CDMA2000 1x시스템에서 전송률제어를 이용한 부하제어 방식

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Load Control Scheme Using Rate Control for CDMA2000 1x System

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요 약

CDMA시스템의 용량은 다중접속 간섭의 양에 의존한다. 다중접속간섭은 전송 또는 수신전력과 밀접한 관계를 갖는다. CDMA2000 1x시스템은 주로 순방향 용량에 의해 제한된다. 본 논문에서는 기지국 총 송신전력이 셀의 부하를 대변할 수 있음을 보이고 CDMA2000 1x 시스템을 위한 새로운 형태의 부하제어방식을 제안한다. CDMA2000 1x시스템은 빠른 전력제어를 하고 있으며 총 송신전력을 측정함으로 써 송신링크의 셀 부하를 측정할 수 있다. 제안된 알고리즘은 이와 같은 총 송신전력을 모니터링하여 셀의 부하에 따른 데이터 전송률제어를 수행함으로써 무선자원을 효율적으로 사용할 수 있게 하였다. 제안된 알고리즘은 전력제어되는 CDMA시스템에 적용될 수 있으며 시스템은 용량과 서비스품질 (QoS)을 향상시킬 수 있다.

ABSTRACT

In a CDMA system, the capacity is variable and mainly depends on multiple access interference. The multiple access interference has a deep relationship with transmitted or received power. The capacity of CDMA2000 1x system is considered to be limited by the forward link capacity. In this paper, we show that the transmitted power can represent the total cell load and we propose a load control scheme for CDMA2000 1x system. CDMA2000 1x system has fast power control scheme and we can measure forward link cell load by using total transmitted power. In the proposed algorithm, by monitoring the total transmit power, we can simply adjust data rate to channel conditions and efficiently use radio resources. The proposed algorithm is practical algorithm to implement in the power controlled CDMA systems and enhances the system throughput and quality of service(QoS)

키워드

Rate Control, CDMA2000, Load Control

Ⅰ. Introduction

Contrary to frequency-division multiple access (FDMA) and time-division multiple access(TDMA), CDMA system has not absolute number of maximum available channels. The limit in CDMA capacity is determined by the multiple access interference. Hence, in the interference limited CDMA systems, good interference handling scheme for radio resource allocation plays akey role to enhance the

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접수일자 : 2004. 06. 15

performance and increase the capacity.

It is generally accepted in industry that the capacity of IS-95 CDMA systems are reverse link limited. On the other hand, CDMA2000 1x [1] improves reverse link with pilot aided coherent demodulation and emerging data services are likely to require higher data rates in forward link than the reverse link. Hence, the capacity of CDMA 2000 system is limited by the forward link [2][3] and load control mechanism for forward link becomes important issue. Load control is one of the radio resource management techniques. Load control takes care that the network is not overloaded and remains in a stable state. If system is overloaded, load control returns system to normal load state in a fast and controlled way. To perform load control, we should be able to measure the total load in a cell. For forward link limited system, transmitted power at base station can represent total cell load. In the radio channel, transmission rates are closely related to signal-to-interference ratios (SIR), and the SIR can be efficiently controlled by power control. And so, the system resources such as transmitted power and data rate need to be efficiently controlled to maintain overall system feasibility and optimize network performance. Lots of works have considered the reverse link[4]-[6],For forward link, specific SIR and rate control issues can be found in [7] where some complex computation is required at the base station. For optimum resource allocation, joint power and rate control is studied [8], [9]. However, above methods requires accurate channel estimation or prediction and complex computations such as Lagrangian relaxation technique which requires lots of iterations and increase system computational load, and those techniques are difficult to be implemented in real system.

In this paper, we show that the transmitted power can represent the total cell load and we propose a very practical load control scheme for CDMA2000 1x system. Since high rate data has a low processing gain, the allocated power to the data call is proportional to the data rate. In this paper, we assumed perfect power control and the assigned power to each traffic is controlled to satisfy its required SIR at mobile station. Even with perfect power control, users at higher data rates in a system with mixed traffic result in large adjacent cell interference variation which drastically degrade the system capacity. The proposed load control scheme using rate control mechanism according to current cell load. A base station monitors periodically transmitted power which represent total cell load. With the monitored transmitted power, the system controls the cell load by controlling the transmitted data rate. The proposed load control algorithm guarantees QoS and enables the system to utilize radio resource dynamically by controlling data rate according to the cell load status.

This paper is organized as follows: Section II shows that the cell load can be measured by transmitted power. Section III describes the proposed call admission control strategy. Section IV shows the simulation model. Section V shows the simulation results and the conclusions are given in Section VI.

II. Forward link cell load measurement

Call admission control is an essential strategy to utilize radio resources dynamically and guarantee QoS. To determine the call admission, the system should know the total cell load. In this Section, we show that the total cell load can be measured by the total transmitted power at base station.

As a generally accepted radio propagation model for DS-CDMA system, log normal distribution of shadowing with its mean path loss of l-th power is adopted. The long term path loss model used in this paper is given by

$$g_{k,i} = r(k,i)^{-l} \cdot 10^{\xi/10} \tag{1}$$

where l is path loss exponent, typically 3 or 4 and ξ is a Gaussian random variable with mean of zero and standard deviation of σ [dB], representing shadow fading and typically σ is

4~12dB. r(k,i) is the distance from the base station k to the mobile station i. In the forward link, the received SIR from base station k to mobile station i is given as follows

$$\gamma = \frac{S_{0,i} g_{0,i}}{\delta P_0 g_{0,i} + I_{oc,i} + \eta} \quad (2)$$

where δ is the orthogonality factor, Pk is the total output power of base station k, Ski is the transmitted power allocated to mobile i in the k-th base station coverage, and ηis back ground noise. The other cell interference to the i-th mobile, from adjacent base is given by

$$I_{oc,i} = \sum_{k=1}^{K-1} P_k g_{k,i} \quad (3)$$

Under perfect power control assumption, it is assumed that $\gamma = \gamma_{target}$. In this paper we consider voice and data traffic and the target SIR can be γ_v and γ_d for voice and data call, respectively. In general, the background noise is negligible compared to the total power received from all base station. From (2) the transmitted power of mobile station can be obtained.

$$S_{0,i} = \frac{\gamma (\delta P_0 g_{k,i} + I_{oc,i})}{g_{k,i}} \quad (4)$$

The total transmitted power at base station can be written as

$$P_0 = \alpha_v \sum_{i}^{N_v} S_{0,i} + \alpha_d \sum_{j}^{N_d} S_{0,j} + P_{over} \quad (5)$$

where Nv and Nd is the number of data and voice users in the cell, and αv and αv is voice and data activity factor, respectively. Pover is the allocated power for overhead channels such as pilot, synch and paging channels. The ratio Fk,i for k-th cell and i-th user is defined as the ratio of the received intercell and inracell power.

$$F_{k,i} = \frac{I_{oc,i}}{P_k g_{k,i}} \quad (6)$$

Assuming that $F_{k,i} \approx F_{k,j} \approx F$ for all users [10], the equation for the total base station output power can be obtained

$$P_0 = \alpha_v \gamma_v P_0 N_v (\delta + F) + \alpha_d \gamma_d P_0 N_d (\delta + F) + P_{over} \quad (7)$$

From (7), the total transmitted power at base station, P0, can be obtained as follows.

$$P_0 = \frac{P_{over}}{1 - \{\alpha_v \gamma_v N_v (\delta + F) + \alpha_d \gamma_d N_d (\delta + F)\}} = \frac{P_{over}}{1 - \left(\frac{N_d}{N_{pole,d}} + \frac{N_d}{N_{pole,d}} \right)} \quad (8)$$

where Npole is the absolute maximum downlink pole capacity [10]. When the power control problem has no feasible solution and transmitted powers are unconstrained, all powers will increase without bound.

$$N_{pole,v} = \frac{1}{\alpha \gamma_v (\delta + F)}, \quad N_{pole,d} = \frac{1}{\alpha \gamma_d (\delta + F)} \quad (9)$$

Maximum downlink capacity shown in (9) is obtained on the assumption of an infinite base station power and no overhead channel. To measure the load of the cell, the load factor L is defined as

$$L = \frac{N_d}{N_{pole,d}} + \frac{N_d}{N_{pole,d}} \quad (10)$$

From (8) and (10), the load factor can be expressed by the function of total transmitted power of base station.

L=1-Pover/P0 (11)

The maximum transmitted power should be chosen such that users can have sufficient transmitted power to achieve their quality requirements when the system reaches the allowable system load. The maximum load function is obtained when the transmitted power reaches maximum power. Equation (11) shows that call load can be measured by total transmitted power at the base station.

In this paper, we consider the variable data rate but the feasible transmission rates are limited to a small number of discrete values. For the radio configuration 3 of IS-2000, the feasible data rates are 19.2Kbps 38.4Kbps, 76.8Kbps and 153.6Kbps [7]. Since the high rate data has small spreading gain, the assigned power should increase as the data rate increase to guarantee the required QoS. We assume equal bit energy for the data traffic and the allocated power increases in proportion to the data rate and the required Eb/N0 of data call is identical regardless of data rate and the relationship between the required SIR of Ri data rate call and Rj data rate call

$$\gamma_{Ri} = \frac{R_i}{R_j}\gamma_{Rj} \tag{12}$$

Different data rate call requires different γ and different transmitted power. It enables the system to handle the cell load by controlling data rate. A large fraction of transmitted power is assigned to a small fraction of data users. Hence, the capacity of the cell is limited if the higher data user is closer to the boundary. In that case, by reducing the data rate of the data user in the cell boundary, the system can have redundant resources and reduce blocking probability.

III. Proposed Load Control Strategy

In the CDMA2000 1x system, the feasible transmission rates are limited to a small number of discrete values. In this paper, we consider radio configuration 3 of IS-2000 and the data rates are 19.2Kbps 38.4Kbps, 76.8Kbps and 153.6Kbps [1]. CDMA2000 1x system should support voice and data simultaneously in a cell. If the data call is near cell boundary, data call requires strong transmitted power via power control. It induces high interference to the other calls. In that case, in spite of just one data user, lower rate than 153.6kbps should be allocated to reduce other cell interference. To solve this problem, transmitted power based rate control scheme is necessary.

The basic concept is as follows. Total transmitted power is periodically monitored for every load control period. Load condition is divided into three states such as overload, stable and under load state. The load states are shown in Fig. 1.

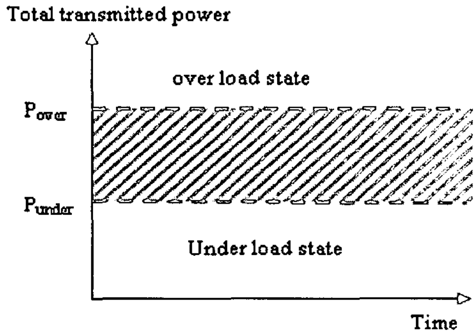

Fig. 1 Load state based on transmitted power

In the overload state, the system cannot accommodate calls in the cell and the some of calls should be dropped. In Fig.1, Pover is the power threshold for overload state and it is determined as a smaller value than the real overload power value. In this paper, we choose 10% smaller value for Pover than the overload state. It is because the system should prevent overload condition and reduce data rate before the system goes into overload state. In under-load state, the system has enough radio resource and the system can raise data rate to increase throughput. The power, Punder in Fig. 1, is threshold power level for under-load state.

Fig.2 shows rate control scheme according to load states. In the over load state, the system starts to reduce the data rate of which data call has highest transmitted channel power compared to its data rate. The reason why reduce the data rate of which highest power data call is that the user suffering worse channel condition requires more transmitted power by power control algorithm. In this paper, we assume EBE (Equal Bit Energy) regardless of data rate for convenience. In the same channel condition, the system allocates power proportional to data rate.

$$E_{bi}=\frac{P_i}{R_i}=\frac{\beta_i P}{\alpha_i R}=E_b \qquad (12)$$

where $S_{k,i}$ is transmitted power and $R_{k,i}$ is data rate for i-th data call in the k-th base station coverage. However, under the different channel condition, the required transmitted power is changed and the system can monitor channel condition by calculating $S_{k,i}/R_{k,i}$, and the difference of the calculated values shows the difference of channel condition. When the system tries to reduce data rate, the system choose the date call having highest $S_{k,i}/R_{k,i}$ value which suffers from worst channel condition.

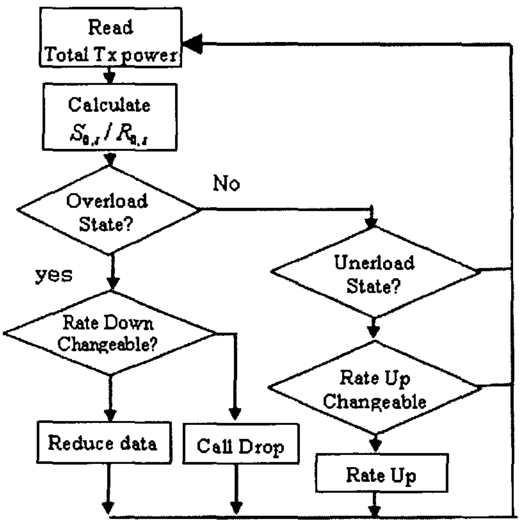

Fig. 2 Load control scheme

The reduction of data rate means the reduction of required transmitted power. If there is no data call to reduce data rate, the system drops in-service call to reduce transmitted power. The users in the cell can enjoy their specified quality of service (QoS)by reducing data rate or dropping call.

In the under load state, there are enough resources and the system can raises data rate. When the system raise data rate, the system chooses data call having lowest $S_{k,i}/R_{k,i}$ value. To raise data rate of data call having lowest $S_{k,i}/R_{k,i}$ requires smaller transmitted power than the other data calls in the cell. The system tries to maximize data rate and gives each user best throughput as possible.

IV. Simulation Modeling

To evaluate the performance of the proposed call admission strategy, system level simulation is performed.

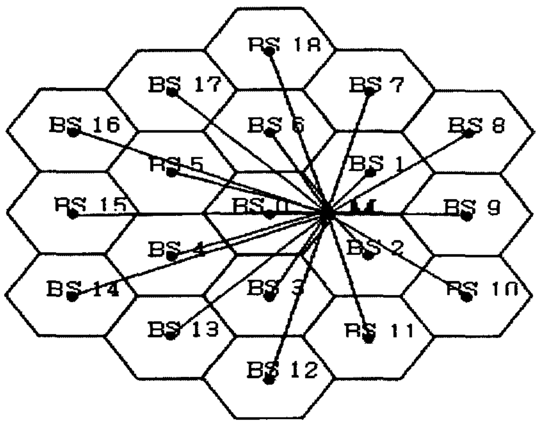

Fig. 3. Cell configuration and forward-link interference model

In this simulation, only the forward link is considered. Hence it is assumed that, whenever the forward link channel is assigned, the reverse link is established. The simulated area consists of 19 hexagonal cells and the geometry of the interference model is shown in Figure 2. The cellular layout consists of 2 tier of surrounding cells of radius R.

Table 1 Simulation parameters

Parameter	Value
Cell radius	1Km
Mean of voice service rate (μ_v)	1/90(1/sec)
Mean of data service rate (μ_d)	1/200(1/sec)
Maximum Power of base station	20W
Target $(E_b/N_o)_v$	5dB
Target $(E_b/N_o)_d$	4dB
Activity Factor	0.4 (voice), 1 (data)
Standard deviation of shadowing	8dB
The power ratio of over head channel	30%

The call arrival process is modeled as an independent Poission process with mean arrival rate λ_v and λ_d for voice and data call respectively, and call duration has the exponential distribution with mead call duration $1/\mu_v$ and $1/\mu_d$ The parameter μ_v and μ_d is the mean of service rate for voice and data call respectively. The users are assumed to be uniformly distributed and the velocity of mobile is assumed to be uniformly distributed over 0~100km/h. For the forward link, each user communicates with the strongest base station and was perfectly power controlled by serving base station. We assume equal bit energy for data traffic and it is assumed that the required Eb/No for data traffic is 4dB regardless of data rate.For data call, the available data rates are 19.2kbps, 38.4kbps, 76.8kbps and 153.6kbps. In this simulation, the fraction of overhead channel is fixed and not varies with traffic load, that is, 30% of maximum transmitted power. The overload threshold and under-load threshold are assumed to be 90% and 60% of maximum transmitted power, respectively. The simulation parameters used in simulations are listed in table 1.

V. Simulation Results

For the performance measure, blocking probability is defined as the probability that the call does not meet the required SIR and is terminated before call is not finished. Throughput is averaged data rate that is defined as the average total data rate served by base station.

Fig. 4 and 5 show blocking probability according to load of data call. TLC is load control period. At every load control period, the system monitors total transmitted power and calculates P_i/R_i value, and performs rate control in case of overload or under load state. As the load of data call increases, blocking probability of voice and data call increase. If load control scheme is not adopted, blocking probability is much higher than the case of load control scheme.

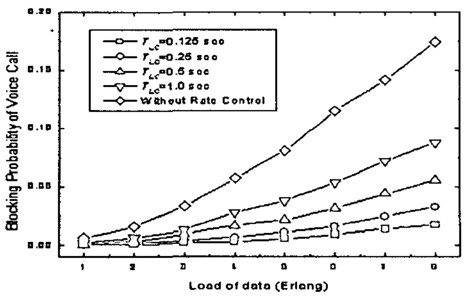

Fig. 4. Blocking probability of voice call with varying data load.

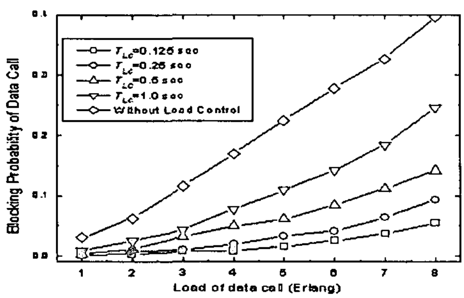

Fig. 5. Blocking probability of data call with varying data load.

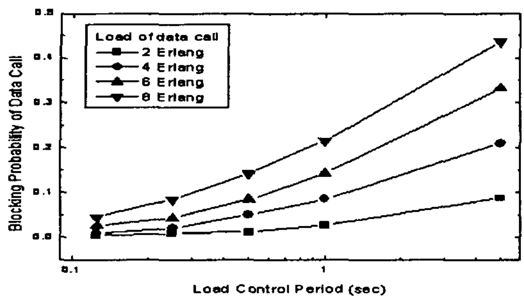

Fig. 6. Blocking probability of data call with varying load control period.

Fig.6 show the blocking probability according to load control period. As shown in Fig. 6, as the load control period decreases, blocking probability also decreases. As the load control period comes smaller, reduction of blocking probability comes smaller. As shown in Fig.7, the proposed rate control algorithm enhances the throughput performance. As the load control period comes smaller, the throughput becomes higher. If the system has not load control algorithm, blocking probability increase due to overload condition and it induce decrease of system throughput.

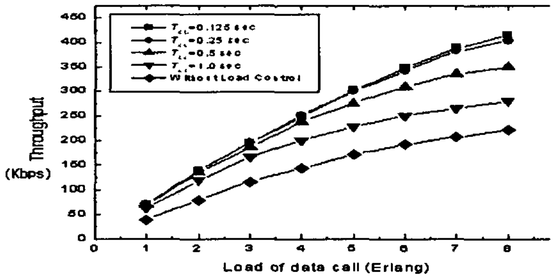

Fig. 7. Throughput with varying data call load and load control period

As shown in the simulation results, Smaller load control period can reduce blocking probability and increase system throughput. However, smaller load control period can induce higher system load and it is important to find an optimal load control period. As shown in Fig.6 and7, the difference of blocking probabilities for case of TLC=0.25 and 0.125 is not so high, and Fig. 8 shows that for TLC=0.25 and 0.125, the throughput is almost same. And so, load control period should be smaller than 0.25 sec. for the lower blocking probability and higher throughput.

VI. Conclusion

In this paper, we show that the transmitted power can represent system cell load and we propose the load control algorithm for CDMA2000 1x system using the total transmitted power and rate control algorithm. CDMA system has a flexible radio resource since the CDMA system is the interference limited system. By adopting the load control algorithm, we can reduce the call blocking probability and it means the enhancement of system quality of service. This load control also enhances the system throughput. Enhancement of System throughput has a deep relationship with the cost of data service. We also shows the effecto of load control period on the with system performance. As shown in this paper, the proposed load control scheme can be applied to the CDMA2000 1x system and it is very practical scheme to be applied to CMDA2000 system.

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