Speed and Direction Based Fuzzy Handover System

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***Abstract*—Handover is a very common event in Cellular Mobile network; however QoS could be severely affected by the handover performance. More handover cause more signaling traffic. Therefore, it is desired that handover should be done only when it is necessary. Besides, handover decision should be precise by taking account all possible options and considering the best one. For moving Mobile Station (MS) handover takes place more frequently. Some fuzzy logic based methodologies have already been proposed in literature to provide handover decision. In this paper, a method has been proposed to calculate speed and direction of MS relative to base station as a single metric using measurement data. Accordingly, a fuzzy logic based handover algorithm is implemented to avoid ping pong effect. By taking relative speed and direction, traffic load, signal strength and distance, the fuzzy inference system determines the best candidate neighbor based on the measurement reports from MS. Simulation has been carried out in Matlab environment and a comparison of different approaches has been performed. Simulation results demonstrate that proposed algorithm provides prediction based handover decision more accurately and avoid unnecessary handover and ping pong effect.**

Keywords— Fuzzy Inference System, Handover, Cellular Mobile Network, Ping Pong effect, GSM Measurement Data.

I. INTRODUCTION

In GSM technology, more frequencies are allocated to meet the need of users in mobile network and frequency reuse has been an effective solution. However, to ensure more frequency reuse, cell size is getting smaller and as a result more handover is taking place as users roam. If proper handover mechanism is not used there may be huge ping pong at the cell border area or ping pong can take place because of fading [6]. If the metrics are not balanced then unnecessary handover attempt will be there which will increase system load or lead to bad handover decision. As a result QoS will be hampered, even call drop can be occurred. In recent days, this has been an active research area and several algorithms have been proposed in [1, 2, 3]. Many approaches have been used like Fuzzy Logic, neural Network, Genetic Algorithm and other AI approaches. Different types of handover have been introduced, like, Network Controlled Handover (NCHO), Mobile Assisted Handover (MAHO), Soft Handover (SHO), and Mobile Controlled Handover (MCHO) [9].

In this paper, MAHO is used along with Fuzzy Logic to make handover decision more efficiently.

II. LITERATURE REVIEW

A. Conventional Handover and application of Fuzzy Logic

Conventional Handover depends mostly on signal strength. Like Fig. 1, if MS moves away from BTS, signal gets weaker and after reaching a certain threshold, control of that call is transferred to another base station with strong signal.

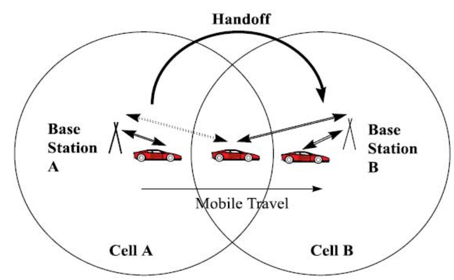

Fig. 1. Handover

The conventional RSS based handoff method always selects the Base Station (BS) with strongest received signal. However, the fluctuations of signal strength due to shadowing and fading cause ping-pong effect [2, 6].

To improve handover performance of the network, various metric and methods are introduced. Barolli et al. [1] proposed fuzzy logic based handover system taking 3 metric into consideration: change in signal strength, signal strength of the neighbor and distance and established a comparison between two system using different metrics [5]. They also addressed ping pong problem by introducing a threshold. Sati1et al. [2] used network load along with other metric and C. G. Patil et al. [3] used velocity and hysteresis with other metric for better handover performance. In [4], predicted signal strength has been used. Yet another technique is used by Lin et al. [6] which use location and velocity based algorithm to avoid ping-pong effect and GSM measurement data was used in this work. Fuzzy Logic with different metric were also used in vertical handover in heterogeneous network [7, 8, 10] in which authors considered different metrics like data rate/bandwidth, user preference and proposed rules for intra and inter system handover. Singh et al. used fuzzy logic based handover system and performed a comparison of this method with traditional network [11] along with the minimization of ping pong effect. In [9], Tripathi provided an overview of each type of handover system. The Basic fuzzy system which has been used in those literatures is depicted in Fig. 2.

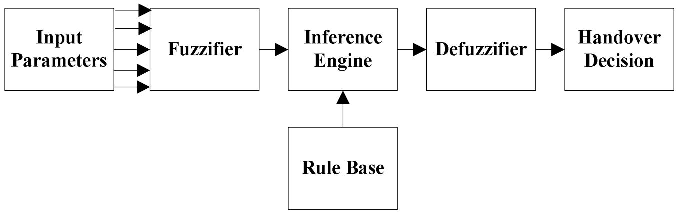

Fig. 2. Fuzzy inference system for Handover

Like [1, 2, 3], different combination of metrics has been used in this paper along with a new metric i.e., speed & direction. Analysis shows that the addition of this metric result in better handover decision and a threshold is used to avoid ping pong.

B. *GSM Measurement Report*

MS continuously provides status report to BTS and sends a report which is called measurement report or Radio link measurement Report or SACCH (Slow Associated Control Channel) Report Measurement [9, 12, 13, 14]. Measurement reports transmitted periodically every 480ms interleaved over 4 SACCHs. In *Mobile Assisted Handover* – MAHO, handover decision is dependent on this report. Normally, MS sends report of 6 neighbor cell to BTS and then BSS processes it to make decision. A brief summary of the information from measurement report is given below which will be used in this paper.

1) Signal strength: Signal strength (RXLEV) is considered from -110dBm to -48dBm with relative accuracy of 1dB and absolute accuracy of 4dB (up to -70dBm) and 6dB and average is calculated over SACCH multiframes (480ms). Measurement of RXLEV is taken from the allocated TCH in every frame.

2) Signal quality: This is measured in Bit Error Rate (BER) before channel decoding (based on training sequence) and mapped onto RXQUAL levels with different accuracy levels. The following Table I describes how RXQUAL is calculated.

TABLE I. RXQUAL MAPPING WITH BIT ERROR RATE (BER)

Bit error [%]	Average	RXQUAL
… 0.2	0.14	0
0.2 … 0.4	0.28	1
0.4 … 0.8	0.57	2
0.8 … 1.6	1.13	3
1.6 … 3.2	2.26	4
3.2 … 6.4	4.53	5
6.4 … 12.8	9.05	6
12.8 …	18.1	7

3) Distance: Distance can be calculated from the received signal strength [9]. From measurement report, TA (Timing Advance) is found. It can also be converted into distance and be used. To calculate distance from TA, one must consider that the propagation delay that will be used is for two ways. The first leg is the synchronization signal traveling from the BTS to the MS, and the second leg is the access burst traveling from the MS to the BTS. To find out actual distance of the MS from the BTS, half of the total propagation delay must be considered. Relation of distance with TA [13, 14, 15] can be expressed as (1), where $D_{MStoBTS}$ is distance, TA is timing advance, and P_{delay} is two way propagation delay which is 3.69 *10-6 s.

$$D_{MStoBTS} = \frac{TA*3x10^{-8}*P_{delay}}{2} \tag{1}$$

C. *Ping pong effect*

Radio signal fluctuates due to environmental disruption which may result in signal fading and/or other effects. Signal strength received by MS depends on these effects. In the boundary of two cells, MS can find strong signal from different cell alternatively in each measurement period because of the aforementioned signal fluctuation for shadowing fading effect [6]. If a handover algorithm is completely dependent on signal strength, it will give alternative handover decision, so number of handovers will be increased. This scenario is called ping pong in handover. To avoid ping pong a threshold value of handover decision probability has been used in [1]. In this paper, we have used a threshold based on difference between participating neighbors.

III. PROPOSED MODEL

In this paper, an algorithm has been designed which will provide handover decision only when it is necessary by considering the speed and direction of MS. To avoid ping-pong effect, a threshold has been used based on handover metric, which is the output of proposed Fuzzy Inference System. To choose the best candidate from 6 neighbor cells, a fuzzy system has been proposed which will assign high value to the most deserved participant. In this fuzzy system we have used four metrics which will be used to calculate the handover probability. Following is a brief description of the input of our fuzzy systems, new metric (speed & direction), the algorithms and the membership functions.

A. *Metrics for handover*

We use four metrics in total to calculate the handover probability of different cells and accordingly the best neighboring cell will be chosen as serving if defined threshold is crossed. The metrics are:

1) *Signal Strength (dbm)*
2) *Distance from Base station(m)*
3) *Cell Traffic Load (%)*
4) *Speed and Direction (kmph)*

Signal strength can be found from MR of MS. Distance can be calculated from signal strength or timing advance provided by MR in MS. Distance can also be calculated from propagation delay as discussed earlier in (1). Cell load, the percentage of busy channel of total capacity, is found from BSC. Speed and direction can be calculated by the technique we described below.

B. Speed and direction calculation

A method is proposed here to calculate speed and direction by a single metric. We are interested about the relative speed of MS with respect to BTS. In MAHO, distance can be calculated from MS to BTS from the measurement report of MS. As MS sends 6 neighboring cell data in each SACCH period, the idea is to store distances and if we subtract current measured distance with previously measured distance, we can find how much close the MS came to the BTS or went away from the BTS. Dividing this difference by elapsed time between these two measurement will provide the speed and the positive or negative sign will indicate the direction whether the MS is coming close or going away from BTS. If the calculation is done in every alternate measurement period (as every measurement period is 480ms long), then total time to be considered will be 2x480m=960ms. The equation for Speed and direction is (2), where, $S_{S\&D}$ speed and direction, D_{cm} distance measured from current measurement and D_{pm} is the distance measured from previous measurement, M_p is measurement period which is 480ms, S_s is step size which is set to 2 during simulation as calculation is performed in every alternate measurement period and C_p is conversion parameter to convert it to kilometer per hour, which is *3600*1000/1000.* This conversion parameter converts second to hour, millisecond to second and meter to kilometer.

$$S_{S\&D} = \frac{D_{cm} - D_{pm}}{S_s * M_p} * C_p \ kmph \qquad (2)$$

Distance can be measured from received signal strength from the measurement data and it also can be calculated from propagation delay. To calculate distance, timing advance can also be used by replacing D_{cm} and D_{pm} from (1) in (2). $S_{S\&D}$ can be found in terms of TA where TA_{cm} is timing advance of current measurement and TA_{pm} is timing advance of previous measurement and P_{delay} delay is propagation delay for timing advance 3.69 $*10^{-6}$ s.

$$S_{S\&D} = \frac{(TA_{cm} - TA_{pm}) * 3x10^{-8} * P_{delay}}{2 * S_s * M_p} * C_p \ kmph \qquad (3)$$

We are using two measurement periods as a single step because 960ms is almost equal to 1 second as speed and direction is not likely to change in 480ms. Also, this practice reduced the overall calculation down to 50% which will in turn make the system faster. Therefore, we will calculate speed and direction in every alternate measurement period. For example, in Fig. 3 the MS is moving from left to right. From the 1st measurement period, MS is closer to BTS1 and the 3rd measurement period MS is closer to BTS 2. Now the speed and direction is calculated using (2). Here the distance can be calculated from timing advance with step size 2. It could be found that, for BTS1 the value of $S_{S\&D}$ will be negative and for BTS2 the value will be positive.

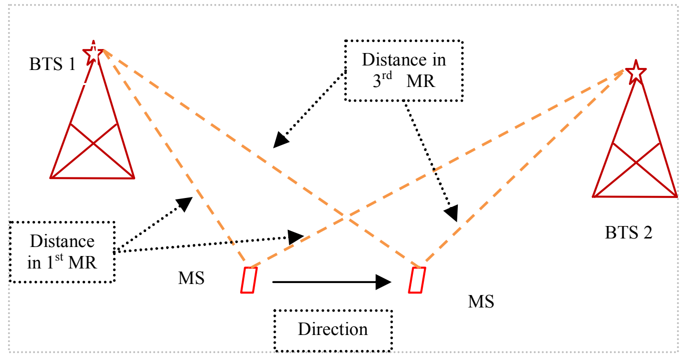

Fig. 3. Calculating Speed and Direction

Algorithm 1.1 Speed and direction calculation

Pre-conditions: *Distance of current measurement* $\boldsymbol{D_{cm}}$*, TA of Distance measurement* $\boldsymbol{D_{pm}}$ *, Step size* $\boldsymbol{S_s}$ *, Measurement period* $\boldsymbol{M_p}$*, Conversion parameter* $\boldsymbol{C_p}$
Post-condition: *Speed and direction* $\boldsymbol{S_{S\&D}}$

1. *Take input* $\boldsymbol{D_{cm}}$ $\boldsymbol{D_{pm}}$ and $\boldsymbol{S_s}$ *;*
2. *Assign values* $\boldsymbol{M_p}$ *and* $\boldsymbol{C_p}$ *;*
3. $\boldsymbol{D_{diff}}$ *= calculatediffrence(*$\boldsymbol{D_{cm}}$*,* $\boldsymbol{D_{pm}}$*);*
4. $\boldsymbol{S_{S\&D}}$ *= Getspeedanddirection(*$\boldsymbol{D_{diff}}$ *,* $\boldsymbol{M_p}$ *,* $\boldsymbol{C_p}$ *,* $\boldsymbol{S_s}$*);*
5. *Return* $\boldsymbol{S_{S\&D}}$*;*

Algorithm 1.1 calculates speed and direction. At *Step-1* distance value and step size are taken as input. In *Step-2* values are initialized and in *Step-3* difference of distances are calculated. And in *Step-4* the function *Getspeedanddirection* calculates speed and direction based on (2). Finally the value is returned in step 5.

C. Proposed Algorithm for Handover

We have proposed an algorithm which will take all the matrices of six neighbors and will decide the best candidate and will find out if handover is necessary and will also provide a mechanism to avoid ping pong effect.

Algorithm 1.2 Fuzzy logic based Handover(FLBH)

Pre-conditions: *Neighbor data* ***N(6)*** *, Serving cell RXQUAL* $\boldsymbol{RX_{squal}}$ *, Serving Cell signal strength* $\boldsymbol{S_{sst}}$ *, Measurement period* $\boldsymbol{M_p}$ *, Signal Strength of Neighbor* $\boldsymbol{S_{si}}$*, Distance of the Neighbor* $\boldsymbol{D_i}$ *, Stored distance* $\boldsymbol{D_{is}}$*, Cell load of the Neighbor* $\boldsymbol{C_{li}}$ *, Current Speed and direction* $\boldsymbol{S_{s\&d}}$ *, Handover probability of neighbors* $\boldsymbol{HP_i}$ *, Minimum Handover probability* $\boldsymbol{HP_{min}}$ *, Minimum probable Neighbor* ***MIN,*** *Handover probability threshold* $\boldsymbol{Threshold_{HP}}$ *, Threshold of RXQUAL* $\boldsymbol{Thresold_{RX}}$ *, Threshold of Signal Strength* $\boldsymbol{Thresold_{SS}}$

Post-condition: Handover decision

1. *Acquire serving cell* $\boldsymbol{RX_{squal}}$ *and* $\boldsymbol{S_{sst}}$
2. *Acquire 6 neighbor data* ***N(6);***
3. *For Each measurement period* $\boldsymbol{M_p}$
4. *For each **i** neighbors of* ***N(6)***
5. $\boldsymbol{S_{si}}$*=getsignalstrength*$\boldsymbol{(N_i);}$
6. $\boldsymbol{D_i}$*=getdistance*$\boldsymbol{(N_i);}$
7. $\boldsymbol{D_{is}}$ *=storedistance(*$\boldsymbol{D_{is}}$*);*
8. $\boldsymbol{C_{li}}$*=getcellload*$\boldsymbol{(N_i);}$
9. $\boldsymbol{S_{s\&d}}$*=getspeed&direction*$\boldsymbol{(D_{is}, S_s);}$
10. *End*
11. $\boldsymbol{HP_i}$*=Fuzzyhandover*$\boldsymbol{(S_s, D_i, C_l, S_{s\&d});}$
12. *For each **j** !=serving cell of* $\boldsymbol{HP_i}$
13. $\boldsymbol{HP_{min}}$*= compareandassign*$\boldsymbol{(HP_i);}$
14. ***MIN=i;***
15. *End*
16. *If* $\boldsymbol{HP_{serv}}$ ***-*** $\boldsymbol{HP_{max}}$ ***>*** $\boldsymbol{Threshold_{HP}}$
17. *Handover to* ***MIN;***
18. *Else if* $\boldsymbol{RX_{squal}} <$ $\boldsymbol{Thresold_{RX}}$ *and* $\boldsymbol{S_{sst}} <$ $\boldsymbol{Thresold_{SS}}$
19. *Handover to* ***MIN;***
20. *Else*
21. *No handover;*
22. *End*
23. *End*

In *step-1* serving cell RXQUAL $\boldsymbol{RX_{squal}}$ and signal strength $\boldsymbol{S_{sst}}$ is stored and then *step-2* neighbor cell data are collected from measurement report ***N(6). In Step-3*** the algorithm will run for every measurement period $\boldsymbol{M_p}$. *Step-4 is* Metric determination loop for every neighbor. In *Step-5* and *Step-6* Neighbor signal strength $\boldsymbol{S_{si}}$ and distance $\boldsymbol{D_i}$ determined. In *Step-7* distance data is stored for being used in next step in $\boldsymbol{D_{is}}$. In *step-8* Cell load is determined from BSS. In *Step-9* Speed and direction is calculated depending on ***Algorithm 1.1.*** *In step-11* handover probability is calculated for each neighbor using *Fuzzyhandover*$\boldsymbol{(S_s, D_i, C_l, S_{s\&d})}$ function and output is saved in $\boldsymbol{HP_i}$. The *fuzzyhandover* function will be described later in ***Algorithm 1.3.***

In *Step-12, 13* and *14,* Neighbor with minimum handover probability is determined, $\boldsymbol{HP_{max}}$ ***and MIN*** is the neighbor**.** In *step-16* and *step-17* threshold is applied to avoid ping pong effect. $\boldsymbol{Threshold_{HP}}$ is set such a way so that handover happen only if the minimum handover probability neighbor has threshold amount less probability then the serving cell. So for little change the reverse handover will not take place, hence no ping pong effect. **.** In *step-18* and *step-19* based threshold of signal strength $\boldsymbol{Thresold_{SS}}$ and RXQUAL $\boldsymbol{Thresold_{RX}}$ handover is determined. If no criteria is fulfilled the control will remain in the serving cell.

D. Fuzzy Inference System for Handover

A FIS (Fuzzy Inference System) is developed to provide fuzzy handover decision using the four metrics as input. Membership function needs to be defined to develop the FIS. We are using total 5 linguistic variables including Handover as output. We have used Z shaped, Gaussian and S shaped membership function as they are appropriate for their smooth transition rather than triangular or trapezoidal function. Range of the membership functions are chosen following other literatures [2, 3] and based on practical scenario. Membership functions of the linguistic variables are given below:

1) Signal Strength: T(SS) = {Weak, Normal, Strong} {WK,NO,ST};

2) Distance from Base station: T(DFB) = {Near, Not So Far, Far} {NR,NSF,FR}.

3) Cell Traffic Load: T(CL) = {Low, Medium, High} {LO, ME, HI};

4) Speed and Direction: T(S&D) = {Coming Fast, Slow, Going away Fast} {CF, SL, GF};

5) Handover: T(HD) = {Low, Medium, High}

We have used three types of membership function in FIS. Z shaped, Gaussian and S shaped. Equation (4) is for Z shaped, (5) is for Gaussian and (6) is for S shaped membership function:

$$\mu(z) = \begin{cases} 1 & , \; z \le a \\ 1 - 2\left(\frac{z-a}{b-a}\right)^2 & , \; a \le z \le \frac{a+b}{2} \\ 2\left(\frac{z-b}{b-a}\right)^2 & , \; \frac{a+b}{2} \le z \le b \\ 0 & , \; z \ge b \end{cases} \tag{4}$$

$$\mu(z) = e^{\frac{-(z-c)^2}{2*\square^2}} \tag{5}$$

$$\mu(z) = \begin{cases} 0 & , \; z \le a \\ 2\left(\frac{z-b}{b-a}\right)^2 & , \; a \le z \le \frac{a+b}{2} \\ 1 - 2\left(\frac{z-a}{b-a}\right)^2 & , \; \frac{a+b}{2} \le z \le b \\ 1 & , \; z \ge b \end{cases} \tag{6}$$

The membership functions of a fuzzy system designed based on heuristic experience. The parameters are decided as per other research conducted in these arena and heuristic experience, like, signal strength, -95 dbm is acceptable as normal signal strength in telecom industry and used in other literature, therefore it is considered as normal signal strength.

For distance, half kilometer distance is considered as not so far and for cell load, 50% cell load is considered medium. For speed and direction more than 60 kmph is considered as fast. All the membership function of the linguistic variables are shown below and Table II shows the type of the membership function, the equation and the parameter.

TABLE II. PARAMETERS OF MEMBERSHIP FUNCTION

Metric Name	Function Name	Function Type	Equation	Parameter
Signal Strength	Weak	Z shaped	4	a = -105 b = -98
	Normal	Gaussian	5	σ = 3 c = -95
	Strong	S shaped	6	a = -93 b = -85
Distance from BTS	Near	Z shaped	4	a = 0.25 b = 0.45
	Not so far	Gaussian	5	σ = 0.1 c = 0.5
	Far	S shaped	6	a = 0.55 b = 0.75
Cell Load	Low	Z shaped	4	a = 15 b = 40
	Medium	Gaussian	5	σ = 10 c = 50
	Far	S shaped	6	a = 60 b = 85
Speed & Direction	Coming fast	Z shaped	4	a = -60 b = -20
	Slow	Gaussian	5	σ = 20 c = 0
	Going fast	S shaped	6	a = 20 b = 65
Handover	Low	Z shaped	4	a = 0.2 b = 0.45
	Medium	Gaussian	5	σ = 0.1 c = 0.5
	Far	S shaped	6	a = 0.55 b = 0.8

*Membership function of **Signal Strength** {WK, NO, ST}*

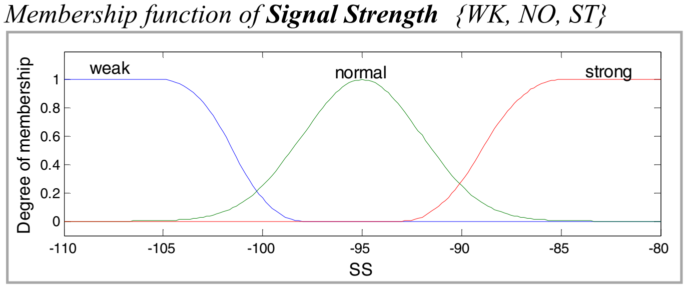

Fig. 4. Member ship functions of Signal Strength(SS)

*Membership function of **Distance from BTS** {NR, NSF, FR}*

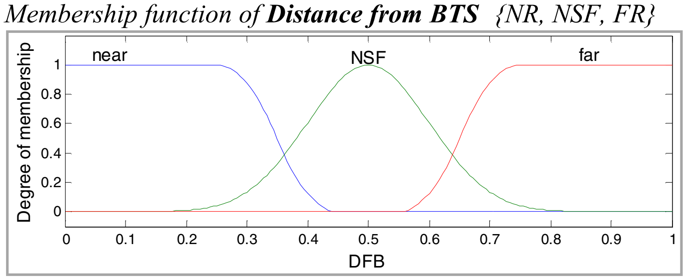

Fig. 5. Member ship functions of Distance from BTS (DFB)

*Membership function of **Cell Load** {LO, ME, HI}*

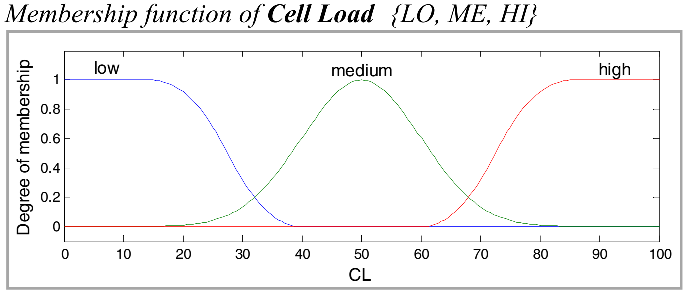

Fig. 6. Member ship functions of Cell Load (CL)

*Membership function of **Speed and direction**{CF, SL, GF}*

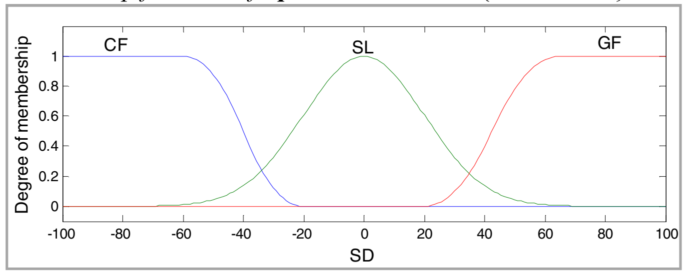

Fig. 7. Member ship functions of Speed and Direction (SD)

*Membership function of **Handover** {LO, ME, HI}*

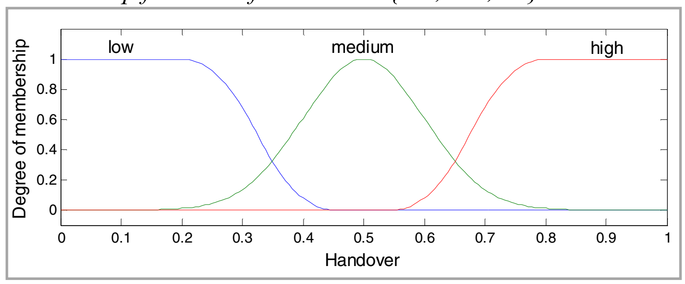

Fig. 8. Member ship functions of Cell Load (CL)

The FIS is created with these four inputs and one output variable and there are total 81 rules (Table III) based on which the FIS will provide decision. As stated in *Algorithm 1.2, fuzzyhandover* function provides handover probability for every neighbor. ***Algorithm 1.3*** is the algorithm for calculating fuzzy handover probability for every neighbor. Input of this algorithm is signal strength, distance, cell load and speed&direction of 6 neighbors and output is handover probability matrix for each neighbors.

Algorithm 1.3 Fuzzy handover probability calculator

Pre-conditions: *Signal Strength of 6 Neighbors* $\boldsymbol{S_{si}}$*, Distance of the 6 Neighbors* $\boldsymbol{D_i}$*, Cell load of the Neighbors 6* $\boldsymbol{C_{li}}$*, Speed and directions of 6 Neighbors* $\boldsymbol{S_{s\&di}}$*,*
Post-condition: *Handover probability of neighbors* $\boldsymbol{HP_i}$

1. *Take input* $\boldsymbol{S_{si}}, \boldsymbol{D_i}, \boldsymbol{C_{li}}$ *and* $\boldsymbol{S_{s\&di}}$
2. *For every neighbors*
3. $\boldsymbol{HP_i} = EvalFIS(\boldsymbol{S_{si}}, \boldsymbol{D_i}, \boldsymbol{C_{li}}\ \boldsymbol{S_{s\&di}});$
4. *end*
5. *Return* $\boldsymbol{HP_i}$*;*

In this algorithm after taking input at *step-1,* for every neighbor handover probability is calculated at *step-3* and stored in $\boldsymbol{HP_i}$. As stated earlier lowest probability has the control of the call depending on the ping pong threshold.

TABLE III. RULE BASE: TOTAL 81 RULES

Serial	SS	DFB	CL	S&D	Handover
1	ST	NR	LO	CF	Low
2	ST	NR	LO	SL	Low
3	ST	NR	LO	GF	Low
4	ST	NR	ME	CF	Low
5	ST	NR	ME	SL	Low
6	ST	NR	ME	GF	Low
7	ST	NR	HI	CF	Medium
8	ST	NR	HI	SL	Medium
9	ST	NR	HI	GF	Medium
10	ST	NSF	LO	CF	Low
11	ST	NSF	LO	SL	Low
12	ST	NSF	LO	GF	Low
13	ST	NSF	ME	CF	Low
14	ST	NSF	ME	SL	Low
15	ST	NSF	ME	GF	Low
16	ST	NSF	HI	CF	Medium
17	ST	NSF	HI	SL	Medium
18	ST	NSF	HI	GF	Medium
19	ST	FR	LO	CF	Low
20	ST	FR	LO	SL	Low
21	ST	FR	LO	GF	Medium
22	ST	FR	ME	CF	Low
23	ST	FR	ME	SL	Medium
24	ST	FR	ME	GF	High
25	ST	FR	HI	CF	Medium
26	ST	FR	HI	SL	High
27	ST	FR	HI	GF	High
28	NO	NR	LO	CF	Low
29	NO	NR	LO	SL	Low
30	NO	NR	LO	GF	Low
31	NO	NR	ME	CF	Low
32	NO	NR	ME	SL	Low
33	NO	NR	ME	GF	Low
34	NO	NR	HI	CF	Medium
35	NO	NR	HI	SL	Medium
36	NO	NR	HI	GF	Medium
37	NO	NSF	LO	CF	Low
38	NO	NSF	LO	SL	Low
39	NO	NSF	LO	GF	Low
40	NO	NSF	ME	CF	Low
41	NO	NSF	ME	SL	Medium
42	NO	NSF	ME	GF	High
43	NO	NSF	HI	CF	Medium
44	NO	NSF	HI	SL	High
45	NO	NSF	HI	GF	High
46	NO	FR	LO	CF	Low
47	NO	FR	LO	SL	Low
48	NO	FR	LO	GF	Medium
49	NO	FR	ME	CF	Medium
50	NO	FR	ME	SL	Medium
51	NO	FR	ME	GF	High
52	NO	FR	HI	CF	Medium
53	NO	FR	HI	SL	High
54	NO	FR	HI	GF	High
55	WK	NR	LO	CF	Medium
56	WK	NR	LO	SL	Medium
57	WK	NR	LO	GF	Medium
58	WK	NR	ME	CF	Medium
59	WK	NR	ME	SL	Medium
60	WK	NR	ME	GF	Medium
61	WK	NR	HI	CF	Medium
62	WK	NR	HI	SL	High
63	WK	NR	HI	GF	High
64	WK	NSF	LO	CF	Medium
65	WK	NSF	LO	SL	Medium
66	WK	NSF	LO	GF	High
67	WK	NSF	ME	CF	Medium
68	WK	NSF	ME	SL	Medium
69	WK	NSF	ME	GF	High
70	WK	NSF	HI	CF	Medium
71	WK	NSF	HI	SL	High
72	WK	NSF	HI	GF	High
73	WK	FR	LO	CF	High
74	WK	FR	LO	SL	High
75	WK	FR	LO	GF	High
76	WK	FR	ME	CF	High
77	WK	FR	ME	SL	High
78	WK	FR	ME	GF	High
79	WK	FR	HI	CF	High
80	WK	FR	HI	SL	High
81	WK	FR	HI	GF	High

IV. EXPERIMENTAL RESULTS

A simulator of the proposed algorithm is developed in Matlab v7.12. In this simulator there is a road and there are network towers in two sides. A car, which is an MS, is moved in different speeds to observe the performance of our proposed algorithm and fuzzy rules. To compare our proposed algorithms, we have designed two more fuzzy handover probability calculator. In one of the fuzzy system, speed and direction metric and ping pong avoidance is not considered, which is a basic Fuzzy handover based on Signal strength, Cell load and Distance. In the other system, ping pong avoidance threshold is considered in the basic Fuzzy handover but our proposed metric (speed and direction) is not used.

For these three methods, the simulated car is moved with different speeds *(i.e., 7kmph, 40 kmph, 70 kmph, 100 kmph, 125kmph, 150kmph and 185kmph)*. In this simulator we have calculated distance from simulation GUI and then converted into kilometer range. To keep it simple, we have calculated signal strength as a function of distance considering free space path loss for decaying signal strength with distance. We have run the simulator for different cell loads *(i.e., 20%, 50% and 80%)* to measure the performance for different traffic scenario. The ping pong threshold is set to be *0.075*.

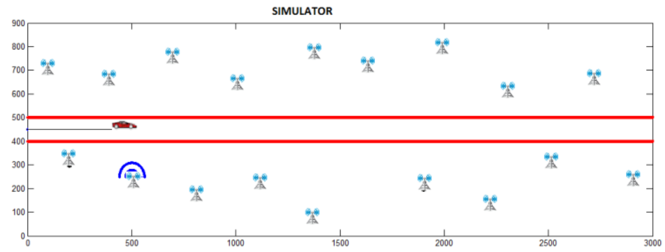

Fig. 9. Simulator

A. Effect of speed&direction:Prediction and less handover

Speed and direction plays an important role in selecting the best candidate. As it is the measure of relative speed with the BTS, it shows how fast the MS is coming towards the BTS or how fast it is going away. So it provides a prediction, after some time MS will be coming closer to a BTS or going farther from a BTS and selects candidate based on that prediction. Based on this metric, the simulators performed reduced number of handovers and avoid unnecessary intermittent handovers. In Fig. 10, 6 BTS (2, 3, 4, 10, 11 and 12) have been considered in calculation because the MS is closer to these six BTSs and signal strength of these six BTS is the highest among all. At this particular moment call is in the control of BTS-11. Based on the scenario shown, a handover will take place shortly and BTS-4 will get the control though in terms of distance, BTS-4 is the 5th out of 6 neighbors.

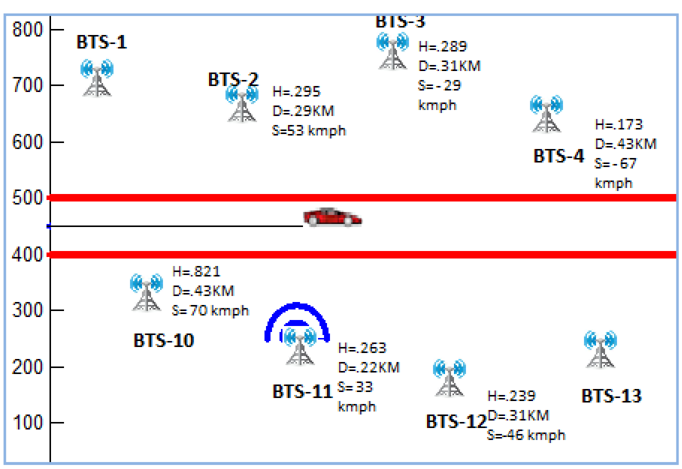

Fig. 10. Simulation Scenario

Even though the BTS-12 is nearer to the MS, the handover probability of BTS-4 is the lowest. Also, signal strength and distance of BTS-4 are in good range and relative speed towards this BTS is as high as -67kmph (negative sign is for direction). So BTS-4 appeared to be the best candidate as a serving cell and gets the control of the call. As the MS is approaching to this BTS with highest speed, it can be predicted that MS will be close to the BTS very soon. This is how the prediction is performed with the help of speed and direction metric.

B. Ping pong avoidance

A ping pong threshold has been set as 0.075. This threshold will prevent ping pong of handover for a very small change. This threshold will make sure that handover will only take place if the competitor neighbor's handover probability is more than the threshold. As in Fig. 10, BTS-12 had lower handover probability than BTS-11. For some steps earlier, when BTS-4 was not considered because signal strength, then BTS-12 was low probability but the call stayed at BTS-11 because BTS-12 was better but not crossed the threshold. If handover were to happen for BTS-12, it had to switch the control to BTS-4 after very short time. So, the threshold suppressed this unnecessary handover. For changing environment this will happen more and will aid to avoid unnecessary handover and ping pong. In Fig. 11, 12 and 13, it can be observed that number of handover is very high for the approach where threshold has not been applied for avoiding ping pong.

C. Number of handover comparison at different cell load

In Fig. 11, 12 and 13, the number of handover in different system has been compared for different cell loads. For different speed 3 approaches are compared. Blue bar graph represent our proposed algorithm, red bar graph the basic Fuzzy Handover algorithm (with signal strength, distance and cell load) with ping pong avoidance mechanism and green bar graph is Basic Fuzzy Handover algorithm without speed and direction metric and ping pong avoidance mechanism.

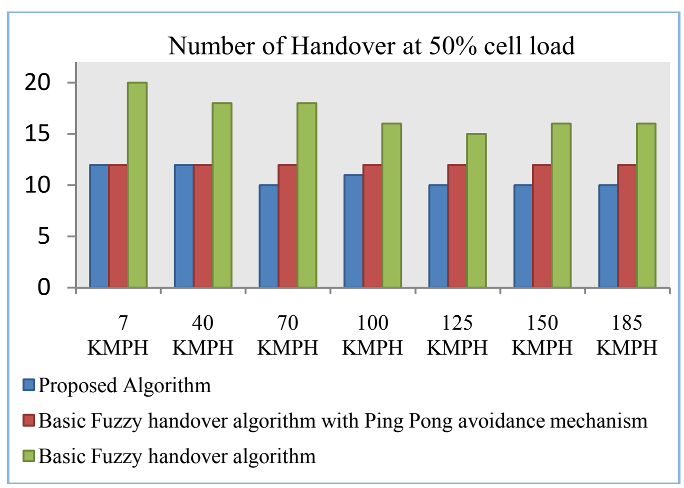

Fig. 11. Number of Handover at 50% Cell load

From graph it is clear that at low speed our proposed algorithm behaves like the second approach, but with the increase of speed, it requires less handover as proposed algorithm uses prediction based on the speed and direction metric.

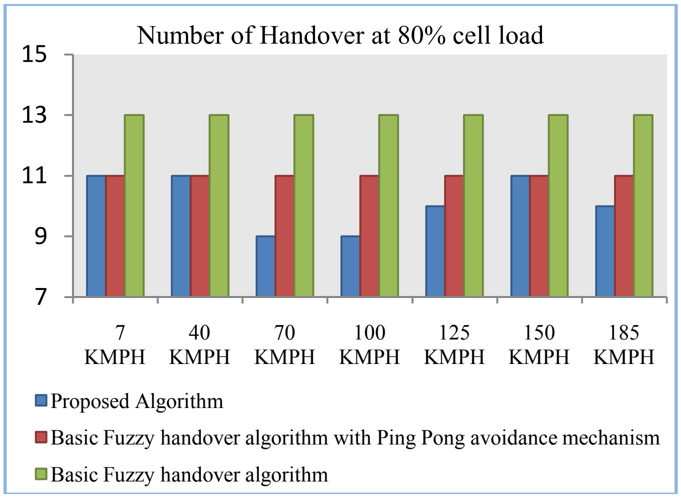

Fig. 12. Number of Handover at 80% Cell load

The effect of ping pong avoidance is clearly noticeable by comparing with the third approach which is without ping pong avoidance mechanism and it clearly shows considerable difference between the numbers of handover with other approaches.

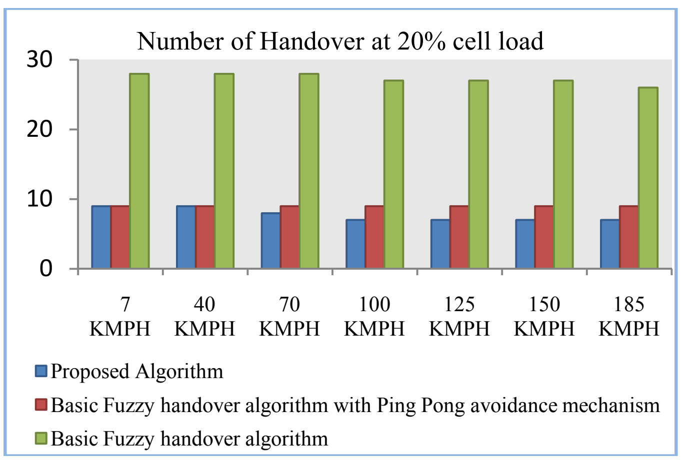

Fig. 13. Number of Handover at 20% Cell load

So, it is clearly visible that, our proposed method works not only better where the MS are in speed but also works well in less speed. Furthermore, the simulator also address ping pong and handles it well. For larger network, we believe our algorithm will decrease considerable number of handover taking place hence reducing signaling traffic in the network.

V. CONCLUSION AND FUTURE WORK

As handover is dependent on fading and other environmental factors, fuzzy logic gives good result as it can work with imprecise data. In our proposed algorithm, it has been found that, maintaining other parameters in an acceptable level handover is decreased for high speed MS, which avoids ping pong effect successfully.

As a future work we will introduce power control metric and intelligent averaging for managing signal fluctuation. A more efficient speed and direction finding process can be introduced to get more realistic handover decision. The threshold can also be tuned further. We have also a plan to design similar type algorithm for vertical handover.

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