A New Traffic Load Shedding Scheme in Microcellular CDMA with Uniform and Non-uniform Traffic Load

Woo-Goo Park, Ja-Gan Rhee, Hun Lee, and Sang-Ho Lee

Abstract

In this paper we proposed a new traffic load shedding scheme which maximizes the throughput of traffic control by decreasing the load of the hot-spot cell using minimum load cell selection (MLCS) algorithm and deployed control flow of calls to define characteristic for handoff region. We compared the performance of the random shedding approach with that of the proposed algorithm. The results of simulation show that MLCS algorithm minimizes the call blocking rate under a high-density traffic compared to the random shedding scheme.

I. Introduction

Future communication systems are expected to handle a variety of user characteristics, including moving and environments[1, 2]. The systems are considered to be offered under a high-density traffic for which an overload status may be caused. This overload status may increase the call blocking rate(CBR). Especially, in reference to some papers, the more a cell decreases, the more a traffic increases. In the part of traffic controls many mathematical models have been studied and developed[3-8] adequate for traffic analysis of mobile communication systems. To prevent the increase of call blocking due to unpredicable high-density traffic in a cell, a reliable and efficient traffic control scheme is required in digital cellular mobile communication systems. Generally, in CDMA digital cellular mobile communication systems, the call service may succeed or fail depending on the availability of radio resources. Especially, some channel resources should be reserved for handoff call to other base stations in charge of being connected with originating calls. The lack of reserved channel resources for handoff call may result in failure of handoff call attempt. It is important to know how to control channel resources in order to maintain originating and handoff call connection[1, 10, 11]. T. P. Yum studied the effect of relieving congestion at a single hot-spot cell by using cell sectoring and cell overlaying [15]. Since a high-density traffic load severely degrades call admission rate and channel utilization by concentrating on an arbitrary cell, traffic load shedding scheme is required[9-11, 14]. To control a high-density traffic, traffic shedding scheme is introduced[9]. For example, such scheme is used for shedding a traffic by changing a pilot signalling strength. X. H. Chen[9] proposed a traffic shedding scheme for which the service boundary can be controlled between hot-spot cell and neighbor cells using random cell selection. However we shall not dwell upon these issues-changing of pilot signalling strength are considered here. We proposed a new traffic shedding scheme using minimum load cell selection(MLCS) algorithm for the microcellular environments. If an arbitrary cell has a high-density traffic, CBR is seriously increased. So we introduce selection algorithm which moves the traffic load on a hot-spot cell into a neighboring cell by selecting a minimum load.

We considered a cell model which consists of a hot-spot cell and 6 neighboring microcells, used for an originating and handoff call subject to the fixed channel assignment scheme to make a traffic model under a high-density traffic. The traffic model parameters such as the arrival rate of an originating and handoff call, and cell service boundary as a CBR are analyzed. We also selected the cell with a minimum load using MLCS algorithm and then reduced the traffic load of a high-density traffic by extending the selected cell service boundary through the pilot signalling control. We compared the performance of the random shedding approach with that of the proposed algorithm. The results of simulation show that MLCS algorithm minimizes the CBR under a high-density traffic environment compared to the random shedding scheme.

The Organization of the paper is as follows. In Section 2 system model and the scheme of the conventional traffic shedding are described in detail and effect of traffic load and cell service boundary is presented in section 3. In section 4 we propose a new

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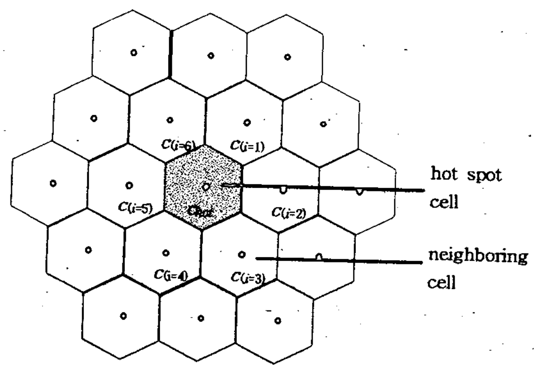


Fig. 1. Cell structure.

traffic shedding scheme using MLCS algorithm. We will compare the performance of the proposed approach with that of the random shedding approach in section 5 and conclude in section 6.

Ⅱ. System Model

1. *Overview of Cell Structure*

In digital cellular mobile communication systems it is necessary to maximize the service capacity by expanding the frequency reuse factor through adopting a variety of cell structures to a number of users to provide good quality of service (QoS). In this paper we propose a model that consists of a core cell named hot-spot cell, and 6 neighboring cells which have 3 sectors. A cell model for much of what we will be discussing is captured, in very general terms, in Fig. 1.

2. *Traffic Load Shedding Scheme*

The call processing of digital cellular communication system based on DS/CDMA is controlled for the received power strength of the mobile by performing power control. Power control is the most important system requirement for CDMA system, since only by control of the power of each mobile accessing a cell can be shared equitably among users and the capacity maximized[3-5]. This feature of conventional CDMA system is what makes it feasible for widespread use. Thus, with controlling of pilot signalling strength, the cell service boundary can be expanded. To understand the feature of the traffic load shedding, let us consider a scheme that is widely used on digital cellular communication systems. X. H. Chen proposed a traffic shedding scheme for which the service boundary can be controlled from r to r' ($r' \geq r$) between hot-spot cell and neighboring cells as shown in Fig. 2[9-11].

3. *Minimum Load Cell Shedding Model*

The MLCS model adopted is based on a traffic load shedding scheme by X. H. Chen. Therfore the overall structure of MLCS

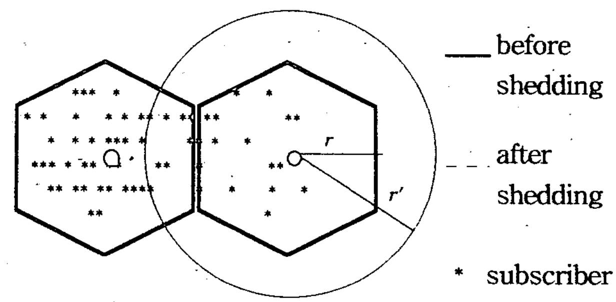


Fig. 2. Traffic load shedding scheme.

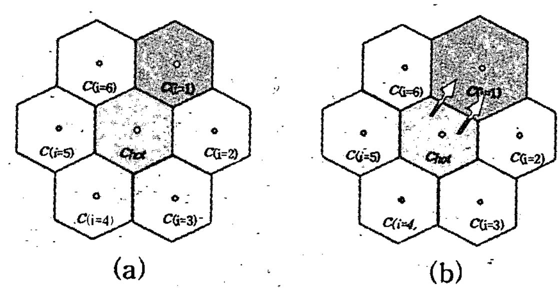


Fig. 3. Model of minimum load cell.

is similar to X. H. Chen. The purpose of MLCS scheme is to maximize not only call capacity but also channel utilization and to minimize the high-density traffic concentrated upon an arbitrary cell via reliable cooperation of traffic control functions. Fig. 3 shows the model of proposed traffic shedding based on MLCS algorithm. C_{hot} is defined as a hot-spot cell and also C_i as i^{th} neighboring microcell of C_{hot}. If there is a high-density traffic load upon an arbitrary cell (C_{hot}) as shown in Fig. 3(a), MLCS algorithm selects one of the neighboring cells to minimize the high-density traffic on a hot-spot cell. And it also expands the service boundary of selected cell and then some mobile users close to neighboring cell will be handed off. By expanding a service boundary of minimum load cell ($C_{(i=1)}$) as shown in Fig. 3(b), we can expect an effective control of high-density traffic of hot-spot cell and can maintain the user's service with reliability. Many research papers are studies based on the assumption of uniform traffic distribution and there are few studies on CDMA systems considering non-uniform traffic distribution[13]. We compared to traffic load shedding schemes with uniform and non-uniform traffic load.

Ⅲ. Effect of the Cell Traffic and Service Boundary for Handoff

The traffic both in a hot-spot cell and selected cell is generated by a new and handoff calls as requests. The arrival rate of a new calls follows a Poisson process-λ and also that of handoff calls may be approximated by a Poisson process-λ_h. In general CDMA digital cellular communication systems λ_h is lower than

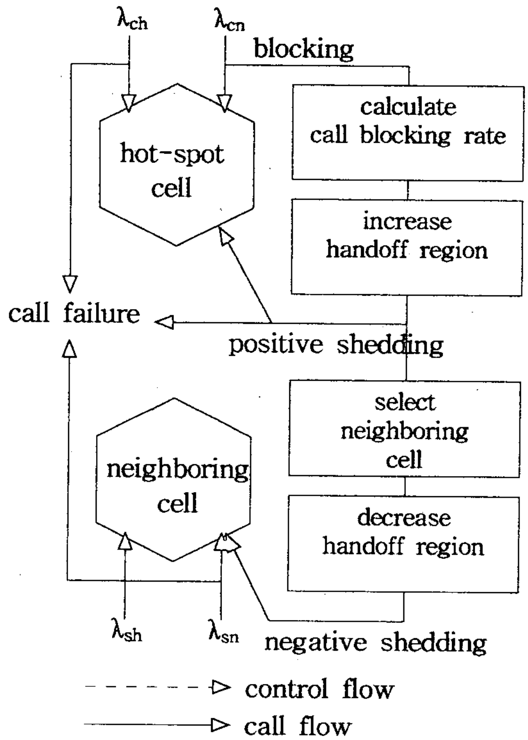
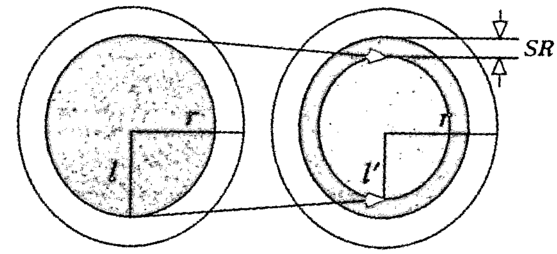


Fig. 4. Traffic control flow of calls.

λ. Suppose that arrival rate of a new and handoff calls is mutually independent. Therefore we regard λ, λ_h as λ_{cn}, λ_{ch} in a hot-spot cell and as λ_{sn}, λ_{sh} in a neighboring cell selected by shedding scheme. Fig. 4 illustrates traffic control flow of calls to define characteristic for handoff region in microcell structure.

The handoff region, in this paper, is modified by CBR. For microcells with a radius, parameter r, the cell service boundary is l ($l < r$). When a call attempt arrives in a hot-spot cell, if no channel is available, the call is blocked and CBR is high. There is an approach to avoidance continuous traffic into a hot-spot cell: the shedding scheme calculates CBR and increases handoff region ($l' \leq l < r$) and a call has a chance to handoff into a neighboring cell as little as decreasing handoff region; it is referred to as positive shedding. On the other hand, in a neighboring cell selected by shedding scheme, service boundary is decreased and a call has a chance to handoff into hot-spot cell; it is referred to as negative shedding. Therefore the total traffic load over cells is decreased as much as CBR in a hot-spot cell. However, the rate of deceased traffic load may limit the level of service boundary/cell radius ratio. Let us take a closer look at the essential elements of a proposed scheme, using Fig. 5. As with any traffic load shedding scheme, there are two elements to the proposed model: the cell radius(r) and the service boundary (l) to be increased or decreased. Fig. 5 shows the relationship of positive shedding between the cell radius and the service boundary. (r-l) is a handoff region. There is a difference between before and after shedding, it is a shedding rate (SR) based on



(a) before shedding (b) after shedding

Fig. 5. Shedding effect of a hot spot cell.

CBR. For efficiency of model, circle model is used for cell.

Since reducing the cell size brings severe non-uniformity in traffic distribution, in this paper we do not change the cell service boundary by shrinking the cell size but change the handoff region by means of the CBR.

IV. MLCS Algorithm for Traffic Load Shedding

As previously stated, with a pilot signalling strength, cell service boundary expansion is achievable on this proposed model. The scope of this algorithm, which can be considered the simplest attempt to counteract traffic unbalancing, is to load each cell unequally, even if the traffic distribution is uniform. If the traffic load in an arbitrary cell is likely to be high, so traffic load increases its required channel resources more, but the channel is not available. Consequently, call attempt is rejected and CBR is increased. In our algorithm, we calculate the CBR as it can be considered the factor of the performance achievable by means of this algorithm. Fig. 6 illustrates the procedure of the MLCS algorithm. The MLCS algorithm consists of a load calculation module and a minimum load selection module. The load calculation module is a process that checks the load of neighboring cells. The minimum load selection module will selects a cell which has a minimum load among neighboring cells. If it detects a high-density traffic depending on traffic monitoring which periodically performed, it checks traffic load for all neighboring cells of a hot-spot cell. If it is possible to apply for this algorithm, it calculates the traffic load of all neighboring cells and also selects the minimum load cell used to expand a cell service boundary. By distributing a heavy traffic among cells simultaneously, base station with a hot-spot cell avoids the abrupt system malfunction. In order for an MLCS algorithm to be able to play its role as traffic controller, it must know the needs of power control within a cell. This algorithm makes more effective use of the channel resource as it allows some power control technique to occur between a hot-spot cell and its neighboring cells.

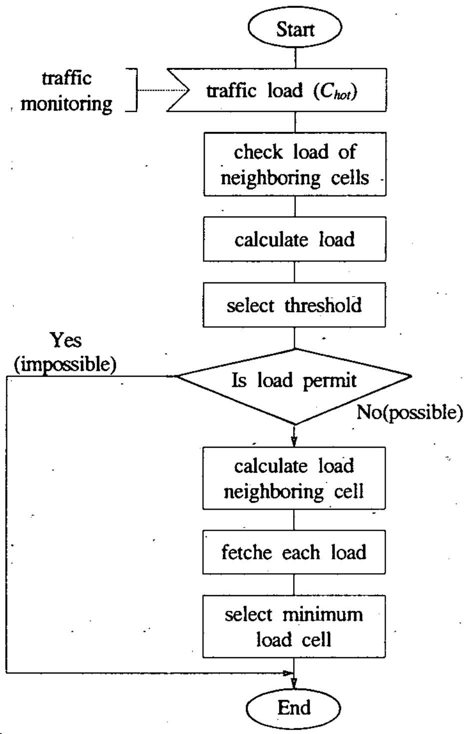


Fig. 6. MLCS algorithm.

V. Performance Evaluation

1. Simulation Considerations

We consider only the traffic load by CBR as it is usually recognized easier than the interference. The simulation model adopted is based on the received signal power, namely P_r[12]. The received signal power is generally modeled as the product of the $(-\alpha)$th power of distance and a log-normal component representing random deviation.

$$P_r = P_t \cdot r^{-\alpha} \cdot 10^{(\sigma/10)} \tag{1}$$

where P_t is the transmitter signal power, r the distance from mobile subscriber to base station. α *is* usually set to 3.5 as propagation constant, and σ is described as distributed random deviation with a mean of 0. In order to evaluate the performance, we defined the CBR associated with the offered load.

$$CBR = \frac{no.\ of\ call\ blocking}{arrival\ rate\ of\ calls} \tag{2}$$

In the simulation, the arrival rate of call, call holding time and no. of channels are assumed as described in Table 1. The handoff region is less than cell radius, whereas the adopted cellular type is the conventional hexagonal type[8], with cell radius equal to 1000m. Here, λ_{cn}, λ_{s1n}, λ_{s2n}, λ_{s3n}, λ_{s4n}, λ_{s5n}, and λ_{s6n} are also assumed as originating call arrival rate and λ_{ch}, λ_{s1h}, λ_{s2h}, λ_{s3h}, λ_{s4h}, λ_{s5h}, and λ_{s6h} denote the arrival rate of handoff calls per unit area of each cell. All arrival rates of cells are the same. We consider C_1 with a minimum load and C_3 with a random cell, which are the neighboring cells. λ_{1n} of C_1 is less than among λ_n of C except C_{hot}. Similarly, with traffic shedding on a hot-spot cell C_{hot}, it is natural that λ_{1h} of C_1 is less than λ_{3h} of C_3 moving into C_{hot}. Therefore the total arrival rate λ_T adopting the proposed scheme may be less than proportional to $(\lambda_{3h}-\lambda_{1h})$ compared with and without the random shedding. To evaluate the shedding schemes as described in 4.3, from Erlang-B formula, the total traffic load is 46.8 Erlang per cell with CBR, 0.02.

Table 1. Simulation parameters.

call arrival	Poisson Distribution
call holding time	Exponential Distribution in 100sec in average
no. of channel / cell	52
no. of guard channel	5
call direction	one direction
cell radius	1000m
user's velocity	10m/sec

2. Shedding Schemes

There are three schemes of traffic load shedding within the microcellular CDMA communication environment, no-shedding scheme, random shedding scheme, and minimum load shedding scheme. Here we will evaluate the following three typical traffic shedding schemes. The arrival rate of handoff call in a cell may be increased, if l is expanded by adopting CBR. Accordingly, each schemes controls the SR at a rate that is consistent with the CBR agreed during call conversation.

1) NSS (no-shedding scheme) : This scheme is simple to know for analyzing the traffic. It is not necessary for shedding on a high-density traffic.

2) RSS (random shedding scheme) : In this scheme if traffic load is heavy, this algorithm selects an arbitrary cell among neighboring cells and expands a service boundary on a selected cell.

3) MSS (minimum load shedding scheme) : It is equivalent to RSS without a selected minimum load cell. This is the main difference between RSS and MSS. When a cell takes a high-density traffic load, CBR is increased. This scheme selects the minimum load cell among neighboring cells and expands a service boundary on a selected cell using the MLCS algorithm as required for measured CBR.

3. Results Analysis

1) Performance with uniform traffic load

We evaluated the blocking performance with and without shedding under uniform traffic load per cell. Consider that 57 channels (including 5 guard channel for handoff call) can be assigned by call with the weight value assumed as 2.0. Assume that there are 7 mutually independent Poisson processes with arrival rates (assumed equal to 2.73), $\lambda_{c(n+h)} = \lambda_{s1(n+h)} = \lambda_{s2(n+h)} = \lambda_{s3(n+h)} = \lambda_{s4(n+h)} = \lambda_{s5(n+h)} = \lambda_{s6(n+h)}$ with the call holding time (μ), and μ ($1/\lambda$) is taken equal to 100sec. Based on the superposition of independent Poisson processes, the total arrival rate in service area is ($\lambda_{s0}=\lambda_c$),

$$\lambda_T = \sum_{i=0}^{6} \lambda_{si} = 7\lambda \tag{3}$$

The simulated CBR with shedding scheme is lower than the results obtained without shedding scheme. Results are shown in Fig. 7 with and without shedding scheme. The total CBR for shedding is about 0.0178 in lower case and 0.0225 in the upper case. For all cases, simulation presents that the simulated CBR with shedding is much lower than that without shedding, and the difference is about 20.97%.

2) Performance with non-uniform traffic load

To simulate three shedding schemes under non-uniform traffic load between cells efficiently, we introduce non-uniform traffic load into all cells. For the offered load in a hot-spot cell 66.8 Erlang is used and for minimum shedding cell has 26.8 Erlang and other cells 46.8 Erlang. As explained, for simulation with non-uniform traffic load, the arrival rate can be assumed 1.49 (hot-spot cell) : 2.13 (cell for random shedding) : 3.73 (cell for minimum load shedding) with the weight value assumed as 5.0. Assume that there are 7 mutually independent Poisson processes with arrival rates, $\lambda_{c(n+h)} > \lambda_{s2(n+h)} = \lambda_{s3(n+h)} = \lambda_{s4(n+h)} = \lambda_{s5(n+h)} = \lambda_{s6(n+h)} \geq \lambda_{s1(n+h)}$ with the call holding time. Based on the superposition of independent Poisson processes (in case of fixing the mean Erlang of 7 cells as 46.8), thus we may express the total arrival rate per cell as

$$\lambda_T = \lambda_c + \lambda_{s1} + \sum_{i=2}^{6} \lambda_{si} \tag{4}$$

Fig. 8 and Fig. 9 are shown the blocking performance of originating and handoff calls among three schemes based on this paper for given offered load. From this result we can see that the blocking performance of MSS is very similar to that of RSS. Moreover, the CBR of NSS is greatly larger than that of RSS. The reason is due to the increase arrival rate of calls in a hot-spot cell by adding calls in the cell selected by a random load shedding scheme. Therefore it is likely that the CBR of RSS compared with NSS and RSS decreases the possibility of the channel assignment at the handoff request from other cells to the cell selected by the minimum load shedding scheme. Thus we can see that the CBR of RSS is much higher than the difference between the arrival rates in a cell selected by a random load shedding scheme and that in a minimum loaded cell.

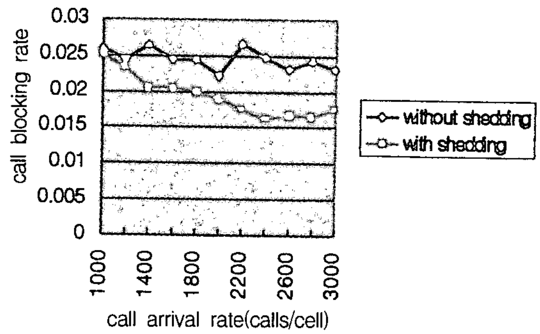


Fig. 7. Blocking performance with and without shedding.

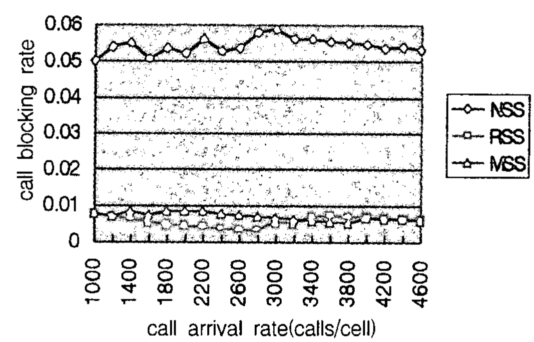


Fig. 8. Blocking performance of schemes for originating calls.

The algorithm that determines the SR must be chosen so as to balance the service boundary and cell radius.

For handoff calls in Fig. 9, it is shown that the CBR of all schemes is the same under 1800 calls as the arrival rates. However the CBR of RSS is higher than that of MSS because the arrival rate of calls of random shedding cell is increased by the hot-spot cell compared to that of minimum load shedding cell. This Fig. illustrates that the higher the CBR of originating calls the greater that of handoff calls compared to that of originating calls for improving the traffic density in a hot-spot cell.

Fig. 10 compares the blocking performance of NSS and MSS as well as RSS. This result shows, at least for this simulation model, that MSS provides effective traffic control and better channel resource utilization in high-density loaded situations than not only NSS but also RSS. It is worth pointing out that the CBR of MSS is less than 0.0467 for that of NSS case and also less than 0.006 for RSS case.

As far as the blocking performance of various traffic shedding schemes is concerned, first we compared the blocking performance between with and without shedding schemes which lead to an equal average traffic load in every cell. Then we also compared the blocking performance among shedding schemes which lead to an unequal traffic load in every cell. Now let us discuss more closely the shedding rate for a weight of the CBR, as illustrated in Table 2.

We can see, in Table 2, the SR of service boundary subject

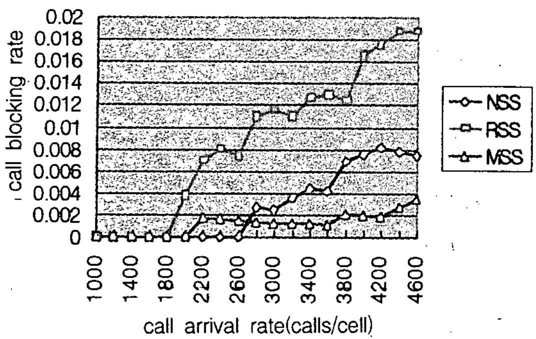


Fig. 9. Blocking performance of schemes for handoff calls.

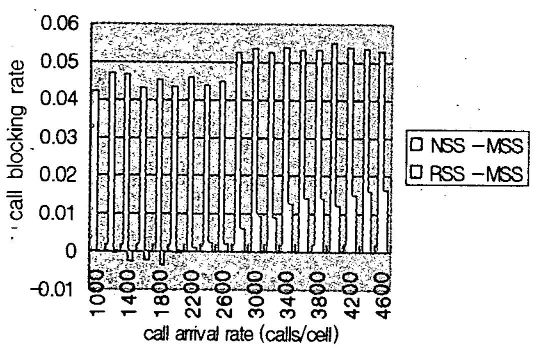


Fig. 10. Comparison of blocking performance among schemes for originating and handoff calls.

Table 2. Effect of shedding rate (SR) on increased weight of CBR (ω)

Type \ ω	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
RSS	2.88	2.69	8.69	3.20	6.10	3.87	15.03	13.39	20.80	23.05
MSS	4.66	4.49	3.93	5.15	6.94	7.57	21.25	14.90	11.39	14.56

Table 3. Influence of CBR according to the increased weight of CBR (ω)

Type \ ω	1.0 / 6.0	2.0 / 7.0	3.0 / 8.0	4.0 / 9.0	5.0 / 10.0	Σ	Mean
RSS	0.0166	0.0078	0.0108	0.0073	0.0235	0.1308	0.0131
	0.0154	0.0192	0.0118	0.0081	0.0103		
MSS	0.0191	0.0173	0.012	0.0089	0.0088	0.1248	0.0125
	0.0137	0.0157	0.0132	0.0045	0.0116		

to the increase in weight for the SR and also see that the variance of SR for weight of CBR is slightly large for ω = 10.0 because the increased weight of the CBR (ω) severely degrades the SR with shedding rather than without shedding for ω > 7.0. The SR of MSS is lower than that of RSS. Therefore it is efficient for MSS to apply to a high-density traffic compared to RSS, and we find out how the performance of each traffic load shedding scheme is affected by CBR under a high-density traffic loaded situations. Table 3 illustrates influence of CBR according to the increased weight of the CBR and it compares the MSS of our algorithm with that of the RSS when we use the weight of CBR. From the simulation result, on average, it is shown that the MSS provides about 4.58% CBR over the RSS.

Ⅵ. Conclusion

In this paper, we proposed a new traffic load shedding scheme and compare the performance of MSS with that of NSS and RSS schemes. In order to introduce a traffic model, we selected the cell with a minimum load using MLCS algorithm and then reduced the traffic load of a high-density traffic by extending the selected cell service boundary through the pilot signalling control. We concentrate upon the performance analysis of shedding schemes rather than how to shrink the cell coverage. The proposed scheme is a scheme by which each base station controls adaptively cell service boundary for handoff call according to the observed call blocking rate. Simulation results show that MLCS algorithm keeps the traffic load and channel resources well controlled and minimizes the CBR for even the offered high-density traffic load exceeding the cell service capacity. It is found that our proposed model can achieve a better performance than a random shedding scheme under a high-density traffic loaded situation. Consequently, these studies will be used to assist the developers in implementing their studies to fully solve the high-density traffic of wireless multimedia communication systems based on CDMA.

Futher studies should be considered the other factor, such as E_b/N_0 (The ratio between the energy of each information bit (E_b) and the noise spectral density (N_0)) in terms of system reliability.

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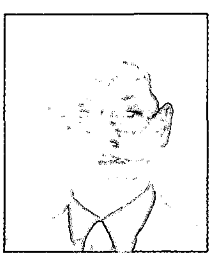

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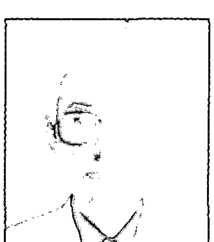

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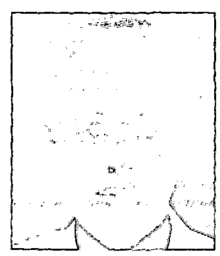

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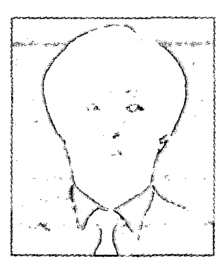

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