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Design of Intelligent Handoff Controller based on Fuzzy Logics

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Abstract

Handoff is an essential part of any Mobile Communication Network. Efficient handoff algorithms provide cost-effective way for enhancing the capacity and QOS of cellular system. Fuzzy handoff algorithm has been developed based on Received Signal Strength (RSS), Network Load, Distance between Mobile station (MS) and Base Trans-receiver Station (BTS) and velocity as input parameters. Decision to handoff or not is based on Multiple Attribute Decision Making. Comparison is made between analog and fuzzy based technique.

1. Introduction

Handoff is described as a process of transferring an ongoing call or data session from one access point to another in wireless networks. It can also be defined as the process of changing the communication channel (frequency, data rate, spreading code, or combination of them) associated with the current connection while a call is in progress. Traditional handoff process, called horizontal handoff, takes place to provide a seamless service when a user moves between two adjacent cells. Generally, horizontal handoff is based on only single parameter such as RSS (Received Signal Strength) in which success rate of handoff is very less. Intelligent system is designed using Fuzzy logic and Neural network in which decision is based on 4 parameters - Received Signal Strength (RSS), Network Load ,Distance between Mobile station(MS) and Base Tran receiver Station(BTS) and velocity.

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. The conventional RSS based handoff method selects the Base station (BS) with strongest received signal at all times. However the fluctuation 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.

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 Fuzzy Logic (FL), and Artificial Neural Networks (ANN) can prove to be efficient for next generation wireless networks.

2. Signal Strength Based Technique

Four base stations, BS1, BS2, BS3 and BS4 are separated by D meters from each other. We assume each BS is equivalent to a hexagonal cell that is covered by single omni-directional antenna. Mobile station (MS) is moving from BS1 to BS2 with constant speed. The signal level received from four

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BSs (in dB) at a distance, d from BS1 can be expressed as follows:

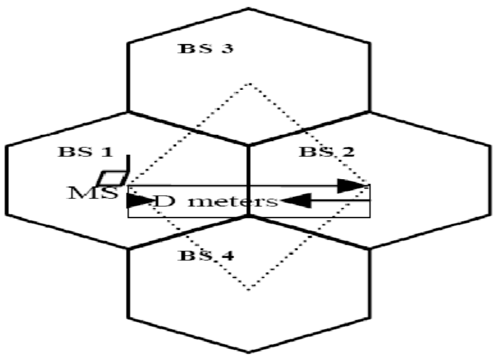

Fig: 1. Signal Strength Based System Model

$$P_{rx1}(d) = K_1 - K_2 \log_{10}(d) + x_1(d)$$

$$P_{rx2}(d) = K_1 - K_2 \log_{10}(D - d) + x_2(d)$$

$$P_{rx3}(d) = K_1 - K_2 \log_{10}\left(\sqrt{\left(\frac{D}{2} - d\right)^2 + \frac{3}{4}D^2}\right) + x_3(d)$$

$$P_{rx4}(d) = K_1 - K_2 \log_{10}\left(\sqrt{\left(\frac{D}{2} - d\right)^2 + \frac{3}{4}D^2}\right) + x_4(d)$$

$P_{rx1}(d)$, $P_{rx2}(d)$, $P_{rx3}(d)$ and $P_{rx4}(d)$ are received signals from BS1, BS2, BS3 and BS4 respectively at a distance *d* meter from BS1. Rayleigh fading is neglected since it has shorter correlation distance compared to shadow fading. *K1* and *K2* are due to path losses. *K2* is actually 10n, where n is path loss component. We assume that *K1* = 0 and *K2* = 30. x1(d), x2(d), x3(d) and x4(d) are independent zero mean stationary processes.

Received signal strength is sampled at discrete time instants, $t_i = kt_s$ where t_s is sampling time.

$$P_{rx1}(kd_s) = K_1 - K_2 \log_{10}(kd_s) + x_1(d_s)$$

$$P_{rx2}(kd_s) = K_1 - K_2 \log_{10}(D - kd_s) + x_2(d_s)$$

$$P_{rx3}(kd_s) = K_1 - K_2 \log_{10}\left(\sqrt{\left(\frac{D}{2} - kd_s\right)^2 + \frac{3}{4}D^2}\right) + x_3(kd_s)$$

$$P_{rx4}(kd_s) = K_1 - K_2 \log_{10}\left(\sqrt{\left(\frac{D}{2} - kd_s\right)^2 + \frac{3}{4}D^2}\right) + x_4(kd_s)$$

Received signal strengths from all four BSs are averaged using exponential averaging window-

$$P_{rxi,avg}(k) = e^{-\left(\frac{d_s}{d_{av}}\right)} P_{rxi,avg}(k-1) + \left(1 - e^{-\left(\frac{d_s}{d_{av}}\right)}\right) P_{rxi}(k)$$

Where *i* = 1, 2, 3 and 4 for received signal strengths from BS1, BS2, BS3 and BS4 respectively.

Signal Strength Ratio-

Signal strength from any BS at any instant *k* is-

$$S^{w}_{i}(k) = 10^{\frac{P_{rxi}(k)}{10}}; i \in \{1,2,3,4\}$$

Next we define signal strength ratio at each of the BSs. For example, signal strength ratio at BS 1-

$$S^{r}_{11}(k) = \frac{10^{\frac{P_{rx1}(k)}{10}}}{10^{\frac{P_{rx2}(k)}{10}} + 10^{\frac{P_{rx3}(k)}{10}} + 10^{\frac{P_{rx4}(k)}{10}}}$$

We can generalize the expressions for signal strength ratio as follows:

$$S^{r}_{ii}(k) = \frac{10^{\frac{P_{rxi}(k)}{10}}}{\sum_{j \neq i} 10^{\frac{P_{rxj}(k)}{10}}} \quad \text{where } j \text{ is 1, 2, 3, 4 except } i$$

$$S_{jj}(k) = 10 \log_{10}\left(S^{r}_{jj}(k)\right)$$

Condition for handoff from BS *i* to BS *j* at *k* th instant

$$S_{jj}(k) \geq S_{ii}(k) + h$$

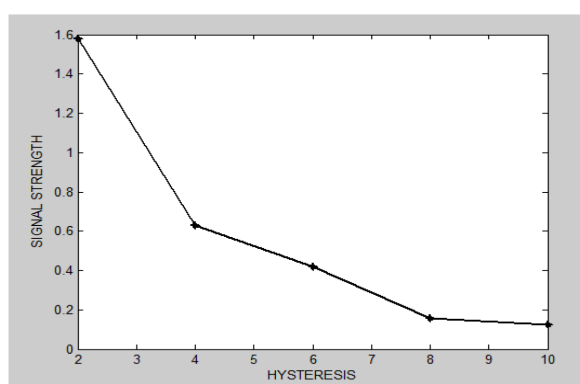

Fig: 2. Relation between Received Signal Strength and Hysteresis at time (t_1)

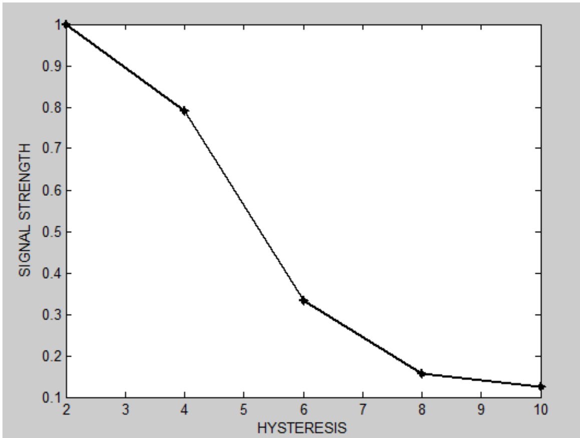

Fig: 3. Relation between Received Signal Strength and Hysteresis at time (t_2)

3. Intelligent Fuzzy Based Handoff Controller

The proposed fuzzy logic based system initiates handoff using fuzzy logic, it uses velocity, distance, RSS and network load as input and handoff decision as output. The proposed algorithm results in fewer dropped calls, better communication quality, potentially lower MT transmit power requirements; give good performance at different MT speeds, and decreases handoff failure probability.

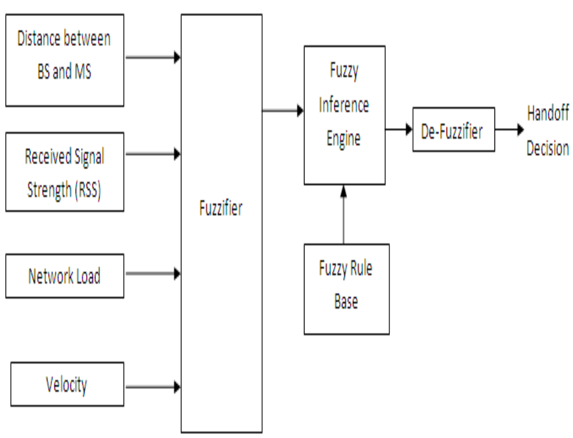

Fig: 4. (Fuzzy Logic Based System Model)

Sr. No	Velocity	RSS	Network Load	Distance	Handoff Decision
1	Low	Poor	Low density	Near	Wait
2	Low	Poor	Low density	Medium	Handoff
3	Low	Poor	Low density	Far	handoff
4	Low	Poor	Medium density	Near	Handoff
5	Low	Poor	Medium density	Medium	Handoff
6	Low	Poor	Medium density	Far	Immediate handoff
7	Low	Poor	High density	Near	Handoff
8	Low	Poor	High density	Medium	Handoff
9	Low	Poor	High density	Far	Immediate handoff
10	Low	Average	Low density	Near	no handoff
11	Low	Average	Low density	Medium	no handoff
12	Low	Average	Low density	Far	wait
13	Low	Average	Medium density	Near	no handoff
14	Low	Average	Medium density	Medium	wait
15	Low	Average	Medium density	Far	wait
16	Low	Average	High density	Near	wait
17	Low	Average	High density	Medium	wait
18	Low	Average	High density	Far	handoff
19	Low	Good	Low density	Near	no handoff
20	Low	Good	Low density	Medium	no handoff
21	Low	Good	Low density	Far	wait
22	Low	Good	Medium density	Near	wait

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23	Low	Good	Medium density	Medium	wait
24	Low	Good	Medium density	Far	wait
25	Low	Good	High density	Near	wait
26	Low	Good	High density	Medium	wait
27	Low	Good	High density	Far	handoff
28	Medium	Poor	Low density	Near	wait
29	Medium	Poor	Low density	Medium	handoff
30	Medium	Poor	Low density	Far	Immediate handoff
31	Medium	Poor	Medium density	Near	handoff
32	Medium	Poor	Medium density	Medium	handoff
33	Medium	Poor	Medium density	Far	Immediate handoff
34	Medium	Poor	High density	Near	wait
35	Medium	Poor	High density	Medium	handoff
36	Medium	Poor	High density	Far	Immediate handoff
37	Medium	Average	Low density	Near	no handoff
38	Medium	Average	Low density	Medium	wait
39	Medium	Average	Low density	Far	wait
40	Medium	Average	Medium density	Near	no handoff
41	Medium	Average	Medium density	Medium	wait
42	Medium	Average	Medium density	Far	wait
43	Medium	Average	High density	Near	wait
44	Medium	Average	High density	Medium	handoff
45	Medium	Average	High density	Far	handoff
46	Medium	Good	Low density	Near	no handoff
47	Medium	Good	Low density	Medium	wait
48	Medium	Good	Low density	Far	wait
49	Medium	Good	Medium density	Near	no handoff
50	Medium	Good	Medium density	Medium	no handoff
51	Medium	Good	Medium density	Far	wait
52	Medium	Good	High density	Near	wait
53	Medium	Good	High density	Medium	wait
54	Medium	Good	High density	Far	handoff
55	High	Poor	Low density	Near	wait
56	High	Poor	Low density	Medium	handoff
57	High	Poor	Low density	Far	immediate handoff
58	High	Poor	Medium density	Near	wait
59	High	Poor	Medium density	Medium	handoff
60	High	Poor	Medium density	Far	immediate handoff
61	High	Poor	High density	Near	immediate handoff
62	High	Poor	High density	Medium	immediate handoff

63	High	Poor	High density	Far	immediate handoff
64	High	Average	Low density	Near	wait
65	High	Average	Low density	Medium	wait
66	High	Average	Low density	Far	Handoff
67	High	Average	Medium density	Near	wait
68	High	Average	Medium density	Medium	wait
69	High	Average	Medium density	Far	handoff
70	High	Average	High density	Near	wait
71	High	Average	High density	Medium	handoff
72	High	Average	High density	Far	handoff
73	High	Good	Low density	Near	wait
74	High	Good	Low density	Medium	handoff
75	High	Good	Low density	Far	handoff
76	High	Good	Medium density	Near	wait
77	High	Good	Medium density	Medium	wait
78	High	Good	Medium density	Far	handoff
79	High	Good	High density	Near	wait
80	High	Good	High density	Medium	handoff
81	High	Good	High density	Far	immediate handoff

Table: 1. Fuzzy Logic Based Handoff Decision

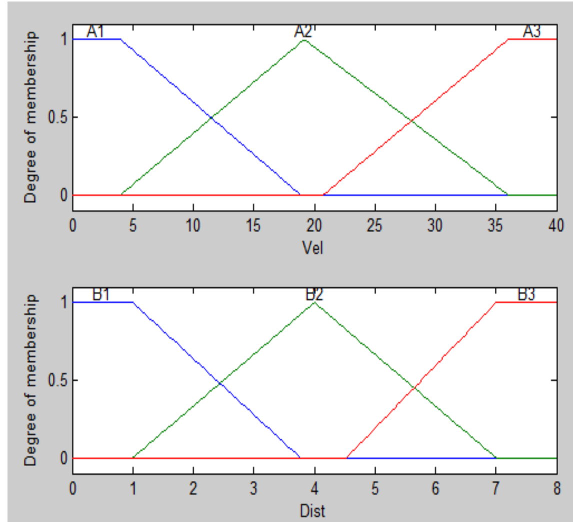

Fig: 5. Membership function of Velocity & Distance

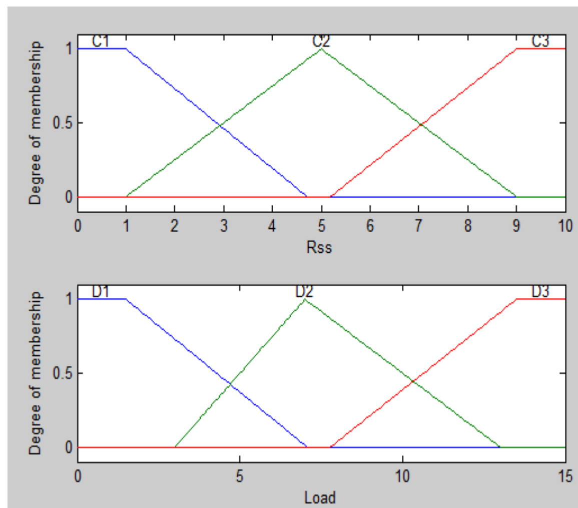

Fig: 6. Membership function of RSS and Load

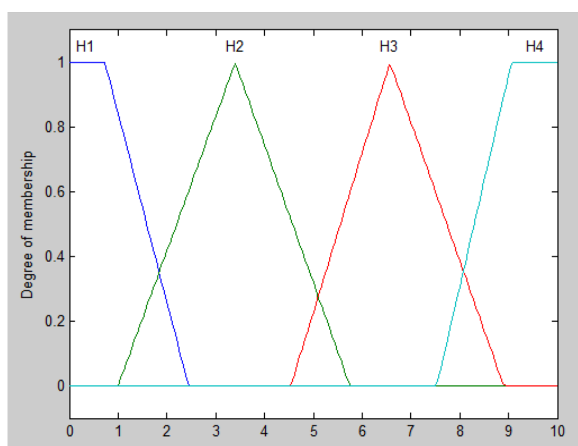

Fig: 7. Output Membership Function- Handoff Decision

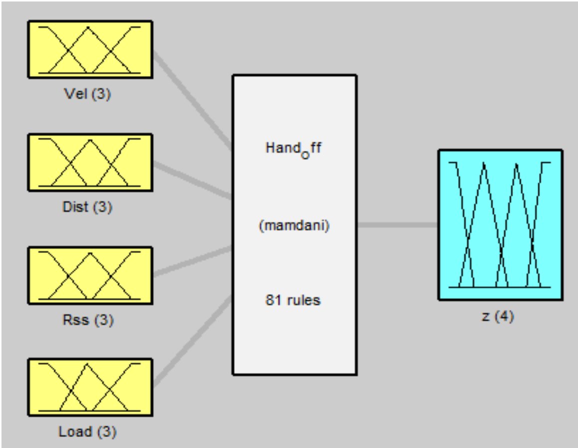

Fig: 8. MAMDANI Model for fuzzy decision

Designing of Fuzzy Inference System (FIS)

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

1. Input Parameters taken-
   (i) Received Signal Strength (RSS)
   (ii) Network Load
   (iii) Distance between MS and BTS
   (iv) Velocity

(ii) Membership functions are assigned to the variables.

(iii) Rule base is designed depending on four input parameters as depicted in Table -1.The rule base in a fuzzy system takes the form of IF---AND---OR, THEN with the operations AND, OR, etc.

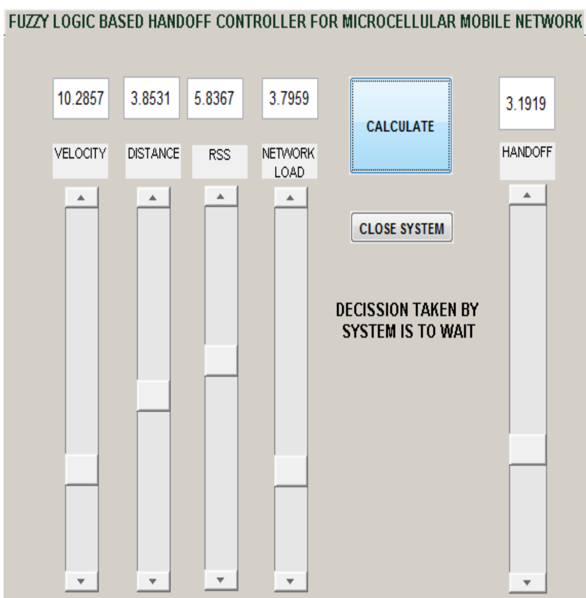

Fig: 9. Graphical User Interface for Fuzzy Handoff Controller

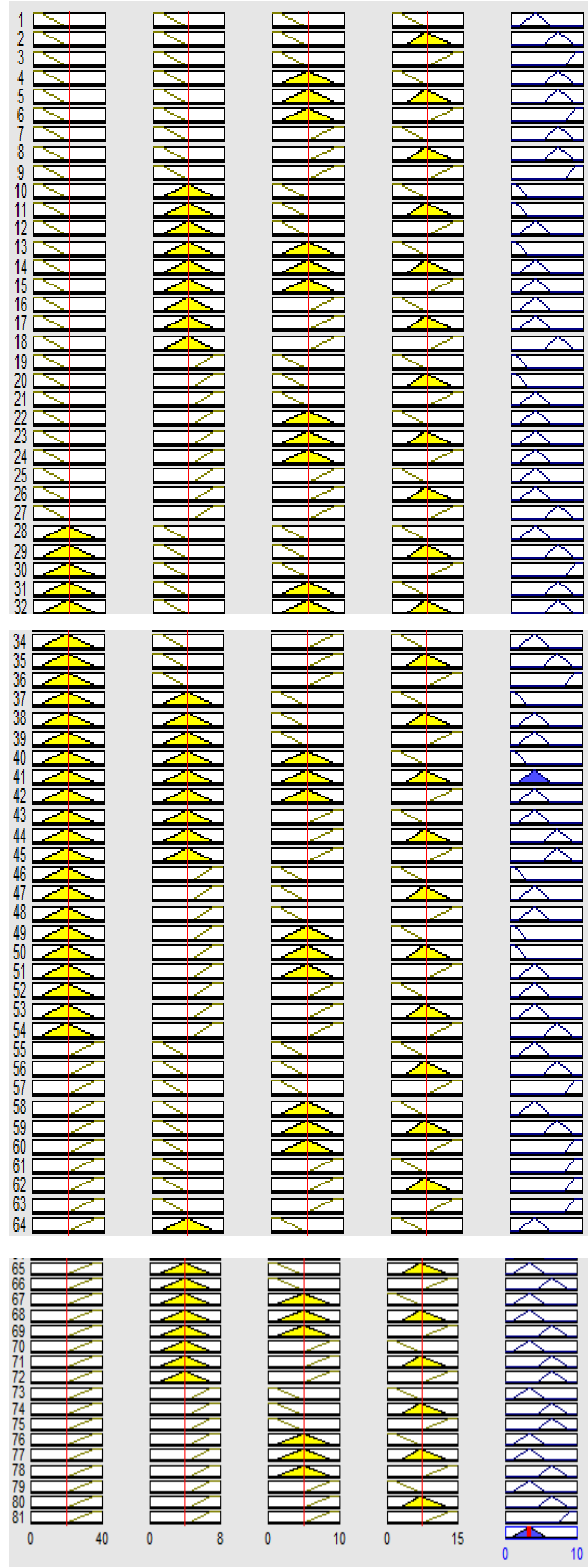

Fig: 10. Rule Viewer –Handoff

4. Conclusion

SSR based handover algorithms have been proposed for cellular networks. It is shown, via simulation that proposed SSR gives very good performance in comparison with combined relative and absolute signal strength measurements based algorithm particularly in terms of handoff delay. Moreover, it is easy to make receiver for proposed handover scheme, as there is no need of expensive filter for averaging. Secondly Fuzzy logic based approach for a handoff decision is presented. The proposed algorithm provides an intelligent handoff decision, in which four input parameters: Distance between BTS and MS, Received signal strength from BS and network load on the cell are evaluated and velocity with which user moving away from current base station 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.

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