Efficient Radio Resource Management for Circuit and Packet Services using SIR Measurement

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Abstract: In this paper, we propose a new algorithm to calculate the maximum amount of available resource while preventing the outage to the currently serviced users not only in the home cell but also in adjacent cells. The effect of resource management in adjacent cells is simulated.

1. Introduction

The wireless communication system classifies services into two classes as circuit-switched service, which is suitable for delay-sensitive and long-holding-time media, and packet-switched service, which is suitable for less delay-sensitive and short-holding-time media. In [1], for the system which has only a single service class, circuit-switched service class, only the call admission control(CAC) is used by *comparing* SIR value with the threshold value. In [2], the remaining amount of resource is used by the adaptive processing gain and assigned to the packet-switched service after being assigned to circuit-switched service without consideration of the outages in adjacent cells. If we first assign the resource to circuit-switched service and then assign the remaining resource to packet-switched service, the latter can be serviced while guaranteeing the QoS of the former. Because circuit-switched service has priority over packet-switched service, the resource of packet-switched service has to be released in order to prevent the increase in blocking and outage probabilities. Because there is no increase in blocking probability of circuit-switched service of our algorithm in comparison with the algorithm in [1], we will focus on the outage case.

2. Basic Theories

2.1. System Model

The reverse link of WCDMA system is assumed. The radio propagation model used in this paper is the log-normal distribution of shadowing with its mean the path loss of the $\alpha - th$ power of the distance. Supposing a mobile is at distance r_{ij} from a base station, the average received field strength in real value can be expressed as:

$$S(r_{ij}) = 10^{\xi_{ij}/10} r_{ij}^{-\alpha} \tag{1}$$

where ξ_{ij} in decibels has a normal distribution with zero mean and standard deviation of σ, which is independent of the distance and ranges 5 ~ 12 dB with a typical value of 8 dB. Typical values of α in a cellular environment are 2.7 ~ 4.0. In this paper, we use α as 4.0. The calls in k-th cell are uniformly distributed and are generated according to Poisson distribution with average λ_k. The call durations are exponentially distributed. [4]

2.2. Conventional SIR based RRM [1]

If $P_i(h,k)$ is assumed as the received power from the i^{th} mobile which is serviced in h^{th} cell, the total received power at the k^{th} cell is

$$\begin{aligned} P(k) &= \sum_{h=1}^{K}\sum_{i=1}^{n_h} P_i(h,k) + N_o \\ &= Sn_k + \sum_{h\neq k}\sum_{i=1}^{n_h} P_i(h,k) + N_o \end{aligned} \tag{2}$$

The first term is the power generated by the users who are in the home cell or k^{th} cell and who use the power S, the second term is by the users who are in the other cells with a log-normal shadowing effect, and the last term is the thermal background noise. The SIR_k value at k^{th} cell is express as eq. (3):

$$\begin{aligned} SIR_k &= \frac{S}{P(k) - S} \\ &= \frac{1}{n_k + \sum_{h\neq k}\sum_{i=1}^{n_h}\left(\frac{r_{ih}}{r_{ik}}\right)^{\alpha} 10^{(\xi_{ik}-\xi_{ih})/10} + \frac{N_o}{S} - 1} \end{aligned} \tag{3}$$

The available amount of resource calculated by SIR_k is A_{k0}, which has to satisfy eq. (4):

$$\begin{aligned} \frac{1}{SIR_{TH}} &\geq A_k{}^0 + n_k + \sum_{h\neq k}\sum_{i=1}^{n_h}\left(\frac{r_{ih}}{r_{ik}}\right)^{\alpha} 10^{(\xi_{ik}-\xi_{ih})/10} + \frac{N_o}{S} - 1 \\ &= A_k{}^0 + \frac{1}{SIR_k} \end{aligned} \tag{4}$$

$E[I_i(k,j)]$ is the average effective ratio from k^{th} cell to jth cell by the users in k^{th} cell. The condition of j^{th} cell must satisfy $1/SIR_{TH} - 1/SIR_j \ge 0$. It can be represented as eq. (5):

$$0 \le A_k^{\,j} \le \frac{1}{E[I_i(k,j)]}\left(\frac{1}{SIR_{TH}} - \frac{1}{SIR_j}\right) \tag{5}$$

The outage may occur at j^{th} cell when $A_k^{\,0}$ is larger than $A_k^{\,j}$. Therefore the maximum amount of available resource that can satisfy all the conditions of the home cell and adjacent cells is calculated by the eq. (6):

$$A_k = \min\left(A_k^{\,0}, A_k^{\,1}, \cdots, A_k^{\,j}, \cdots\right) \tag{6}$$

3. Calculation of Safely the Available Capacity

In h^{th} cell, if we set N_h as the number of circuit-switched service users and $N_{h,2^i}$ as the number of packet-switched service users who use the power which is 2^i times as much as the received power from each circuit-switched service user. If we also set the normalizing factor of packet-switched service F_h as $\sum_{i=0} 2^i N_{h,2^i} / N_h$, the total effective number of users of h^{th} cell is

$$n_h = N_h + \sum_{i=0} 2^i N_{h,2^i} = N_h + F_h N_h = (1+F_h) N_h \tag{7}$$

$P_i(h,k)$ can be expressed as below:

$$\begin{aligned} P(k) &= \sum_{h=1}^{K}\sum_{i=1}^{n_h} P_i(h,k) + N_o \\ &= Sn_k + S\sum_{h\ne k}(1+F_h)\sum_{i=1}^{N_h}\left(\frac{r_{ih}}{r_{ik}}\right)^{\alpha} 10^{(\xi_{ik}-\xi_{ih})/10} + N_o \end{aligned} \tag{8}$$

and the SIR_k value at k^{th} cell can be expressed as follows:

$$\begin{aligned} SIR_k &= \frac{S}{P(k)-S} \\ &= \frac{1}{n_k + \sum_{h\ne k}(1+F_h)\sum_{i=1}^{N_h}\left(\frac{r_{ih}}{r_{ik}}\right)^{\alpha} 10^{(\xi_{ik}-\xi_{ih})/10} + \frac{N_o}{S} - 1} \end{aligned} \tag{9}$$

A_{k0} has to satisfy the eq. (10):

$$A_k^{\,0} \le \frac{1}{SIR_{TH}} - \left(N_k + \sum_{h\ne k}(1+F_h)\sum_{i=1}^{N_h}\left(\frac{r_{ih}}{r_{ik}}\right)^{\alpha} 10^{(\xi_{ik}-\xi_{ih})/10} + \frac{N_o}{S} - 1\right) \tag{10}$$

By this equation, k^{th} cell can decide the amount of resource, which is bounded by $A_k^{\,0} \ge F_k N_k$, to the packet-switched service users. Because of the asynchronous properties of each base station, the interference of packet-switched service users of adjacent cells has to be considered in the calculation of $A_k^{\,0}$ for packet-switched service.

At the adjacent cells or j^{th} cell where j=1,2,..,and 6, if the resources currently in use are near the threshold, the outage can occur by this $A_k^{\,0}$ value. The safe amount of available resource not only in the home cell but also in adjacent cells is calculated by the below method. After the $A_k^{\,j}$ assignment in the k^{th} cell, the $1/SIR_j$ at the j^{th} cell is represented in eq. (11).

$$\begin{aligned} \frac{1}{SIR_j} &= (1+F_j)N_j \\ &\quad + \sum_{h\ne j}(1+F_h)\sum_{i=1}^{N_h}\left(\frac{r_{ih}}{r_{ij}}\right)^{\alpha} 10^{(\xi_{ij}-\xi_{ih})/10} + \frac{N_o}{S} - 1 \\ &= (1+F_j)N_j + E[I_i(k,j)](N_k + A_k^{\,j}) \\ &\quad + \sum_{\substack{h\ne j\\ h\ne k}}(1+F_h)\sum_{i=1}^{N_h}\left(\frac{r_{ih}}{r_{ij}}\right)^{\alpha} 10^{(\xi_{ij}-\xi_{ih})/10} + \frac{N_o}{S} - 1 \end{aligned} \tag{11}$$

By inserting eq. (11) into eq. (5), we can get the result as in eq. (12).

$$A_k^{\,j} \le \frac{1}{E[I_i(k,j)]} \times \left[\frac{1}{SIR_{TH}} - \left\{\begin{aligned} &(1+F_j)N_j + E[I_i(k,j)]N_k + \\ &\sum_{\substack{h\ne j\\ h\ne k}}(1+F_h)\sum_{i=1}^{N_h}\left(\frac{r_{ih}}{r_{ij}}\right)^{\alpha} 10^{(\xi_{ij}-\xi_{ih})/10} + \frac{N_o}{S} - 1\end{aligned}\right\}\right] \tag{12}$$

Finally the maximum amount of available resource can also be found by eq. (6) with eq. (10) and (12).

4. Simulation Results

We assume the reverse link of WCDMA system has chip rate of 3.84Mcps and perfect power control. Circuit-switched service and packet-switched service are used and the latter is simply normalized by the former. We set the 6 adjacent hexagonal cells and 12 2^{nd} tier hexagonal cells. The calls are uniformly distributed in each cell, the average service time of each voice call is exponentially distributed with the mean of 180 sec, and the calls are generated with Poisson distribution according to *Erlang* variations. In a log-normal shadowing channel, ξ_{ij} has the zero mean value and standard deviation σ is 8dB with the attenuation factor α being 4.0[3]. If we take the required E_b/N_o of the voice service as $6.1dB$ and the data rate of the voice service as $12.2kbps$, the processing gain will be $25.0dB$ and SIR_{TH} will be $6.1dB$-$25.0dB$=-18.9 dB.

Fig.1 shows the amount of available resource for two categories, one is to consider just the home cell and the other is to consider both the home cell and adjacent cells. Keeping the blocking probability below 2%, the amount of available resource is plotted according to F_j for some *Erlang* conditions of circuit-switched service users, which are 10, 20, 30, 40 and 50 *Erlangs*. For example, let's consider the case having N_j =20 and F_jN_j =30. By the proposed algorithm, the home cell has to assign at most A_k=18 even though it may be as much as 41 only by the status of home cell. In Fig.2, we varied N_6 at one adjacent cell or 6th cell from 20 to 40 whereas other 5 adjacent cells and the home cell were kept with 20 *Erlangs*. For the case having N_6 =20 and F_j =1.0, totally 240(=6x20(1+1.0)) effective users exist in adjacent cells and the maximum A_k equals 44. But for the case having N_6 =40 an F_j =0.7, totally 238(=(5x20+1x40)(1+0.7)) effective users which are almost same users as previous configuration, there is no available resource to assign to packet-switched service at the home cell. Thus, even though totally effective *Erlangs* are the same, the concentration of some *Erlangs* to one hot cell would restrict the available resource of the home cell more strictly.

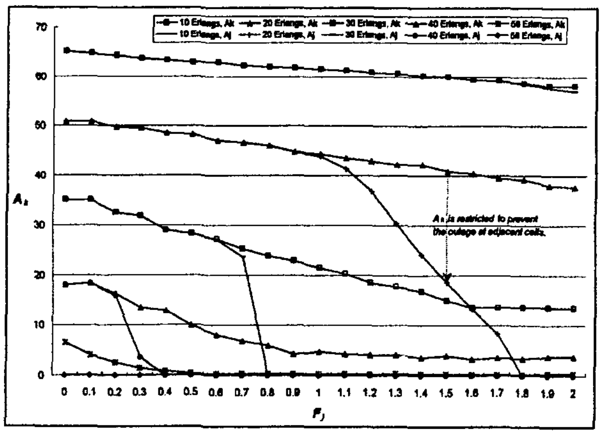

Fig.1. A_k according to F_j for various Erlangs

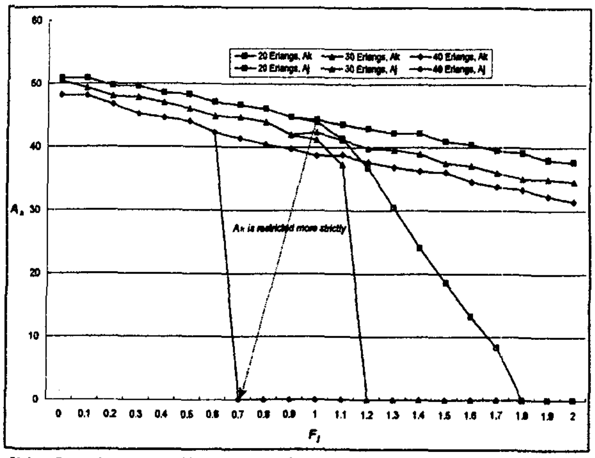

Fig.2. A_k according to F_j for one concentrated adjacent cell

5. Conclusions

We proposed a new algorithm to safely assign the resource for packet-switched service at the home cell. Because this offers an upper bound of its assignment, the resource will be maximally utilized while preventing outage to users who are even in adjacent cells as well as in the home cell. Even if a similar amount of resource is allocated in adjacent cells, the concentrated cell can restrict the available resource more strictly.

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