Call Admission Control Algorithm for Adaptive Array Antenna at the Base Station in DS-CDMA System

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1. INTRODUCTION

Up to now, studies of Adaptive Array Antennas (AAA) have focused on the transmission technologies, which are mainly related to antenna pattern control algorithms to reduce the interference from other mobile stations (MSs) in the case that the number of mobile stations (MSs) is fixed. With AAA, the active user's antenna pattern varies according to the number of active MSs and their locations, so that the transmission quality of the active MSs varies. Therefore, admission control (CAC) of a new MS, which determines the number of active MSs, is a very important issue for introducing the AAA into cellular systems [1].

This paper proposes a novel CAC algorithm for introducing AAA into the BS. First, the BS estimates the direction of arrival (DOA) of signals received from the MSs by using an array antenna system together with a DOA estimation technology such as MUSIC algorithm [2], [3]. Next, when a new call request packet is received from a new MS, the BS calculates the optimum antenna pattern of each active MS by using the estimated DOA of the received signals on the assumption that the new call is connected, and then predicts the transmission quality of each MS. If the transmission quality of any active MS is degraded from the required quality, the new call is blocked. Therefore, the proposed CAC algorithm ensures that all active MSs receive required transmission quality. We assessed the proposed CAC algorithm by computer simulation and confirmed that it can increase the system capacity in proportion to the number of antenna elements of without degrading the transmission quality of active MSs.

2. PROPOSED CAC ALGORITHM

Fig.1 shows a flowchart of the proposed CAC algorithm. The flowchart basically consists of 4 steps as follows:

(A) *First Step :* When the BS receives a new call request packet from a MS, the BS checks the number of the idle channels, N_{idle}. If there is no idle channel, the new call is blocked. If there are some idle channels, the BS proceeds to the next step.

(B) *Second Step :* The BS obtains the DOA, θ_i , and the received power, P_i , from the received signals by using array antenna system together with MUSIC algorithm [3].

(C) *Third Step :* The BS calculates the

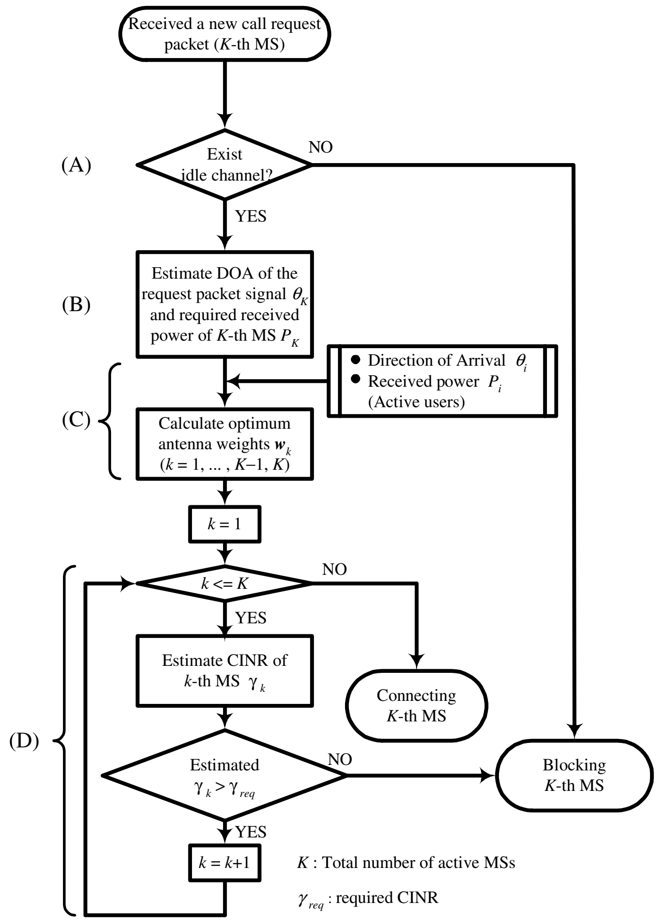

Fig.1 Flowchart of CAC based on the proposed algorithm.

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correlation matrixes $\boldsymbol{R}_{xxi}$ and optimum antenna weights $\boldsymbol{w}_i$ of all active MSs (including the new MS) on the assumption that the new call was connected. When the DOA and received power of all MSs are known, the optimum antenna weights $\boldsymbol{w}_i$ can be represented as well-known solution of Wiener-Hopf equation by using the correlation matrixes $\boldsymbol{R}_{xxi}$ as follows,

$$\boldsymbol{R}_{xxi} = \Sigma P_i \boldsymbol{v}(\theta_i) \boldsymbol{v}^H(\theta_i) + P_n \boldsymbol{I} \quad (1)$$

$$\boldsymbol{w}_i = \boldsymbol{R}_{xxi}^{-1} \boldsymbol{v}(\theta_i) \quad (2)$$

where, $\boldsymbol{v}(\theta_i)$ is array response vector with arrival angle θ_i, P_n is the noise power of each antenna and $\boldsymbol{I}$ is an identity matrix.

(D) *Fourth Step :* The BS calculates the antenna pattern of each MS from its antenna weight $\boldsymbol{w}_i$ and estimates the CINR of each MS. In general, DS-CDMA systems can improve the CINR of each MS by using different pseudo-orthogonal spreading codes. Let spreading factor be PG, the average interference power is reduced to P_I/PG, where P_I is a total interference power. Therefore, the CINR of k-th MS, γ_k, can be approximated as follows

$$\gamma_k = \frac{D_k(\theta_k) P_k}{\frac{1}{\text{PG}} \sum_{i \neq k} D_k(\theta_i) P_i + P_n'} \quad (3)$$

$$D_k(\theta_i) = \frac{1}{2} \left| \boldsymbol{w}_k \boldsymbol{v}(\theta_i) \right|^2, \quad P_n' = \frac{1}{2} P_n \boldsymbol{w}_k \boldsymbol{w}_k^H \quad (4)$$

where, $D_k(\theta)$ is the antenna pattern of AAA for the k-th MS. If the estimated CINR of all MSs (both active MSs and the new MS) exceed the required CINR, the new call is connected. If the estimated CINR of all MSs is bellow the required CINR, the new call is blocked.

Therefore, the proposed CAC algorithm ensures that all active MSs receive the required transmission quality.

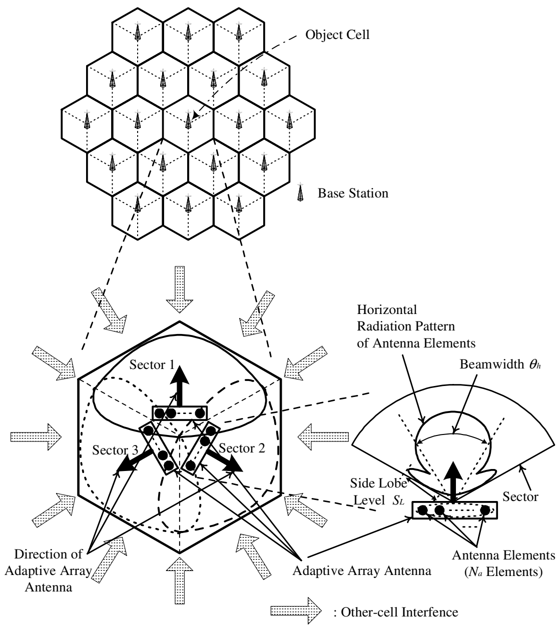


Fig.2 Cell model.

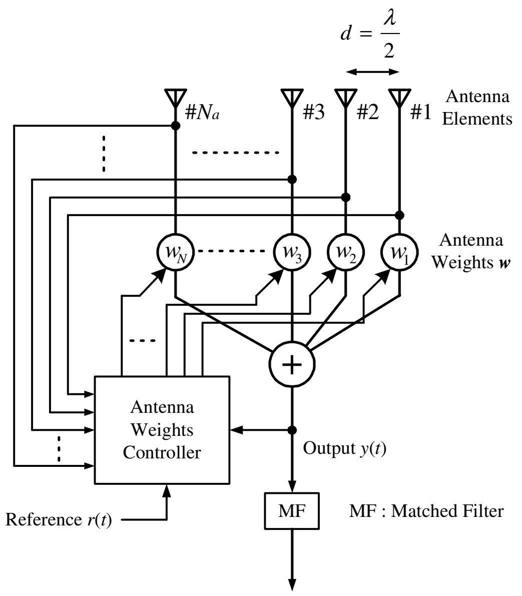


Fig.3 Structure of adaptive array antenna.

3. Simulation Models

3.1 Cell model

The simulated area consists of many hexagon cells with three sectors and the BS is located at the center of the cell as shown in Fig.2. DS-CDMA systems generally estimate the interference power from other cells assuming that the thermal noise is reduced by process gain PG [4]. In this paper, we use this estimation method and add the noise power equivalent to interference from other cells in the simulation. Therefore, we consider one cell as shown in Fig.2. To simplify the estimation of CINR in DS-CDMA systems, the ratio of other-cell interference $I_{other\text{-}cell}$ to total interference I_{total} (= $I_0 + I_{other\text{-}cell}$) is set at about 0.4 for omni-cell layout [5], where I_0 is the interference power from self-cell. Thus the interference factor $f_{other\text{-}cell}$ (= $I_{other\text{-}cell}/I_0$) is about 0.7 the omni-cell layout. On the other hand, other-cell interference power for three-sector-cell layout decreases to about 1/3 of other-cell interference power for the omni-cell layout. Therefore, we assume that the other-cell interference factor $f_{other\text{-}cell}$ (= $I_{other\text{-}cell}/I_0$) is 0.3 for easy estimation.

3.2 Radio propagation model

For simplicity, we consider only distance attenuation and do not consider instantaneous fading and log-normal shadowing. Accordingly, received power E can be expressed as $E = T{\cdot}Ar^{-\alpha}$ [W], where T is MS transmitter power, r is the distance between a mobile unit and the BS, α is a distance attenuation factor (here $\alpha = 3.5$) and A is a constant that depends on antenna gain and other factors.

3.3 Traffic model and mobile station model

MSs are uniformly distributed in each sector. The offered traffic is ρ [erl/sector]. The call duration is random and exponentially distributed with the mean call duration of T_s (=120) [sec]. The inter-arrival time of the request packets is exponentially distributed. Therefore, the mean inter-arrival time T_a is expressed as $T_a = T_s / \rho$ [sec].

3.4 Transmitter power control model

We assume perfect transmitter power control, so received power at the BS from each MS is constant with the necessary received power E_{th}. Therefore, transmitter power of the i-th MS, T_i, can be expressed as $T_i = E_{th} / \{D_i(\theta_i) A r_i^{-\alpha}\}$, where $D_i(\theta_i)$ is the antenna pattern of AAA for the i-th MS.

3.5 Array antenna model

As shown in Fig.3, we assume a linear array with antenna spacing of half wavelength ($d = \lambda/2$). The number of antenna elements is N_a. Fig.4 shows the horizontal radiation pattern. The beamwidth θ_h and the side lobe level S_L are 120 [deg.] and –15 [dB], respectively [5].

3.6 Communication model

All MS communicate at the same transmission rate and the same transmission power. In this paper, we set the spreading factor PG to 64, the required CINR γ_{req} to 8 dB and the CNR (Carrier-power-to-Noise-power Ratio) to 30 dB for all MSs.

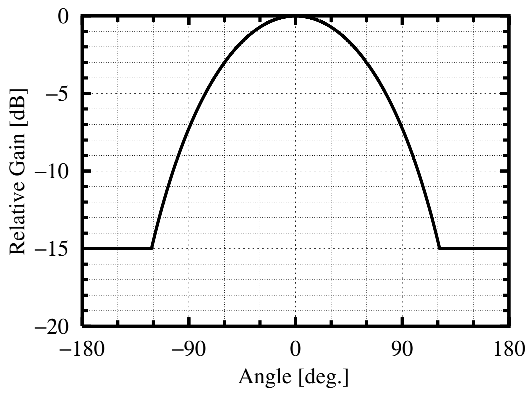


Fig.4 Horizontal radiation pattern of antenna elements

4. SIMULATION RESULTS

The performance of the proposed algorithm was evaluated in terms of blocking probability, outage probability of CINR and system capacity. Outage probability of CINR P_{outage} is defined as the ratio of MSs having CINR less than the required CINR γ_{req}. System capacity is defined as the carried traffic when the blocking probability is 0.03 (3%).

Fig.5 shows the cumulative probability of CINR with and without proposed CAC, where the number of antenna elements is 8 ($N_a = 8$), the number of channels is 64 [channels/sector], which corresponds to the number of spreading codes, and the offered traffic ρ is 40 [erl/sector]. At the point of the required CINR γ_{req} of 8 dB, we find P_{outage} without CAC is about 10%, but P_{outage} with CAC is zero, so the proposed CAC does not degrade the transmission quality.

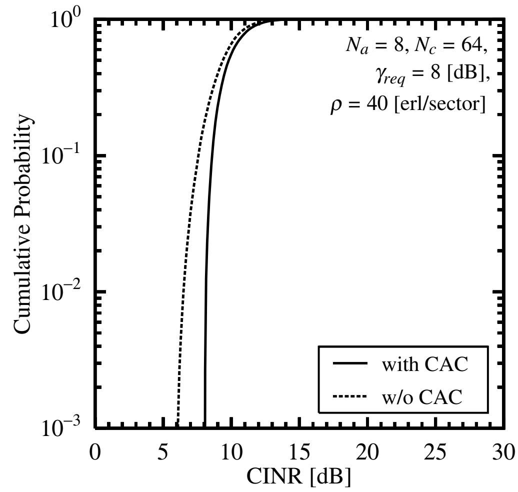


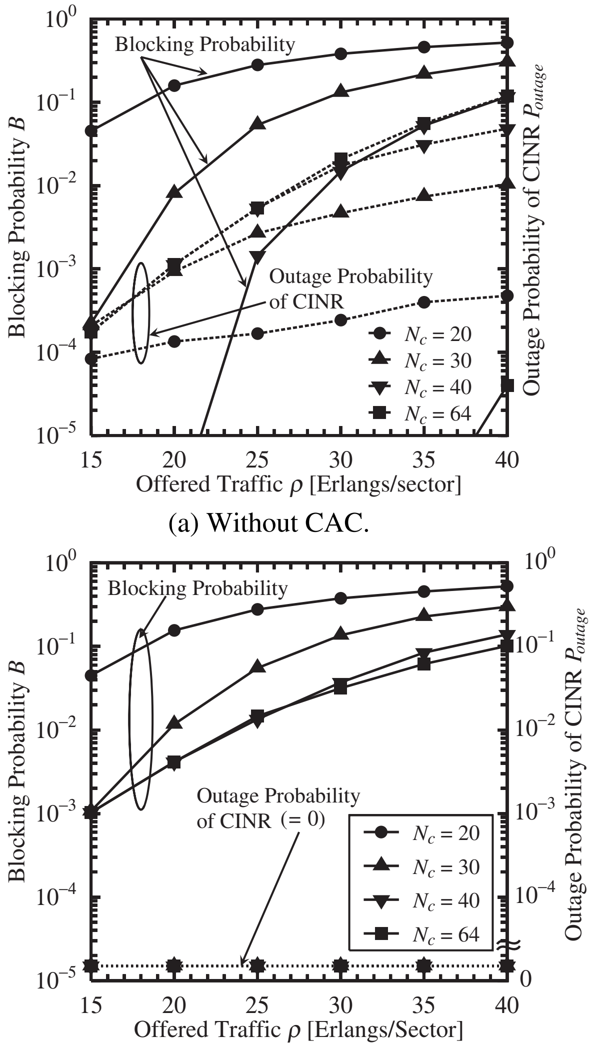
Fig.5 Cumulative probability of received CINR.

Fig.6 shows blocking probability and outage probability, where the number of the antenna elements is 8 ($N_a = 8$) and the number of channels, N_c, is a parameter. Fig.6 (a) shows these characteristics with and without proposed CAC. From Fig.6 (a), we find that the outage probability of CINR without CAC varies according to the channel number or offered traffic. On the other hand, we find that the proposed CAC algorithm keeps outage probability of CINR to zero and avoids any increase in outage probability due to a new call as shown in Fig.6 (b). Therefore the proposed CAC algorithm is very effective for call admission control in AAA systems.

Fig.7 shows the relation between the antenna element number, N_a, and the system capacity with the proposed algorithm. This figure confirms that AAA with the proposed CAC algorithm can increase the system capacity in proportion to the number of antenna elements, N_a.

5. CONCLUSION

We proposed a novel CAC algorithm for AAA at the BS in DS-CDMA systems. Simulations confirmed that the proposed CAC algorithm ensures that all active MSs receive the required transmission quality. Furthermore, we confirmed that proposed CAC algorithm can increase the system capacity in proportion to the number of antenna elements without degrading the transmission quality of active MSs.



(a) Without CAC.

(b) With CAC (Proposed Algorithm).

Fig.6 Blocking probability and outage probability.

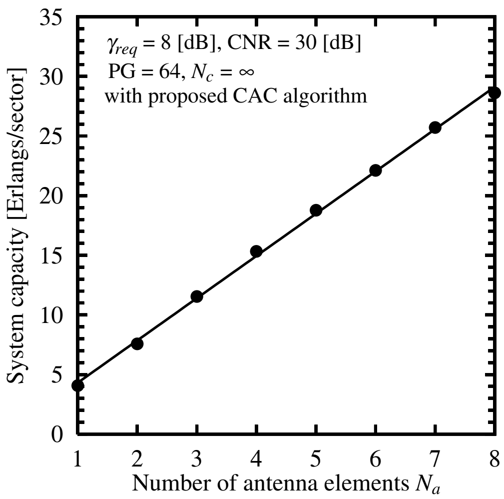


Fig.7 Relation between the number of antenna elements on adaptive array antenna and system capacity.

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