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Decentralized Handoff for Microcellular Mobile Communication System using Fuzzy Logic

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***Abstract*—**Efficient handoff algorithms are a cost-effective way of enhancing the capacity and QoS of cellular system. The higher value of hysteresis effectively prevents unnecessary handoffs but causes undesired cell dragging. This undesired cell dragging causes interference or could lead to dropped calls in microcellular environment. The problems are further exacerbated by the corner effect phenomenon which causes the signal level to drop by 20-30 dB in 10-20 meters. Thus, in order to maintain reliable communication in a microcellular system new and better handoff algorithms must be developed. A fuzzy based handoff algorithm is proposed in this paper as a solution to this problem. Handoff on the basis of ratio of slopes of normal signal loss to the actual signal loss is presented. The fuzzy based solution is supported by comparing its results with the results obtained in analytical solution.

***Keywords*—**Slope ratio, handoff, corner effect, fuzzy logic.

I. Introduction

HANDOFF is the key operation in cellular mobile communication systems which is accomplished by the system and is imperceptible for the user. It is the means through which the continuity of a call is maintained when mobile moves from one cell area to another. Handoff is defined as the process of changing the current radio channel to a new radio channel which mainly takes place because of the movement of mobile unit and unfavorable radio conditions (deterioration of received signal quality) inside an individual cell or between a numbers of adjacent cells.

A handoff algorithm with fixed parameters cannot perform well in different system environments. Specific characteristics of the communication system should be taken into account while designing handoff algorithms. The current trend of exponential growth in the use of personal communication services is causing the industry to examine ways to use the available bandwidth more efficiently. The dimension of reduced micro-cells to meet the demand for increased capacity causes the number of handoffs to increase and thus the handoff decision time must be significantly reduced. In addition, there is corner effect phenomenon in microcells (Fig. 1). The corner effect causes the reduced signal strength at a mobile station (Ms) to drop off by 20dB or more in few meters when turning a corner. Thus, there are handoff issues that must be revived before the development in microcells.

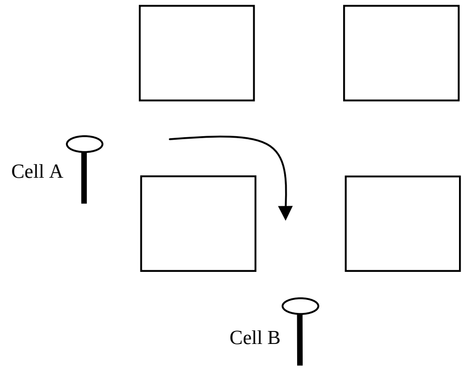

Fig. 1 Mobile station turning a corner in microcell

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Handoff techniques in cellular networks are reported in [1]-[3]. Performance analysis with bandwidth efficient handoff scheme is presented in [3]. Fuzzy logic based techniques for handoff in cellular communication has been reported in [4]-[6]. The handoff criteria use threshold values to membership functions. The possible weakness in [4] and [5] is the jump values inherent in some fuzzy sets and takes only non line of sight (NLOS) transmission into consideration. The fuzzy sets chosen in this work have smooth membership function that increases or decreases gradually.

A normal handoff scheme for channel carrying in mobile cellular networks has been reported in [7]. It increases the channel reuse factor by 1 and is more difficult to take advantage of channel carrying if traffic were to exhibit strong deterministic correlations between neighboring cells.

The nature of the decaying signal can be determined by the slope or tangent of angle subtended by the two corresponding points on signal line with respect to two axes. In this paper we present the handoff on the basis of ratio of slopes of normal decaying signal to the actual signal. On the basis of nature of

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decaying signal a threshold value is selected which decides whether a handoff is required or not. Reaching to this threshold value mobile station can make handoff to another nearby base station. Thus the handoff process is fast reduces the risk of dropped calls to a good extent. In this paper emphasis is given to the handoffs due to corner effect.

II. Analytical Solution for Handoff

The rapid decrease in signal strength is due to corner effect or any other NLOS condition in a cellular system. This may result in dropped call if handoff algorithm does not support. The decrease in received signal strength is always monitored by determining the ratio of slopes of expected normal signal and the actual signal (Fig. 2). The slope of expected signal is obtained by the difference in previous sample and expected new sample determined by extrapolation method.

Slope of normal signal

$$\tan(\theta_1) = \frac{\Delta RSS}{\Delta S_1}$$

Slope of actual signal after corner effect at A

$$\tan(\theta_2) = \frac{\Delta RSS}{\Delta S_2}$$

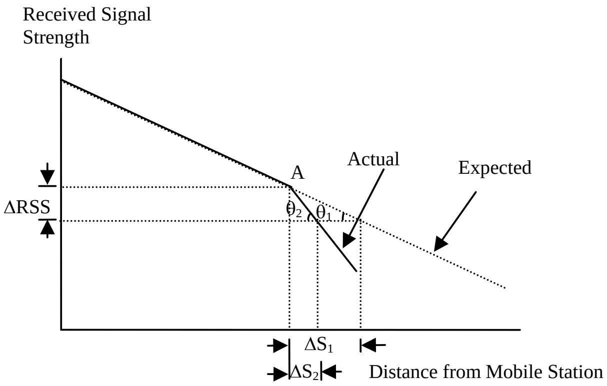


Fig. 2 Slopes of actual signal and expected signal

Slope ratio of normal and actual signals

$$S_R = \frac{\tan(\theta_1)}{\tan(\theta_2)} = \frac{\Delta S_2}{\Delta S_1}$$

$$When\, \theta_1 = \theta_2$$

$$\Delta S_1 = \Delta S_2$$

$$\Rightarrow S_R = 1$$

Where RSS =Received signal strength

ΔS_1 and ΔS_2 are small changes in distances of mobile station from base station with respect to normal and actual signals respectively.

S_R= Slope ratio

For different values of θ_1 and θ_2 various values of S_R are obtained. But for handoff to take place θ_2 must always be greater than θ_1. Thus we have only taken the values for $\theta_2 > \theta_1$ into consideration. The ratio from $\theta_1=10^0$ to $\theta_2=50^0$ has been considered with high probability. To avoid the overcrowding of data, the difference of two degrees in θ_1 and θ_2 are considered. The various values of $S_R=\tan\theta_1/\tan\theta_2$ are shown in Table I. The tabulated values are plotted in Fig. 3. For handoff to occur handoff factor is set as

S_R = .6

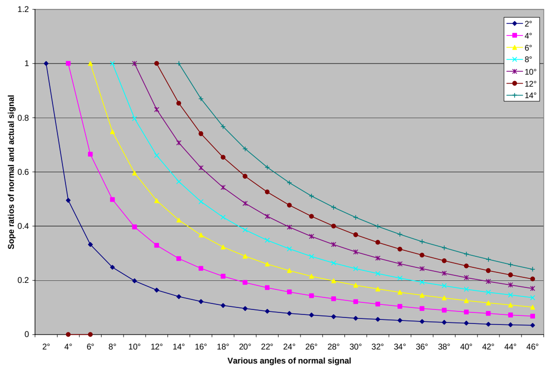


Fig. 3 Slope ratios with varying angles

III. Fuzzy Logic Solution for Handoff

Fuzzy set theory allows a linguistic representation of the control and operational laws of a system. The main strength of fuzzy set theory is that it excels in dealing with imprecision. Fuzzy logic can be used to control a complex system [8]-[10]. In classical set theory an element is either a member of a set or it is not. Classical set theory does not allow for partial membership. This kind of logic is called a crisp logic. Fuzzy set on the other hand realizes that there are a very few crisp sets in nature and so considers partial membership. Fuzzy set theory allows the gradual transition from full membership of a set to full non membership. The block diagram for a fuzzy logic system is shown in Fig. 4.

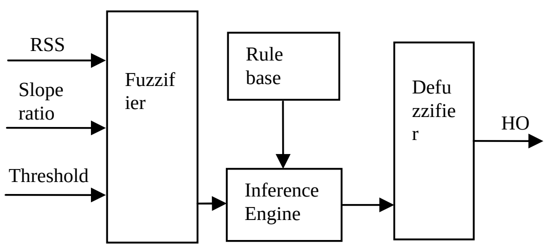
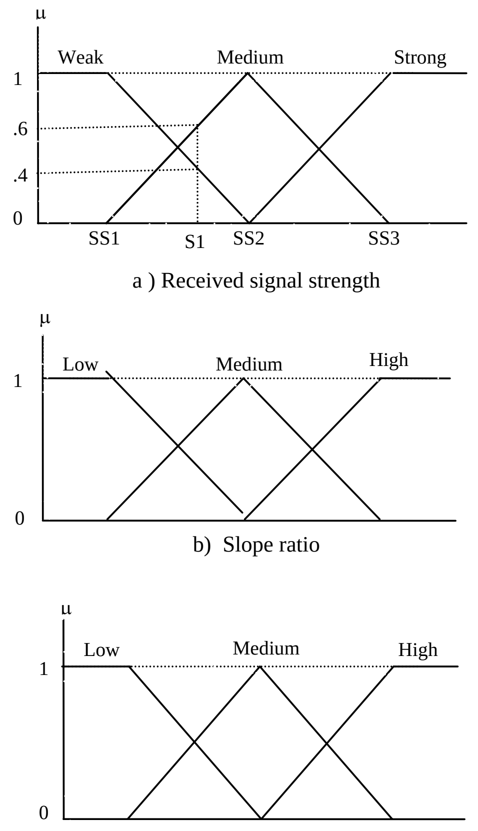


Fig. 4 Block diagram of fuzzy logic system

TABLE I
SLOPE RATIO WITH VARYING ANGLES

	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	32°	34°	36°	38°	40°	42°	44°	46°
2°	1				$\theta_1 \rightarrow$																		
4°	0.495	1			θ_2																		
6°	0.332	0.665	1		$\downarrow$																		
8°	0.248	0.498	0.748	1																			
10°	0.198	0.397	0.596	0.797	1																		
12°	0.164	0.329	0.494	0.661	0.83	1																	
14°	0.14	0.28	0.422	0.564	0.707	0.853	1																
16°	0.122	0.244	0.367	0.49	0.615	0.741	0.87	1															
18°	0.107	0.215	0.323	0.433	0.543	0.654	0.767	0.882	1														
20°	0.096	0.192	0.289	0.386	0.484	0.584	0.685	0.788	0.892	1													
22°	0.086	0.173	0.26	0.348	0.436	0.526	0.617	0.71	0.804	0.901	1												
24°	0.078	0.157	0.236	0.316	0.396	0.477	0.56	0.644	0.73	0.817	0.907	1											
26°	0.072	0.143	0.215	0.288	0.362	0.436	0.511	0.588	0.666	0.746	0.828	0.913	1										
28°	0.066	0.132	0.198	0.264	0.332	0.4	0.469	0.539	0.611	0.685	0.76	0.837	0.917	1									
30°	0.06	0.121	0.182	0.243	0.305	0.368	0.432	0.497	0.563	0.63	0.7	0.771	0.845	0.921	1								
32°	0.056	0.112	0.168	0.225	0.282	0.34	0.399	0.459	0.52	0.582	0.647	0.713	0.781	0.851	0.924	1							
34°	0.052	0.104	0.156	0.208	0.261	0.315	0.37	0.425	0.482	0.54	0.599	0.66	0.723	0.788	0.856	0.926	1						
36°	0.048	0.096	0.145	0.193	0.243	0.293	0.343	0.395	0.447	0.501	0.556	0.613	0.671	0.732	0.795	0.86	0.928	1					
38°	0.045	0.09	0.135	0.18	0.226	0.272	0.32	0.367	0.416	0.466	0.517	0.57	0.624	0.681	0.739	0.8	0.863	0.93	1				
40°	0.042	0.083	0.125	0.167	0.21	0.253	0.297	0.342	0.387	0.434	0.481	0.531	0.581	0.634	0.688	0.745	0.804	0.866	0.931	1			
42°	0.038	0.078	0.117	0.156	0.196	0.236	0.277	0.318	0.361	0.404	0.449	0.494	0.542	0.591	0.641	0.694	0.749	0.807	0.868	0.932	1		
44°	0.036	0.072	0.109	0.146	0.183	0.22	0.258	0.297	0.336	0.377	0.418	0.461	0.505	0.551	0.598	0.647	0.698	0.752	0.809	0.869	0.932	1	
46°	0.034	0.068	0.101	0.136	0.17	0.205	0.241	0.277	0.314	0.351	0.39	0.43	0.471	0.513	0.558	0.603	0.651	0.702	0.754	0.81	0.87	0.933	1

For handoff initiation three membership functions: Received Signal Strength (RSS), Slope ratio (S_R) and Threshold are used. Fuzzy sets contain elements that have a varying degree of membership in a set. Therefore, it is different from an ordinary or crisp set, where elements will only be considered members of a class if they have full membership in the class. For example, if signal strength is considered in a crisp set, the signal can only be considered to be either strong or weak, not both simultaneously, whereas in a fuzzy set the signal can be classed as quite weak, not so strong, or medium, this indicates that an element in a fuzzy set can have membership in more than one set. The membership values are obtained by mapping the values obtained for a particular parameter onto a membership function. This function is a curve or line that defines how each data or value is mapped onto a membership value. It is represented graphically in Fig. 5a, where the three lines represent the range available for weak, medium, and strong. SS1, SS2, and SS3 represent the threshold for weak, medium and strong, respectively. Then, by mapping the position of the received signal strength onto the graph of the membership function µ, the signal will be allocated with a membership value in each set ranging from 0 to 1. Therefore, if a signal falls between SS1 and SS2, it could be assigned a value of 0 in strong set and 0.6 in the medium set, and 0.4 in the weak set. This is shown in Fig. 5a for the membership function related to signal strength.



a) Received signal strength

b) Slope ratio

c) Threshold

Fig. 5 Various membership functions

Fig. 5b and c refer to slope ratio and threshold respectively. The fuzzified data is passed to the inference engine, where the fuzzified data is matched against a set of fuzzy rules using fuzzy techniques to produce output fuzzy sets. Fuzzy rules can be defined as a set of possible scenarios utilizing a series of IF-THEN rules, which decides whether handoff is necessary. Following this, a set of different handoff decisions can be obtained. An example of IF-THEN rules is as follows:

IF signal strength is weak and slope ratio is low and threshold is low THEN handoff =Yes.

The output fuzzy sets are then passed to the defuzzifier which computes a crisp output value. The fuzzy IF-THEN rules provide knowledge base to the system and results in proper handoff. The simulation data obtained from Mumdani inferences system is shown in Table II. The tabulated data plotted is shown in Fig. 6. These results are in coincidence with the results obtained by analytical solution.

TABLE II
MEMBERSHIP VALUES OBTAINED FROM MAMDANI INFERENCE SYSTEM

RSS	Slope ratio	Threshold	Handoff
0.102	0.102	0.102	0.852
0.151	0.102	0.102	0.844
0.211	0.151	0.151	0.657
0.259	0.211	0.211	0.536
0.307	0.259	0.259	0.5
0.355	0.307	0.307	0.5
0.404	0.355	0.355	0.5
0.5	0.404	0.404	0.5
0.56	0.5	0.5	0.5
0.608	0.56	0.56	0.503
0.657	0.608	0.608	0.52
0.705	0.657	0.657	0.526
0.753	0.705	0.705	0.531
0.801	0.753	0.753	0.495
0.849	0.801	0.801	0.41
0.898	0.849	0.849	0.29
0.946	0.898	0.898	0.146
0.982	0.982	0.982	0.13

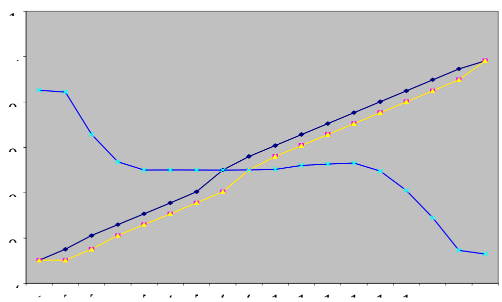


Fig. 6 Handoff with varying RSS, Slope ratio and Threshold

IV. Comparison of Results

From Fig. 3, it is evident that with the increase in slope ratio values, the curves become smoother indicating that handoff's decrease. The higher value of slope ratio means decreasing denominator value in ($\tan\theta_1/\tan\theta_2$) or in other wards θ_2 approaches θ_1 thereby the actual and normal signals approach coincidence. From Fig. 6, the slope ratio and handoff factor act inversely proportional to each other. Thus higher value of slope ratio produces lower handoff's and vice versa.

V. Conclusion

In this paper a new fuzzy based handoff algorithm capable of responding to the fast changes that occur in a microcellular environment is presented. Indeed, a fast handoff response obtained with the fuzzy algorithm is imperative for sustaining continuous communication under microcellular corner condition. These results are to be expected because fuzzy algorithms are superior to conventional ones when working in areas of uncertainties. The results obtained by both analytical and fuzzy methods are coinciding. The handoff is independent of the received signal strength of neighboring base stations, so it is mobile controlled or decentralized and is fast. But on the other hand if signal from neighboring station is low enough for handoff to take place, the call is dropped.

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