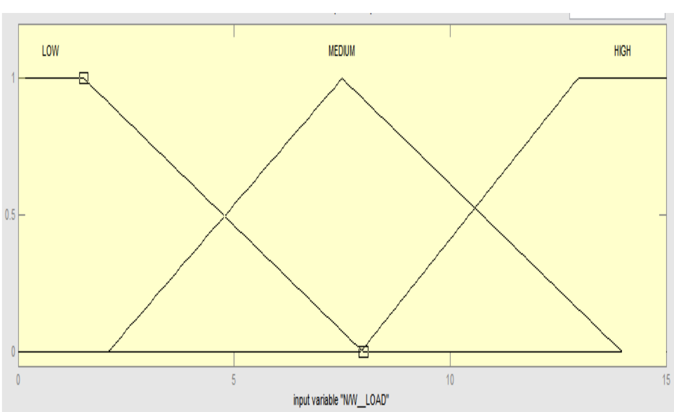

Figure 5. Membership functions of Network Load

The membership functions of input parameters for the proposed fuzzy logic controlled handoff mechanism are shown in figure 3, 4 and 5. The output parameter i.e. fuzzy handoff decision (FHD) is divided in four levels: Handoff, Be-careful, Wait and No- handoff.

The fuzzy rule base (FRB) for the proposed handoff mechanism is shown in Table 1 and has total 3×3×3= 27 rules. The rules have the form like: IF "Condition" THEN "Control Action".

Table 1: Fuzzy Rule Base For Proposed Handoff Controller

Rule No.	DISTANCE	RSS	NETWORK LOAD	HANDOFF STATUS
1	Near	Strong	High	Wait
2	Near	Strong	Medium	No Handoff
3	Near	Strong	Low	No Handoff
4	Near	Medium	High	Wait
5	Near	Medium	Medium	No Handoff
6	Near	Medium	Low	No Handoff
7	Near	Weak	High	Handoff
8	Near	Weak	Medium	Wait
9	Near	Weak	Low	Wait
10	Medium	Strong	High	Be Careful
11	Medium	Strong	Medium	No Handoff
12	Medium	Strong	Low	No Handoff
13	Medium	Medium	High	Handoff
14	Medium	Medium	Medium	Wait
15	Medium	Medium	Low	No Handoff
16	Medium	Weak	High	Handoff
17	Medium	Weak	Medium	Be Careful
18	Medium	Weak	Low	Wait
19	Far	Strong	High	Handoff
20	Far	Strong	Medium	Be Careful
21	Far	Strong	Low	No Handoff
22	Far	Medium	High	Handoff
23	Far	Medium	Medium	Be Careful
24	Far	Medium	Low	Wait
25	Far	Weak	High	Handoff
26	Far	Weak	Medium	Handoff
27	Far	Weak	Low	Handoff

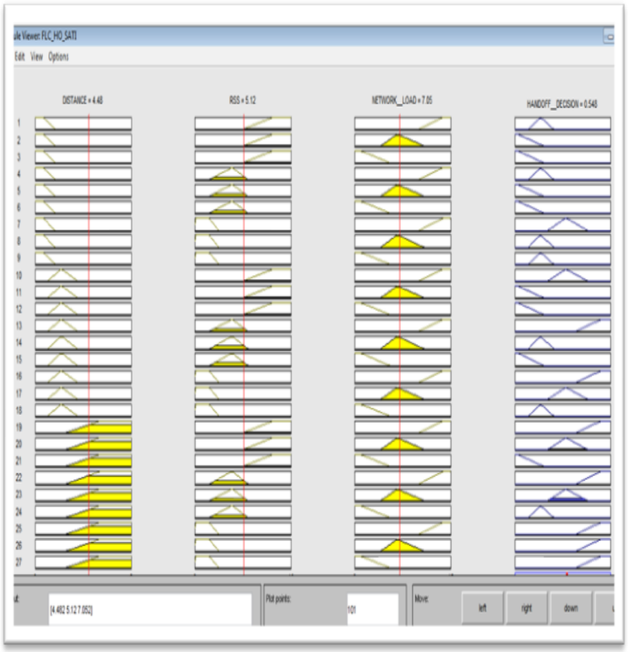

Figure 6. Rule Viewer for the proposed system

4. Results and Discussions

In this section we present and discuss the obtained results of the proposed fuzzy logic based handoff controller. Figure 6 shows the rule viewer of the proposed system. From the rule viewer we have taken readings of different parameters. The figure 7 shows the three-dimensional surface curve between Distance, RSS and Handoff decision. Similarly figure 8 surface curves between Network Load, RSS and Handoff Decision.

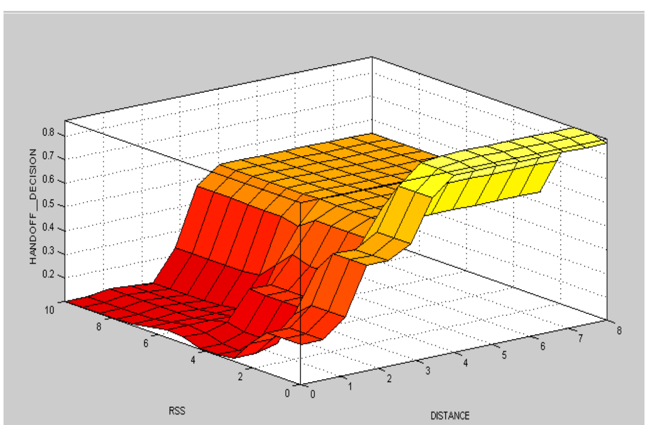

Figure 7. Surface curve between Distances, RSS & Handoff

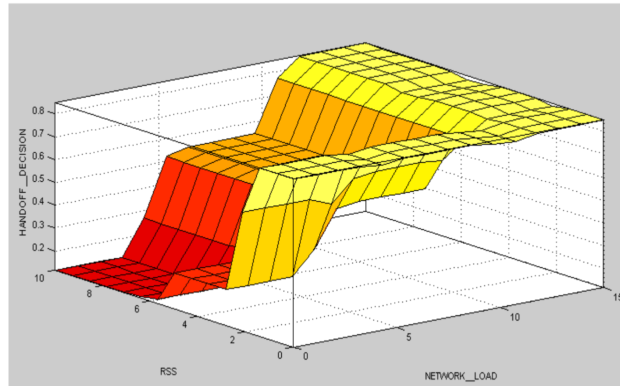

Figure 8. Surface curve between Network Load, RSS & Handoff

The figure 9 shows the relation between distance (between BS & MS) And handoff decision at different network load conditions and at fix received signal strength. The graph shows how handoff factor increases as distance of MS from current BS increases. It is also clear that if network load (i.e. number of users in the cell) increases the handoff factor also increases accordingly.

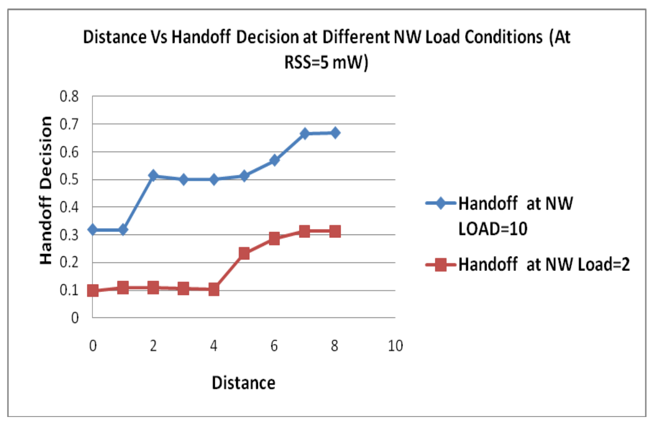

Figure 9. Distance Vs Handoff decision at different network load conditions.

The figure 10 shows the relation between network load and handoff decision. The graph shows that as the network load increases the handoff factor also increases. As the distance of mobile station from base station increases the handoff factor also increases. For example at network load=10 and RSS=5 mW, the handoff factor for a mobile station at 4 Km from current base station is 0.4 whereas it is 0.6 when distance is 4 Km.

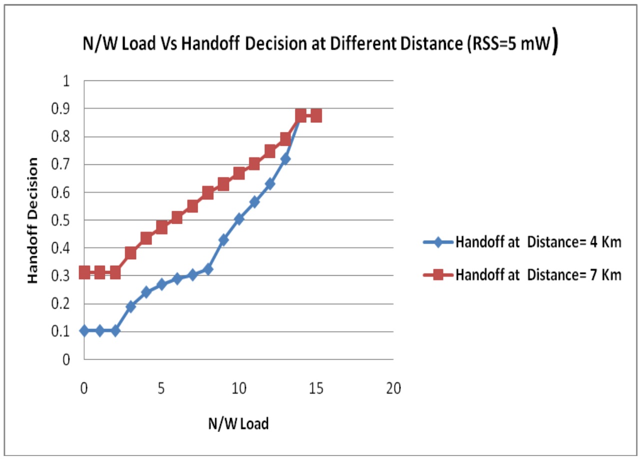

Figure 10 Network Load Vs Handoff decision at different Distance.

5.Conclusion

In this paper a Fuzzy logic based approach for handoff decisions is presented. The proposed algorithm provides an intelligent handoff decision, in which three input parameters: Distance between BS and MS, Received signal strength from BS and network load on the cell are evaluated and feed to the fuzzy inference system. The output of the fuzzy inference system is handoff decision .The handoff factor for the current base station and target base station may be computed and compared. The results show that the handoff factor increases as the mobile station moves away from current base station. The handoff factor also increases as the network load (number of users) in the current cell increases.

6.References

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