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Performance Analysis of Trunk Network for Inter-MSC Soft Handoffs in CDMA Cellular Communication Systems

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Abstract **The soft handoffs between two adjacent MSC's should be employed to support the calls requesting handoffs to an MSC while minimizing the undesirable "ping pong" phenomenon of back-and-forth handoffs between two adjacent cells in conventional hard handoffs. In this paper, the soft handoff scheme between two MSC's is considered using the trunk between the packet routers for the two MSC's. The trunk network is proposed to support the inter-MSC soft handoff scheme in the service area with many MSC's. The probability that a soft handoff to an adjacent MSC will be blocked due to the shortage of the trunk capacity is derived.**

Keywords **CDMA, Soft handoff, Blocking probability**

1. Introduction

Code division multiple access (CDMA) is a promising air interface technique for cellular systems. When a mobile station moves to an adjacent cell, the handoff between the serving cell and the target cell is needed. Compared with the hard handoffs, the soft handoffs between two CDMA channels with the identical frequency assignments and frame offsets can provide a better quality of service. [1–4] The soft handoffs between cells within an MSC (Mobile Switching Center)'s service area have been implemented in commercial CDMA cellular systems. The soft handoffs between two adjacent MSC's should be employed to support the calls requesting handoffs to a new MSC while minimizing the undesirable "ping pong" phenomenon of back-and-forth handoffs between two adjacent cells in conventional hard handoffs.

In this paper, the soft handoff scheme between two MSC's is considered using the trunk between the packet routers for the two MSC's. After a mobile station moves to a new MSC's service area, the old MSC will receive from and send to the mobile station the traffic data through the trunk between the packet routers for the two MSC's and the same vocoder in the old MSC will be used. The trunk network will be proposed to support the inter-MSC soft handoff scheme in the service area with many MSC's. The theoretical approach for the performance analysis of the trunk network will be developed to obtain the probability that a soft handoff to an adjacent MSC will be blocked due to the shortage of the trunk capacity. In the literature, the soft handoff scheme between two MSC's in [4] switches the vocoder in the old MSC to that in the new MSC for the mobile station moving to the new MSC's service area, and the performance of the trunk is investigated using computer simulation in [4]. But, by switching the vocoder for the inter-MSC soft handoff, a new connection for rerouting the call in progress of the mobile station through the new MSC should be established while maintaining the old connection through the old MSC. In addition to this implementation burden for the inter-MSC soft handoff, a new signaling scheme for switching the old call connection to the new one through the new MSC is needed. With the proposed scheme, the same call connection through the old MSC is maintained so the processing load for reestablishing the connection through the new MSC is not needed. The proposed scheme makes the inter-MSC soft handoff processing relatively simple and fast at the expense of reserving the trunk resource between MSC's. However, since the geographical coverages of MSC's are large compared with the size of cells within the coverage, it is expected that the traffic between MSC's due to the inter-MSC soft handoffs will be acceptably small and manageable by the trunk with a not large capacity.

The outline of this paper is as follows. In the next section, the soft handoff scheme between MSC's is described using the trunk between the packet routers. In Section 3, the trunk network for the soft handoffs between MSC's is proposed, and the parameters and random variables are defined to model the cellular system. For a given trunk capacity, an analytical approach is developed to calculate the probability that a soft handoff to an adjacent MSC will be blocked due to the shortage of the trunk capacity in Section 4. Numerical examples and conclusions are given in Sections 5 and 6, respectively.

2. Soft handoff scheme between MSC's

If a mobile station nears a cell boundary, the mobile station may detect the signal from at least two base stations. The area in which two or three base stations can be detected above a certain threshold of signal strength by the mobile station will be called the handoff area. The handoff area in which simultaneously 2 (or 3) adjacent base stations can serve the mobile station will be called 2 (or 3)-way handoff area. If the mobile station communicating with a base station moves to a new cell, the soft handoff

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allows both the original cell and the new cell to temporarily serve the call while it is located in the handoff area, as shown in Fig. 1. Not only does this greatly minimize the probability of a dropped call, but it also makes the handoff virtually undetectable by the user. When the mobile station in service has entered the handoff area between two cells within an MSC's service area, the mobile station transmits a control message to its MSC and MSC initiates the soft handoff by establishing a link to the mobile station through the new cell while maintaining the old link. While the mobile station is located in a 2 (or 3)- way handoff area, two (or three) adjacent base stations serve the mobile station simultaneously and the MSC receives and sends two (or three) channel traffic data through two (or three) links to the mobile station.

In Fig. 2, let a mobile station originate a call in an MSC 1's service area. When the mobile station requests a soft handoff from CELL 1 in MSC 1's service area to CELL 2 in MSC 2's service area, MSC 1 establishes a link to CELL 2 through the trunk between the packet routers of MSC 1 and MSC 2. In the handoff area, MSC 1 maintains two links to CELL 1 and CELL 2, and CELL 1 and CELL 2 serve the mobile station simultaneously. If the mobile station is located in the handoff area of MSC 1 and MSC 2 and one (or two) cells in MSC 2's service area have the mobile station in their service areas, MSC 1 receives and sends one (or two) channel traffic data through the trunk. After the mobile station moves out of the handoff area and the soft handoff is completed, the call of the mobile station will still be served by the vocoder in MSC 1 through the trunk while it is located in MSC 2's service area. While the mobile station is located in a 2 (or 3)-way handoff area in MSC 2's service area and two (or three) cells in MSC 2's service area serve the mobile station, MSC 1 receives and sends two (or three) channel traffic data through the trunk. If the mobile station moves to the service area of another new MSC, MSC 3, the trunk between the packet routers of MSC 1 and MSC 3 will be used to carry the traffic data from the mobile station to MSC 1 and vise versa. While the mobile station is located in a 2 (or 3)-way handoff area in MSC 3's service area, MSC 1 receives and sends two (or three) channel traffic data through the trunk between the packet routers of MSC 1 and MSC 3. For this soft handoff scheme between MSC's, the trunk capacity should be determined to satisfy the required blocking probability of the inter-MSC soft handoffs due to the shortage of the trunk capacity.

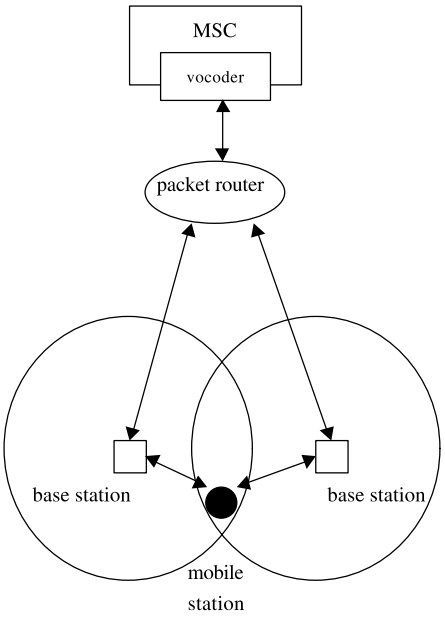

Fig. 1. Soft handhoff between two base stations.

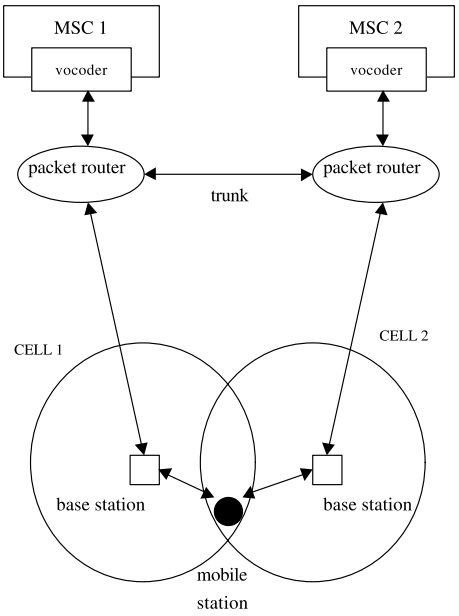

Fig. 2. Soft handhoff between two MSC′s.

3. Trunk network and model description

As shown in Fig. 3, the whole service area is served by many MSC's and each rectangle represents the service area of an MSC. Since the service area of an MSC is large with respect to the mobility of mobile stations, we can have the following reasonable assumptions:

1. When a mobile station originates a call in the service area of an MSC, during the call the mobile station will be located in the service areas of nine MSC's including the original MSC and the eight adjacent MSC's of the original MSC.
2. During the call the mobile station requests at most two inter-MSC soft handoffs (After the first inter-MSC soft handoff, the mobile station can return to the service area of the original MSC.)

After the first inter-MSC soft handoff, the mobile station will be located in one of the service areas of the four adjacent MSC's of the original MSC. If the mobile station will not return to the original MSC, the second inter-MSC