New Approach to Call Admission Control based-on Interference for Hot-spot Cell

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***Abstract*—In this paper, we propose a new call admission control (CAC) scheme for wireless cellular systems supporting a hot-spot cell. Two strategies for CAC are assumed. One is based on the number of calls, which are accepted or not, the other is based on the interference level. The proposed CAC can regulate the call attempts with packet by adopting measured interference used for matrix. A function, specifically a linear interpolation function based on Inverse Transform theory is used to convert controlled predictive average admission ratio in a call rejection ratio. Then, a call admission ratio is obtained from the call rejection ratio. Numerical results show that the proposed scheme yields better performance than the conventional scheme does under the heavy calls on a hot-spot cell.**

Keywords-Call Admission Control; Hot-spot Cell; Traffic Model; Interference; Inverse Transform;

I. INTRODUCTION

In the future wireless communications, the main problem is focused on how to efficiently utilize the limited frequency spectrum. The CAC schemes have been mainly developed in switching system maintained by stored program control. The system is formed with a plurality of processors, which are distributed and are formed in a hierarchical structure. The base station performs a predetermined call control process and a non-call control process in accordance with the internal process. In addition, a designated protocol is performed through an interaction between base stations. When interference of a base station is increased, such a load affects other base stations and the entire cells. As a result, the service of the system may be interrupted thereby. Hot-spot activation scheme in classical wire telephone is based on weighted interference. The conventional call admission schemes are directly used by the weighted interference so as to ensure the rapid response of control [1]. However weighted interference provides only rough information on the predictive offered calls, because the offered load is caused by a call. To reduce this degradation, precise CAC scheme based on interference is required. This paper analyzes the effect of weighted interference and call fail ratio on the system performance in theory. Weighted interference efficiency equations are derived for both systems with and without CAC. Analysis results show that call admission can get maximum call efficiency while adjusting call admission can improve call fail for systems without CAC.

This paper is organized as follows: In section II, related works have been studied and in section III cell, traffic and system model are proposed, and also we classifies calls in terms of their characteristics. Section IV describes the call admission activation scheme using interference and call success ratio considering matrix, and also shows the theoretical backgrounds by re-analyzing the relation between interference and wireless channel resources. In section V, we evaluate the proposed CAC model. Finally, Section VI presents the conclusion.

II. RELATED WORKS

The capacity of a cell is limited by its interference and channel resource, which depends on offered calls [1]. The CAC schemes associated with communication systems have been mainly developed on switching system maintained by stored program control [2]. Recently CAC has been dealt with for data service only [3], [4]. CAC is necessary to guarantee the quality of service (QoS) for the users in service, which is mainly concentration on a hot-spot area. In hot-sot area, cell poses significant challenges because of interference, user mobility, and limited channel resource. To efficiently accept call attempts and effectively maximize cell capacity, the cell size is getting smaller. However the smaller cell size is, the higher interference is. So we need to improve the call admission ratio in bad interference environments.

The CAC thresholds derived from the traffic theory [5] and [10]. In [10], the tri-threshold bandwidth reservation scheme supports multi-class services bearing differentiated QoS requirements. It is directed to a mobile switch formed with processes for a judgment such as an admission, a control and a release. We used weighted interference as traffic load for CAC. A QoS-aware wireless MAC protocol called Hybrid Contention-Free Access (H-CFA) and a VoIP call admission control technique called the Traffic Stream Admission Control (TS-AC) algorithm has been presented in [11] to support VoIP, specially on WiFi technologies which have already matured commercially.

It is practically, however, hard to apply to the real-time system. In this paper we suggest that CAC scheme safely maintain the call service by analyzing the characteristics of the weighted interference and the call fail ratio due to congestion, and increases the call

 ISBN: 978-1-61208-279-0

admission ratio [6]. We deal with data traffic as well as voice.

III. Proposed Model

A. Cell Model

Fig. 1 depicts a cluster of 19 cells being built around interfering base stations. Base station density is based on [9] (cell radius of 4 km for rural/macro and 1.5 km for urban/macro have been assumed). Some comparative simulations were also performed with cell radio as low as 500m and as high as 9 km. The contribution from interferers beyond the closest 19 is considered to be insignificant.

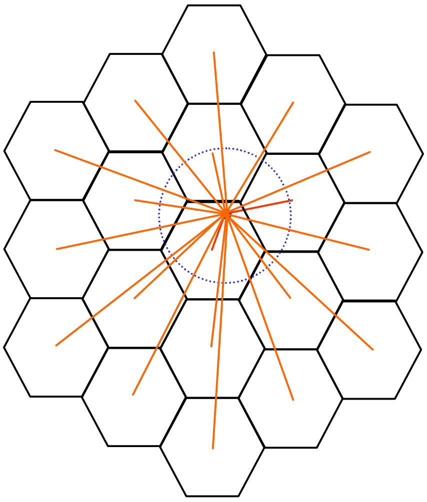

Figure 1. A Cluster of 19 interfering cells

B. Traffic Model

We consider that the call arrival process at the base station is Poisson [7]. Assuming that the call generating process of all the users in a hot-spot cell are independent, the call arrival process from each and every user is also Poisson [8], with a mean call arrival ratio λ , where $\lambda = \lambda^n + \lambda^h$.

TABLE I. Characteristics Of Calls

Location	Service Types	Direction	Arrival Ratio	Priority
Inner Cell	Originating Call	No	λ^n	4
	Terminating Call	No	λ^n	1
Inter Cell	Incoming Handover Call	From Other Cell	λ^h	3
	Outgoing Handover Call	To Other Cell	λ^h	2

The movement of each user is modeled by the two-dimensional random walk and is stationary process including handover from/to neighboring cells. User's channel holding time follows a negative exponential distribution with mean $1/\mu$.

The call admission activation function periodically audits the intensity of call, weighted interference, and call success ratio by time t, in order to avoid the degrading of the performance of system and service ratio. Gradually, a grading limitation of execution module is performed in accordance with the call admission status. The following calls are commonly used to simulate call admission situations [6]:

- Incoming call (new calls)
- Incoming handover call (from other cell)
- Outgoing handover call (to other cell)
- Terminating call

Table I shows the characteristics of call services according to the location-generated services.

C. System Model Description

Considering hot-spot area in base station, some strategies for base station on which calls may concentrate is needed. To obtain the current interference level, a call admission activation scheme must be able to manage interference. For a simple expression of the calculations latter, we use a matrix presentation. The weight sequence in base station can be written as a vector by

$$w_b = [w_1, w_2, w_3, \dots w_n] \quad (1)$$

where n denotes the number of base stations. From the above, we can see that w_b is a simple function of weight distribution. When weight satisfies normal distribution, weighted interference the cell can be written as

$$\rho_i = I \cdot w \quad (2)$$

Equation (2) constructs an equation between interference and the weight sequence. In order to increase call be accepted, it is assumed that each of interferences of cells is required. Interference among base stations can be written as a matrix by

$$I = \begin{bmatrix} i_{11} & i_{21} & \cdots & i_{n1} \\ i_{12} & i_{22} & \cdots & i_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ i_{1m} & i_{2m} & \cdots & i_{nm} \end{bmatrix} \quad (3)$$

where $i_{11}, i_{21}, \dots i_{n1}$ are the interference of cells in an base station and m is the number of base stations. Assume that the system has been perfectly synchronized at the base station. The term ρ_i can be denoted by,

$$\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_m \end{bmatrix} = \begin{bmatrix} i_{11} & i_{21} & \cdots & i_{n1} \\ i_{12} & i_{22} & \cdots & i_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ i_{1m} & i_{2m} & \cdots & i_{nm} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (4)$$

where ρ_i can be simply obtained by

$$\rho_i = \frac{\sum_{k=1}^{m} I_k}{m} \qquad (5)$$

D. Relationship between Weighted Interference and Call Success Ratio

To obtain the current weighted interference level described in the (5), a call admission activation scheme must be able to manage information resulted from the following sources primarily:

- call processing
- handover control
- weighted interference

Letting $\rho_{i\_\max}$ and ρ_{i_other} be the acceptable total interference and interference from other cells, respectively, the communication quality is satisfied [5].

$$E_b((c+h)-1)/pg + N_0 + \rho_{i\_other} \le \rho_{i\_\max} \qquad (6)$$

where E_b, c, h, pg, and N_0 are bit energy, the number of active calls and handover calls in the same cell, processing gain, and thermal noise power density, respectively. In this paper, E_b, pg, and N_0 are used as reference values. The weighted interference can be adjusted by the use of equation (6). $\rho_{i\_cur}(t)$ is current weighted interference activated by time t, which is given by,

$$\rho_i = \rho_{i\_cur}(t) = \rho_{i\_prev} + \rho_{i\_fail}(\rho_{i\_\max} - \rho_{i\_prev}) \qquad (7)$$

where ρ_{i_prev} and ρ_{i_fail} are previous weighted interference and call fail ratio per a base station during inter call admission monitoring time (τ),. We assume a decision scheme where activation time is divided into equal periods- τ . When call admission is increased suddenly, the ratio of call admission is decided by the comparison of the previous call admission-ratio with present one. Using $\rho_{i\_cur}(t)$, the adaptive average weighted interference (AAWI, ρ_{i_aawi}) has very slowly or rapidly increased makes call admission can be expressed,

$$\rho_{i\_aawi}(t) = \frac{\rho_i + \rho_{i\_aawi}(t-\tau)}{2} \qquad (8)$$

where $\rho_{i\_aawi}(t-\tau) < \rho_{i\_aawi}(t)$ for $(t-\tau < t)$. The adaptive average weighted interference naturally makes the activation of rapidly increasing call admission possibly. The following (9) shows the parameter of a heavy transient call admission to activate for $(t-2\tau), (t-\tau)$, and t , respectively. We are interested in the degree of gradient-based on offered load as can be found in (9) and (10). From a gradient of rapidly increasing call admission $(D = \frac{\Delta y}{\Delta x})$, the following equation can be

$$\Delta x = \rho_{i\_aawi}(t-\tau) - \rho_{i\_aawi}(t-2\tau) \qquad (9)$$

$$\Delta y = \rho_{i\_aawi}(t) - \rho_{i\_aawi}(t-\tau) \qquad (10)$$

where $\rho_{i\_aawi}(t-2\tau) < \rho_{i\_aawi}(t-\tau)$ for $(t-2\tau < t-\tau)$. We are interested in the degree of gradient based on offered calls as can be found in (9) and (10). Now, we introduce variable ΔD that indicates whether or not the equivalent number of the degree of rapidly increasing call status D exceeds 2.

$$\Delta D = \begin{cases} 1.2, for\ D > 2 \\ 1.0, for\ D \le 2 \end{cases} \qquad (11)$$

It is hard to predict the flow of load because of user mobility and social events, such as huge accidents, bargain sale, and sports game watching. To solve the problem, we introduce adjusted predictive average weighted interference (APAWI) as the optimization parameter (ρ_{i_apawi}). The adjusted predictive average weighted interference is generated by adaptive average weighted interference with ΔD .

$$\rho_{i\_apawi} = \rho_{i\_aawi}(t) * \Delta D \qquad (12)$$

The call admission status will be detected when $\rho_{i\_apawi} > 50$.

IV. CAC MODEL

A. Call Admission Activation Scheme

The call admission activation scheme is an autonomous call admission-monitoring module to calculate interference on a base station. As a call admission activation scheme starts, it measures weighted interference according to the cell situations. It also shows the scheme showing the entire detecting of the process of CAC feature, which is formed by an initialization, a judgment, activation, and a release. As heavy call attempts disappear, call admission state is released and the system returns to the normal state and the following four cases will happen;

1). Initialization of call admission activation: upon starting this call admission activation scheme, stores the c urrent weighted interference for adaptive average weighte d interference after call admission monitoring time interv al,

2). Reanalysis of weighted interference: the scheme selects the blocking ratio of call services and calculates a new value of weighted interference with maximum interf erence. After calculating a new weighted interference, the current adaptive average weighted interference sets up b oth new weighted interference and previous adaptive aver age weighted interference,

3). Adjustment of heavy transient status: when the a daptive average weighted interference from the weighted interference including blocking ratio of call services can be calculated, the gradient is adjusted to adopt a heavy tr ansient status,

4). Activation of call admission situations: finally, we get the adjusted predictive average weighted interfere nce by multiplying adaptive average weighted interferenc e by the degree of heavy transient status and we activate t he call admission according to the adjusted predictive av erage weighted interference.

B. *Inverse Transform for Call Admission Ratio*

The call admission ratio is generated that adjusted predictive average weighted interference compares with interval for basic call admission ratio (BCAR) and linear interpolation is used for calculating basic call admission ratio. The basic call admission ratio has a capability for admitting a call according to weighted interference. The real underlying distribution, $F(x)$, of basic call admission ratio (the lower line curve in Fig. 2) can be estimated by the empirical cdf, $F'(x)$ (the upper line curve in Fig. 2). The particular curve in Fig. 2 illustrates one changed shape of this underlying distribution, and also that $F'(x)$ is an estimate of $F(x)$.

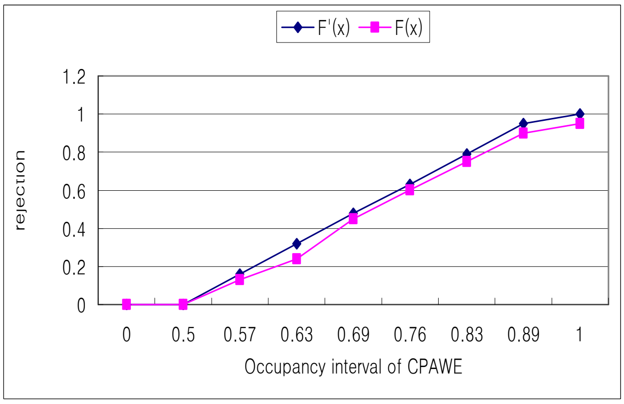

Figure 2 A diagram of Empirical ($F'(x)$) and theoretical ($F(x)$) distribution functions for occupancy interval of adjusted predictive average weighted interference

The empirical cdf $F'(x)$ is defined by using the information in Table II. Each interval defines two points on the graph, which are connected by a straight line. The inverse transform technique applies directly to generating call admission ratio variation, *X*. Recalling the graphical interpretation of the technique, first select adjusted predictive average weighted interference, x. Symbolically this is written as [8]

$$X_1 = F^{-1}(x) \quad (13)$$

but algebraically, since r is between r_i and r_{i+1}, $X_1 (= \Omega_1)$, is computed by a linear interpolation between x_i and x_{i+1}; that is,

$$\Omega_1 = x_j + \left[\frac{r - r_j}{r_{j+1} - r_j}\right](x_{j+1} - x_j) \quad (14)$$

when $r = 0.68$, r is between 0.69 and 0.6 ($r_3 = 0.63 < r = 0.68 \leq x_4 = 0.69$). Therefore (r -0.63) / (0.69-0.63) is 0.833, so that X_1 will be the distance between 0.36 and 0.48 since r is the way between 0.63 and 0.69; that is,

$$\Omega_1 = 0.32 + \left[\frac{r - 0.63}{0.69 - 0.63}\right](0.48 - 0.32) = 0.453 \quad (15)$$

Notice that for all r_s between the interval (0.63, 0.69), the value a_4=(0.48-0.32)/(0.69-0.63)=2.667 will be needed to compute X_1, The value a_4 is the gradient $\Delta r / \Delta x$ of the function $x = F'^{-1}(r)$, which is merely the reflection of the line $r=x$ of the function $r=F'(x)$ of Fig. 2. As a result of it, suppose r=0.68, by the Table II, due to $r_3 = 0.63 < r = 0.68 \leq x_4 = 0.69$, r lies in the interval i=4, and X_1 is 0.453. Therefore, we can control the expected number of calls(Ω_{vcar}) being admitted, that is 0.547(1- X_1) [9].

TABLE II. INFORMATION FOR BASIC CALL REJECTION RATIO

Level (i)	Interval for adjusted predictive average weighted interference	Utilization Dist.	Cumulative Utilization (x_i)	Rejecting Dist.	Cumulative Rejecting Dist. (r_i)	Gradient $a_i = \frac{\Delta r_i}{\Delta x_i}$
1	$0 \leq x \leq 0.50$	0.5	0.5	0	0	-
2	$0.50 < x \leq 0.57$	0.07	0.57	0.16	0.16	2.286
3	$0.57 < x \leq 0.63$	0.06	0.63	0.16	0.32	2.667
4	$0.63 < x \leq 0.69$	0.06	0.69	0.16	0.48	2.667
5	$0.69 < x \leq 0.76$	0.07	0.76	0.15	0.63	2.143
6	$0.76 < x \leq 0.83$	0.07	0.83	0.16	0.79	2.286
7	$0.83 < x \leq 0.89$	0.06	0.89	0.16	0.95	2.667
8	$0.89 < x \leq 1.00$	0.11	1.00	0.05	1.00	0.455

C. *Concept of Call Admission and Rejection*

Assuming that call state keeps in one state in one period, the switching probability between in-adjacent states is very small, so it can be assumed switching just happens between adjacent states. In wireless communication systems, if the call admission scheme of next call is determined according to current call processing condition, and call state is normally in *j*-th state, the following three cases will happen.

- Call admission scheme is adjusted according to (j-1)-th call state in which calls are allowed, in t his case, call efficiency is lost but communicatio n quality can be achieved.
- Call admission scheme is adjusted according to j

-th call state that comes up to maximum boundar y to be processed, in this case, no call efficiency is wasted and communication quality can also be achieved.

- Call admission scheme is adjusted according to (j+1)-th call state that exceeds maximum bounda ry to be processed, in this case, the call cannot s atisfy communication quality request, accordingl y call rejection scheme adjusted by call type is n eeded.

D. CAC Scheme

CAC scheme shows the entire controlling process of the call admission situations, which is formed of an interval selection, a call rejecting ratio calculation, gradient calculation through linear interpolation, and call control by the variable call admission ratio (VCAR). The variable call admission ratio can be derived from BCAR by calculating the linear interpolation, which can improve the call admission ratio. According to the variable call admission ratio, the decision of whether or not to accept calls from mobile subscriber is subject. The CAC scheme on base station is as follows:

1). We calculate total interferences of base station b y using an matrix of each base station.

2). Adjusted predictive average weighted interferen ce (ρ_{i_apawi}) receives from call admission activation module monitored a weighted interference to activate a h eavily loaded situations,

3). The scheme tries to find an interval for adjusted predictive average weighted interference from T able II,

4). If found, $a_i = \Delta r_i / \Delta x_i$ to calculate the BCAR is g iven by inverse transform,

5). Then, calculate VCAR through linear interpolati on based on the calculated BCAR,

6). Finally, call requested from base station is adjus ted by variable call admission ratio according to the adjusted predictive average weighted interference value.

If the level of interval for adjusted predictive average wei ghted interference is 1, state is normal. If it is 2, state is r eady. Otherwise each type of call can be accepted or reje cted by the level of interval for adjusted predictive avera ge weighted interference.

V. NUMERICAL RESULTS

A. Simulation Assumptions

Here numerical results are given for adaptive CAC. The processing of calls in base stations usually takes place in several consecutive steps, separated in time. When such systems are simulated, the calls are generated pseudo-randomly, for instance with an exponential distribution of inter arrival times. We suppose the number of the maximum subscriber 12,000 if the busy hour traffic per subscriber is 0.06 Erlang, when the total Erlang is 720(12,000 * 0.06). For CAC, the blocking ratio is calculated by using the well-known Erlang B formula. The calls are assumed to have a constant holding time of 100 seconds for busy hour call per subscriber: 2.16 calls (0.06 * 3,600 / 100). Completed calls in busy hour are 25,920 (12,000 * 2.16). For offered calls, it is still possible that maximum base station efficiency (= permitted weighted interference) used for base station is below 95%. From the assumptions mentioned above, we simulated that the traffic is from 12,960 up to 38,880, when the offered load is from 50% (normal call state) to 150% (heavy transient call state) [1]-[2], [10].

B. Performance Analysis

Fig. 3 compares the proposed scheme with the conventional one in terms of weighted interference, where the ordinate represents the weighted interference and the abscissa the time that is determined by call admission activation scheme. Fig. 3 shows the examples of between *without_cacl* and *with_cac* under the call admission state as the weighted interference. The *without_cac* means that the offered load results from the processing of the conventional scheme. The *with_cac* means the results from the processing of scheme. The adjusted predictive average weighted interference increases due to the increase of weighted interference depending on lots of call fail. There is a difference in the figure, which system performance of proposed scheme is higher than conventional one under *with_cac*. It is observed that a hot-spot cell has to reduce the number of calls to maintain the same QoS. The difference between proposed scheme and conventional one can be explained by the reanalysis of weighted interference with calls. The main simulation performance measures are variable call admission ratio for basic call admission ratio.

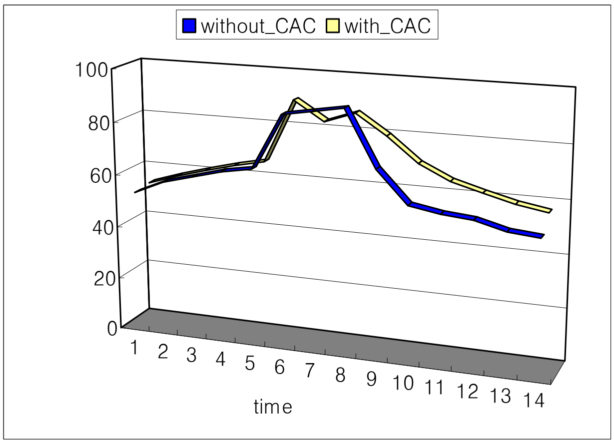

Figure 3. The variance of weighted interference between with and without CAC

Fig. 4 compares the proposed scheme with the conventional one in terms of call admission ratio, where the ordinate represents CAR. Fig. 4 shows examples between for basic call admission ratio (BCAR) and variable call admission ratio (VCAR) under the call admission state as the weighted interference. VCAR decreases due to the reduction of BCAR depending on the *with_cac*. Especially, in time period-7, note that BCAR decreases to 5%, whereas the proposed scheme is able to keep 20% of VCAR on a level with the previous state(time period-6). The result shows that VCAR does have a higher capacity than that of conventional approach based on BCAR. This phenomenon can be explained by the fixed value of BCAR for the conventional scheme. It is observed that a hot-spot cell has to reduce the number of calls to limit the heavy traffic load as an interference of base stations.

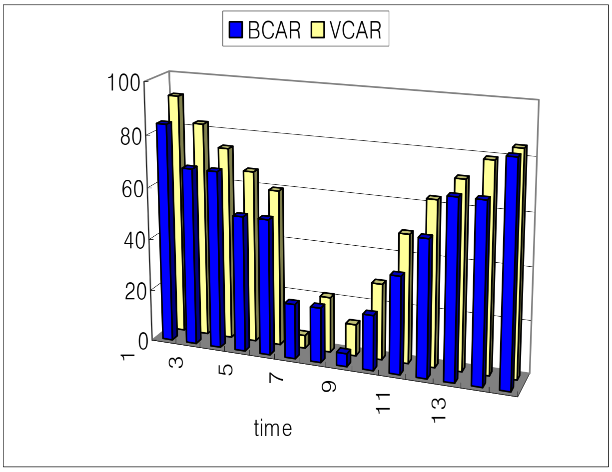

Figure 4. The variance of call admission ratio

VI. Conclusion

We proposed new CAC scheme that offers stability of calls in a hot-spot area possibly, and ensures both QoS on call arrival and handover processing. We regard call arrival ratio as a traffic load as interferences, which means that it obtains performance improvement of about 4.3% compared with the conventional approach is not capable of detecting the heavy transient call attempts, whereas our proposed scheme allows system to overcome the problems encountered in the conventional approach regulating calls well. The call arrival, handover, interference, and call success ratio are derived based on the hot-spot environment and traffic model. In conclusion, it is emphasized that in addition to the weighted interference and offered load presented here, congestion control mechanism among base stations must also take into account a variety of technological issues (e.g., a number of admission ratio, an admission/rejection interval, cell radius).

Acknowledgment

This work was supported by the IT R&D program of MKE/KEIT, Republic of Korea (Project No. 10038765, Development of B4G Mobile Communication Technologies for Smart Mobile Services).

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