Mobile Velocity Based Bidirectional Call Overflow Scheme in Hierarchical Cellular System

G. M. Mir, Moinuddin, and N. A. Shah

Abstract**—**In the age of global communications, heterogeneous networks are seen to be the best choice of strategy to ensure continuous and uninterruptible services. This will allow mobile terminal to stay in connection even they are migrating into different segment coverage through the handoff process. With the increase of teletraffic demands in mobile cellular system, hierarchical cellular systems have been adopted extensively for more efficient channel utilization and better QoS (Quality of Service). This paper presents a bidirectional call overflow scheme between two layers of microcells and macrocells, where handoffs are decided by the velocity of mobile making the call. To ensure that handoff calls are given higher priorities, it is assumed that guard channels are assigned in both macrocells and microcells. A hysteresis value introduced in mobile velocity is used to allow mobile roam in the same cell if its velocity changes back within the set threshold values. By doing this the number of handoffs is reduced thereby reducing the processing overhead and enhancing the quality of service to the end user.

Keywords**—**Hierarchical cellular systems, hysteresis, overflow, threshold.

I. Introduction

THE continuation of an active call is one of the most important qualities of measurements in cellular systems. Handoff process enables a cellular system to provide such a facility by transferring an active call from one cell to another. 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.

In wireless cellular network, a fixed number of channels are assigned to a given cell. If a channel is used by a call, no other call can use the channel again in the same cell at the same time. With the decrease in size of the cells, the system capacity increases because of the more efficient reuse of frequencies in a given area. However, there is also an increase in the number of cell boundaries that a mobile unit crosses. These boundary crossings stimulate handoff calls and location tracking operations, which are very expensive in terms of time delay and communication bandwidth, hence limiting the call handling capacity of a cellular system. One way of controlling the increase in traffic, while preserving the frequency reuse advantage of smaller cells, is to adopt a hierarchical architecture.

When a call originates from a mobile it can move around with different speeds. Based on different mobile velocities and predetermined velocity threshold, all the calls are divided into two groups: fast calls and slow calls (including new calls and handoff calls). In general, the fast calls are served by the macrocells, while the slow calls are served by the microcells [1], [2]. In early schemes introduced in [3], [4], for each individual call, the serving layer does not change at all, e.g.; fast (slow) calls are always served by the macrolayer (microlayer). Both the schemes did not allow overflow from one tier to another. It is obvious that the procedure of allocating calls in different layers is very important. Imperfect calls assignment will result in some disadvantages, i.e., if the macrocell has no free channels, even though its overlaid microcell has many free channels, the fast calls will terminate. Two strategies for traffic management have been desired in [5]. Strategy 1, divided mobile stations into two groups based on their speed and then served by different layers to minimize the handoff rate. In strategy 2, the mobile stations may enter either layer, regardless of their speed. They also discussed how to determine the threshold speed to keep the traffic balanced between the two layers. However, the handoff rate is not the only criterion to judge the system performance, although more handoffs can cause more overhead.

Fuzzy logic control has been successful in various applications; fuzzy algorithms have also been employed to improve the cellular system performance [6], [7]. The approach used by Shun and Sung aims mainly at layer selection in hierarchical cellular systems and the fuzzy rules are constructed in order to reduce the handoff rate and the blocking probability [7], however, another important element, handoff failure probability, in ignored. Shun et al [8] presented an improved bidirectional call overflow scheme. The general performance of this scheme is good except for excessive handoffs between two tiers. Mir et al [9] presented efficient handoffs, between microcells using mobile velocity

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as an effective parameter. [10] presents decentralized handoffs between microcells due to corner effects. The major contribution of our paper is inclusion of hysteresis value in the speed of mobile station, so that a mobile station retains control of its own tier (micro or macro) if its velocity is within the hysteresis value, this avoids excessive handoffs, thus reduces overhead processing.

II. VELOCITY BASED BIDIRECTIONAL CALL OVERFLOW SCHEME

One can not presume mobiles with fixed velocities. A mobile station can change speed anytime from low to high and vice versa. Thus relying to one layer can hamper the performance of a mobile network. Also if a mobile station changes speed above and below the threshold level, the handoff triggering between two layers also increases thereby again increasing the processing overhead.

If the velocity of the mobile originating the call is bigger than the threshold, it is a fast call and will be served by macrocells; otherwise it is a slow call and will be served by microcells during its life time.

In unidirectional call-overflow scheme calls can overflow in one direction only from microcell to macrocell or vice versa [11], [12]. When a slow call originates and if all channels in the current microcell are engaged then this call will overflow into the corresponding macrocell. If all the channels of the target macrocell and microcell which the mobile will move into are used, the slow handoff calls will be terminated. The bidirectional call overflow scheme increases the channel utilization and reduces blocking probability and failure probability of handoff calls.

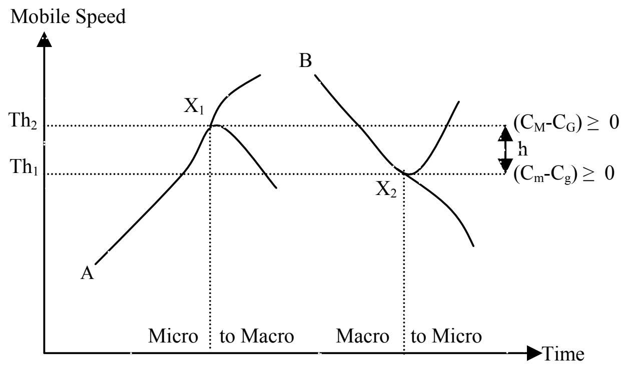


Fig. 1 Movement of MS from microcell to macrocell and vice versa with two thresholds in speed

Figure 1 depicts the movement of mobile station from microcell to macrocell and vice versa with two thresholds in speed of mobile station. Supposing a call is initiated at ‘A’ and mobile station is accelerating. When the mobile station reaches threshold level Th_1 call is not handed off to macrocell layer till another threshold value Th_2 is reached, however the handoff within the same tier (microcell to microcell) can take place. The two thresholds will enable mobile station to retain the call in the same tier if speed of mobile station decreases. Similarly when a call is initiated at ‘B’ and mobile station is decelerating, the call is retained in macrocell tier till threshold level Th_1 is reached. Table I shows the movement of mobile station from one cell to another within same or different tiers with different values of thresholds.

TABLE I
MOBILE MOVEMENT WITH THRESHOLD VALUES

For call starting at A	
Threshold status	Action
$(Th_2\text{-}Th_1) < h$	Microcell to microcell
$(Th_2\text{-}Th_1) \geq h$	Microcell to macrocell $(C_M\text{-}C_G) \geq 0$
For call starting at B	
Threshold status	Action
$(Th_1\text{-}Th_2) < h$	Macrocell to macrocell
$(Th_1\text{-}Th_2) \geq h$	Macrocell to microcell $(C_m\text{-}C_g) \geq 0$

Where C_M, C_m is total channels in macrocells and microcells respectively and C_G, C_g is the guard channels in macrocells and microcells respectively. The bidirectional call overflow scheme is shown in Figure 2. As long as there is free channel either in microcell or in macrocell, a new or handoff call will not be blocked. Table II shows different membership values for various values of hysteresis, threshold and received signal strength. These values are obtained by simulation method with the help of Mamdani inference system

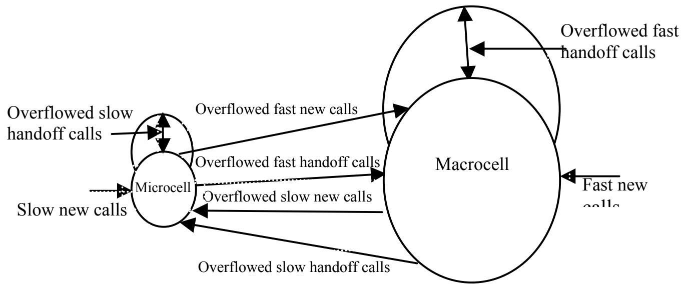


Fig. 2 Bidirectional call overflow scheme

TABLE II
MOVEMENT OF MOBILE WITH DIFFERENT VALUES OF RECEIVED SIGNAL STRENGTH, HYSTERESIS AND THRESHOLD

RSS=2, Hysteresis=1.02, Threshold=2

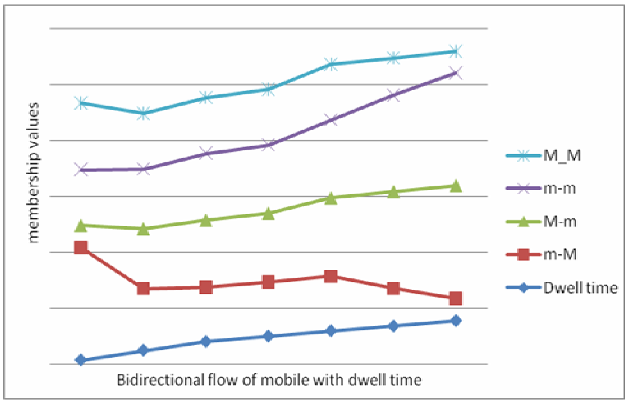
Dwell time	m-M	M-m	m-m	M-M
0.34	10.1	1.94	5	6
1.22	5.52	5.35	5.35	5
2	4.86	6	6	5
2.49	4.86	6.13	6.13	5
2.98	4.86	7	7	5
3.4	3.36	8.64	8.64	3.36
3.89	1.96	10.1	10.1	1.94

RSS=2.98, Hysteresis=3.07, Threshold=2

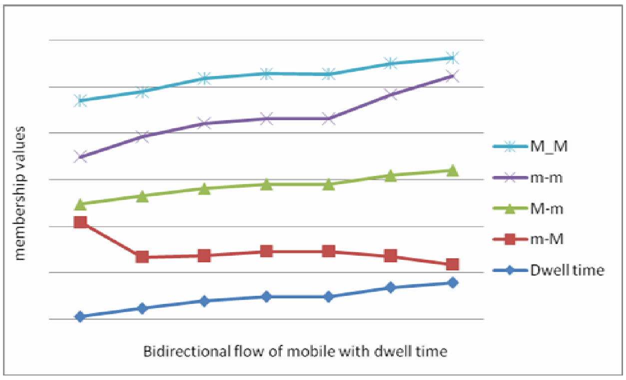
Dwell time	m-M	M-m	m-m	M-M
0.34	10.1	1.94	5.09	6
1.22	5.52	6.51	6.37	4.8
2	4.86	7.2	7	4.8
2.49	4.86	7.2	7	4.8
2.48	4.86	7.2	7	4.8
3.48	3.36	8.64	8.64	3.36
3.99	1.94	10.1	10.1	1.94

RSS=3.95, Hysteresis=2, Threshold=2

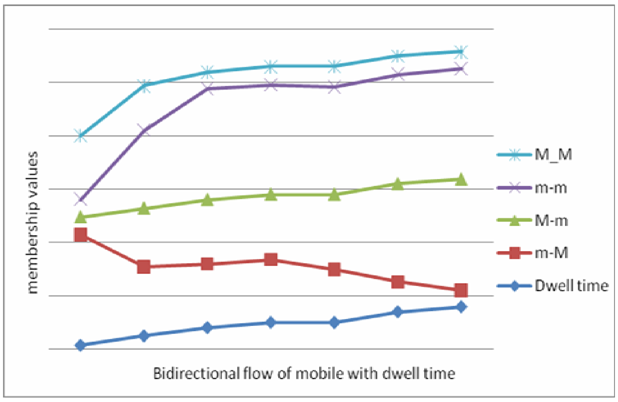
Dwell time	m-M	M-m	m-m	M-M
0.34	10.4	1.63	1.63	6
1.22	6.52	5.46	7.31	4.17
2	6	6	10.4	1.56
2.49	5.91	6.09	10.3	1.68
2.48	5	7	10.1	1.94
3.48	2.83	9.17	10.3	1.7
3.95	1.56	10.4	10.4	1.56



(a)



(b)



(c)

Fig. 3 Movement of mobile station between microcells(m) and macrocells(M)

III. CONCLUSION

The high dimensional expansion of cellular mobile communication requires high capacity cells to cater the new traffic demands. The two tier system with conditional controlled bidirectional movement facility provides the resources for combating with high traffic demands. This work can be extended for conditional traffic control via satellite to reach desired terminal. In the multilayer system, our scheme is more flexible to deal with high teletraffic at peak hours in different layers and getting better system performance.

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