A Soft Handoff Scheme to reduce the Call Failure Rate of CDMA Cellular Systems

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요 약

IS-95를 기본 규격으로 채택한 이동통신시스템에서, 트래픽이 각 셀마다 비균일하게 분포한 실제 시스템의 성능을 향상시키기 위한 하나의 방법으로서 새로운 소프트 핸드오프 알고리즘을 제안한다. 제안된 소프트 핸드오프 알고리즘은 소프트 핸드오프 Threshold값(즉 T_ADD, TDROP)이 각 셀의 트래픽 조건에 따라 동적으로 변화된다. 각 셀의 트래픽 조건은 사용된 순방향 링크의 트래픽량에 의해서 결정된다. 또한 제안된 알고리즘의 성능을 평가하기 위하여, 동적으로 변화되는 Threshold값을 가지는 소프트 핸드오프 알고리즘을 적용한 시스템의 성능은 고정된 Threshold값을 갖는 전통적인 소프트 핸드오프 알고리즘을 적용한 시스템의 성능보다 우수하다는 것이 시뮬레이션 결과에 의해서 보여준다.

Abstract

Traffic nonuniformity degrades the performance of CDMA cellular systems. This paper presents a new algorithm called the Soft Handoff with Dynamic Thresholds (SHDT) which reduces the performance degradation due to traffic nonuniformity in CDMA cellular systems. Unlike the conventional fixed handoff thresholds, the proposed algorithm allows the handoff thresholds (T_ADD and T_DROP) to vary dynamically according to the traffic density of each cell. This algorithm has been implemented by means of computer simulation and the results show that SHDT improves the overall CDMA system performance in terms of outage probability. The SHDT algorithm can easily be applied to CDMA cellular systems without any modification.

Ⅰ. Introduction

Cellular CDMA has been regarded as a system that would meet present and future needs for wireless communications and is currently in commercial service under the common air interface TIA/EIA IS-95 [1]. There have been many theoretical works showing that a CDMA system can support a greater number of subscribers than a TDMA or a FDMA system [2]-[4]. However, it has been

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expected that traffic nonuniformity among cells seriously degrades the overall system performance in real CDMA systems. In an FDMA or a TDMA system, the traffic unbalancing is treated by the scheme such as *dynamic channel assignment* (DCA), where frequency channels are assigned adaptively to the traffic condition of each cell (see [5] and the literature therein). However, in a CDMA system, similar methods to DCA are not available because of the intrinsic feature of CDMA, i.e., reuse of all frequency channels in each cell. In a CDMA system, the carrier-to-interference ratio (CIR) in a cell decreases as the number of users of the cell. This is mainly increases because all base stations (BSs) are communicating with mobile stations (MSs) in the same channel, and the crosscorrelations of the codes are never zero. Cells under heavy traffic loads experience high interference, where some of new and/or ongoing calls would be blocked and/or dropped as a result of the CIR decrease. On the other hand, neighboring cells under the light traffic are still able to accommodate more calls.

Dynamic cell management (DCM) concept [6] has been proposed to resolve the local traffic unbalancing in CDMA systems. With DCM, a heavily loaded cell dynamically shrinks its coverage area to adjust loads it can adequately handle, while adjacent cells that are less loaded increase their coverage area to pick up the extra traffic. There are some algorithms for DCM, which adaptively control the cell coverage area by means of the *required reverse link power* [7]. However, these algorithms cannot be applied directly to IS-95 based CDMA systems, because the cell coverage in IS-95 based systems is determined by the pilot channel power in the forward link and soft handoff thresholds. Furthermore, these algorithms assume the perfect reverse link power control that is almost impossible in real systems.

This paper proposes a new soft handoff algorithm as a possible solution to the traffic nonuniformity in IS-95 based CDMA systems. In the proposed algorithm, soft handoff thresholds such as T_ADD and T_DROP are dynamically varied according to the traffic density in each cell. In developing the algorithm, we define *forward traffic power usage ratio* and use it as the measure of the traffic density of each cell. Most of all, our algorithm can be implemented directly to real IS-95 based systems without any modification and is very simple in spite of its effectiveness in both performance improvement and network overhead.

The remainder of this paper is organized as follows: In Section II, the soft handoff procedure in IS-95 based systems is explained as a preliminary. The forward traffic power usage ratio is defined in Section III. In this section, our soft handoff with dynamic thresholds (SHDT) algorithm is also proposed with the discussion on the relationships between the forward traffic power usage ratio and the traffic density in a cell. In Section IV, computational results that compare the performance of both SHDT and the conventional soft handoff algorithm with fixed thresholds are presented. Finally, Section V concludes the paper with remarks on the future research.

Ⅱ. Soft Handoff in IS-95 Based CDMA Systems

In an IS-95 based CDMA system, soft handoff states of an MS are determined by the pilot strength measurement and predefined soft handoff thresholds [1]. In Fig.1, an MS is initially handled by base station 1 (BS1). Soft handoff commences when the received pilot signal level, E_c/I_t(i.e., pilot chip energy to interference density ratio) at the MS from base station 2 (BS2) exceeds the T_ADD threshold. The MS maintains communication links with both BS1 and BS2 until the received pilot level from BS1 falls below the T_DROP threshold and stays below it for

T_TDROP timer. After the T_TDROP timer has been expired, the MS is handled by only BS2.

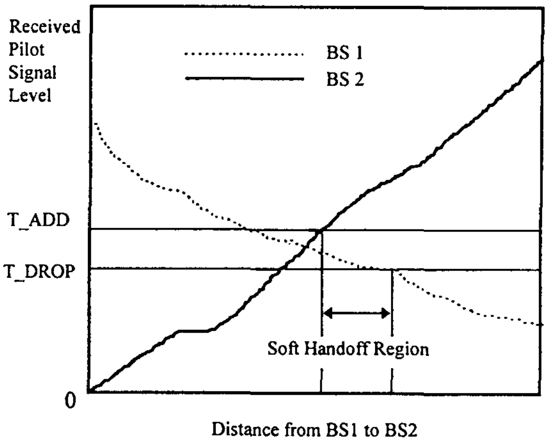

Fig. 1 Typical scenario of soft handoff

In this figure, it is easy to see that the soft handoff region can be controlled by varying handoff thresholds such as T_ADD and T_DROP (In most real systems, the pilot channel power of each BS is fixed). However, the conventional soft handoff algorithm has fixed handoff thresholds, and cell coverage is nearly invariable. Accordingly, new and/or ongoing calls within a heavily loaded cell would be blocked and/or dropped due to the increased traffic, even though calls in such a cell can be served by transferring to neighbor cells with light traffic. To overcome this disadvantage, we propose a soft handoff algorithm with thresholds that are dynamically changed according to the traffic density of each cell. With the proposed algorithm, the calls in a heavily loaded cell could be scattered into the adjacent cells with smaller traffic.

Ⅲ. Soft Handoff with Dynamic Thresholds (SHDT)

In CDMA cellular systems, the forward link power of a BS is a limited resource shared by the pilot channel, the paging channel and the sync channel as well as the traffic channels. In general, each transmitting power of the pilot, the paging and the sync channel is fixed and not varied according to instantaneous traffic conditions. However, the forward traffic channel power between a BS and an MS varies very frequently with the forward link power control. Therefore, the total power allocated to the forward link traffic channels in a BS is varied, due to the power control scheme and the traffic density in a cell.

In order for the thresholds to adaptively vary depending upon the traffic density, it is necessary to measure the traffic density in a given cell. To this end, the forward traffic power usage ratio of cell j is defined as follows:

$$r_j = \frac{P_{j-used}}{P_{j-total}} \quad \cdots\cdots (1)$$

where $Pj\text{-}used$ is the total power currently allocated to the traffic channels connecting the BS and MSs in cell j, and $P_j\text{-}total$ is the maximum power of the BS in cell j that can be allocated to the traffic channels. Note that a larger value of r_j indicates higher traffic density in cell j which may increase the outage probability in cell j. Based on the parameter r_j, the SHDT algorithm is described as follows. Assume that a BS broadcasts the soft handoff thresholds, i.e. T_ADD and T_DROP, to all MSs belonging to the cell. Let T_ADD$_j$ and T_DROP$_j$ be the soft handoff thresholds broadcast by the BS to all MSs in cell j. In the SHDT algorithm, the forward traffic power ratio is compared with the parameter r^* as defined below:

$$r^* = \frac{P_a}{P_{\max}} \quad \cdots\cdots (2)$$

where Pa is the power intended to allocate to the forward traffic channels and P_{max} is the maximum power of the BS. Note that in the SHDT algorithm, r^* should be less than 1. For example, the following handoff scenario can be considered:

$$\text{T\_ADD}_j = \begin{cases} \alpha_1 & \text{if } r_j < r^* \\ \alpha_2 & otherwise \end{cases} \qquad \cdots\cdots (3)$$

$$\text{T\_DROP}_j = \begin{cases} \beta_1 & \text{if } r_j < r^* \\ \beta_2 & otherwise \end{cases} \qquad \cdots\cdots (4)$$

where α_1 and β_1 are the predefined levels for T_ADD and T_DROP thresholds, respectively, whereas α_2 and β_2 are the selected thresholds for SHDT. That is, if r_j is greater than r^* (i.e. heavy traffic load), α_1 is dynamically changed to α_2 and similarly β_1 is changed to β_2 as shown in Fig.2. In SHDT, an MS may receive more than two sets of thresholds, e.g., (T_ADD$_i$, T_DROP$_i$) and (T_ADD$_j$, T_DROP$_j$) from the BS in cell *i* and the BS in cell *j*, respectively. In this case, in order to avoid the *ping-pong* phenomenon, it was assumed that the MS takes the values; T_ADD = min {T_ADD$_i$, T_ADD$_j$} and T_DROP = max {T_DROP$_i$, T_DROP$_j$}. It should be noted that after the traffic load is appropriately managed by the SHDT algorithm, the values of r_j in all cells of the system eventually converge to the predefined value, r^* thereby achieving uniform traffic conditions.

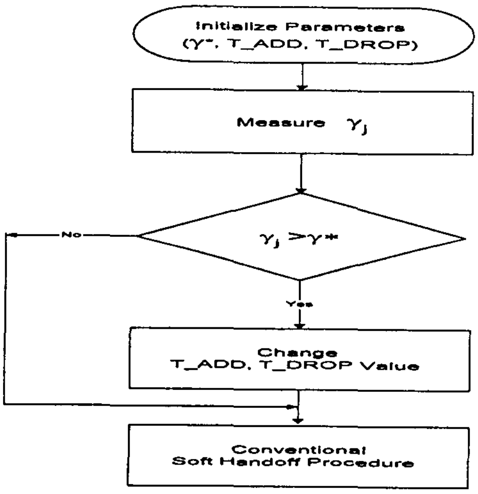

Fig. 2 Soft Handoff with Dynamic Thresholds

Ⅳ. Simulations and Results

Performance of SHDT was evaluated under the following simulation conditions: The used cellular system consists of 25 omni-BSs (i.e., omni-cells) equally spaced over the 20 km×20 km service area. The arrival process of calls for the overall system is a Poisson process with mean of 75-150 (calls/sec), where the call duration is exponentially distributed with mean of 100 seconds. MSs (i.e., calls) are moving around the service area, whose initial speeds (km/hour) and directions (degrees) are generated by uniform distributions U[10,50] and U[0,360], respectively. The speed and direction of an MS is changed after an exponentially distributed duration with mean of 1 minute. In this case, the new speed of an MS is generated by U[10,50] if the current speed, say *v*, is less than 10 and by U[*v*-10, *v*+10], otherwise. The new direction of an MS is generated by a Gaussian distribution with mean *d* and standard deviation 20, where *d* is the current direction of the MS.

Three factors are considered in our propagation model for calculating signal strength and noise amount; path loss, shadow fading, and multipath fading (see also [8]). The instantaneous received power, P$_r$(dBm) at a given receiver from a given transmitter is calculated by using the following formula:

$$P_r = P_{tx} - L_{path} + L_{shd} + L_{\mu lt} \qquad \cdots\cdots (5)$$

In (5), P_{tx} is the transmitted power (dBm), L_{path} denotes path loss (dB), L_{shd} is shadow fading (dB) and L_{mult} denotes Rayleigh distributed multipath fading (dB). Lee model (see [2] and literature therein) is used for generating L_{path} with path loss exponent 4, and L_{shd} is generated from a log-normal distribution with mean zero and standard deviation 7. We have also considered and

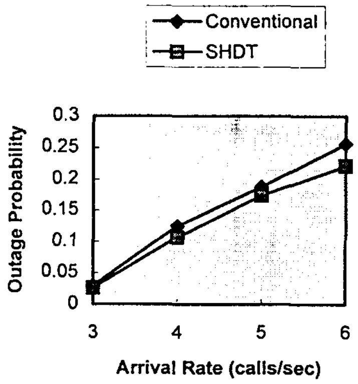

Fig. 3 Outage Probability with = 0.8

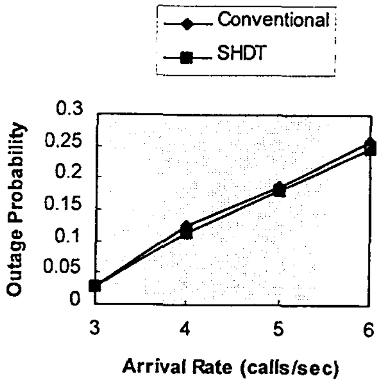

Fig. 4 Outage Probability with = 0.9

implemented major IS-95 functions such as call access, soft handoff and forward link power control in our simulation, which are mainly taken from the modules of *CDMA WiNS*, a CDMA radio network simulator developed by ETRI [8].

Computational experiments were carried out for 150 seconds with the following values of the parameters mentioned above; the values of α_1 and α_2 were set to -14 dB and -14.5 dB, respectively, while β_1 and β_2 were set to -16 dB and -15.5 dB, together with $r^* = 0.8$. Also, T_TDROP was set to 5 seconds. The simulation results are shown in Fig.3. It can be seen that the outage probability of the system with SHDT employed is much lower than the one employing the conventional soft handoff algorithm at a given arrival rate. In order to evaluate the effectiveness of the algorithm with a different value of r^*, a further investigation was carried out with $r^* = 0.9$. Fig.4 shows the better performance in terms of the outage probability with SHDT than that of the conventional scheme (r^* = 1). From the examination of Fig.3 and Fig.4, it can be said that if the predefined r^* value is close to 1 (i.e. close to the conventional scheme), the advantage of the SHDT algorithm will be diminished. Conversely, if r^* is very low, it will cause the reduction in system capacity. Therefore, a trade-off has to be made. It has been found that a significant gain of the SHDT algorithm can be achieved by choosing $r^* = 0.8$

V. Conclusions

This paper has presented a new soft handoff algorithm as a possible solution to the traffic nonuniformity problem in CDMA cellular systems. In this algorithm, the handoff thresholds (T_ADD, T_DROP) in each cell are allowed to vary dynamically according to the difference between the parameter r^* and the forward traffic power ratio r_j. The simulation results have shown that the overall system performance is improved with the proposed algorithm. Note that an important advantage of the proposed algorithm is the easeness of implementation without system modification. There may be a variety of handoff scenario with the different values of the parameters (i.e. r^*, α_2 β_2). It could be of interest to find the optimal values of the above parameters in a CDMA cellular system. This work is being undertaken using the versatile simulator and significant progress has already been made.

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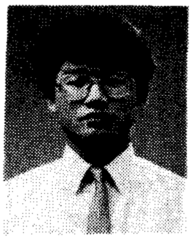

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