Soft Handoff Technology in CDMA Cellular Networks

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Abstract: In mobile communication systems, handoff has been widely applied as one of the key technologies. This thesis introduces soft handoff technology used in the code-division multiple-access cellular networks, discussing its theory, process, advantage and disadvantage. This thesis also discusses the main three parameters of soft handoff by how they affect the system. At the end of the thesis, a new type of handoff, relay handoff used in TD-SCDMA, is introduced and then compared with soft handoff.

Keywords: handoff; soft handoff; CDMA; cellular networks

I. INTRODUCTION

A cellular network is a radio network made up of a number of cells each served by a fixed transmitter, known as a base station. These cells are used to cover different areas in order to provide radio coverage over a wider area than the area of one cell. Cellular networks are inherently asymmetric with a set of fixed main transceivers each serving a cell and a set of distributed transceivers that provide services to the network's users. Usually, the cellular networks provide increased capacity, reduced power usage and better coverage than other alternating solutions. However another problem occurs. When a phone moves away from one cell and enters the area covered by another cell, that this situation often takes place when making a phone call, the communication link of the phone with the previous base station will turn to new link with new base station. We take the process as “handoff” or “handover”.

The study of handoff aims at providing service that is more comfortable for mobile users. To do this, the process of handoff should be quick, effective and as few as possible so that it influences user as little as possible. That is also the purpose of this thesis.

II. SOFT HANDOFF AND HARD HANDOFF

There are two types of handoff, one is soft handoff and the other one is hard handoff. Before we discuss soft handoff, we may introduce these two types of handoff at a glance. Hard handoff occurs when the previous base station and the new base stations have different frequencies. The process of hard handoff acts as follows: when the mobile station is in the status of handoff, it cuts off the call temporary, moves to new frequency and then establishes new connection with new base station. This technology is widely used in the second-generation mobile communication.[1] In the third-generation mobile communication CDMA cellular networks, the same frequency band can be shared by all cells. The orthogonal properties of CDMA waveform are used to discriminate between signals that occupy the same frequency band. Thus, a mobile need not switch its carrier frequency when a handoff call is made from one base station to another. So the soft handoff technology is introduced. The contrast of hard handoff and soft handoff can be illustrated from figure 1 below.

Figure 1

A soft handoff scheme is employed for CDMA cellular networks in which a new base station modem is assigned to a mobile while the old base station continues to serve the call. Since the mobile always communicates through at least one base station, even handoff calls cause no disruptions in calls in process. The soft handoff is executed by a make-before-break switching function while the handoff used in the conventional cellular systems is done by a make-before-break function.[1] One of the most important advantages of CDMA cellular networks is its soft handoff capability other than AMPS, TDMA and GSM cellular networks.

III. THE PROCESS OF SOFT HANDOFF

A pilot (short for "pilot channel") is a signal, usually a single frequency, transmitted over a communications system for supervisory, control, equalization, continuity, synchronization, or reference purposes. The frequencies of different pilots are the same in soft handoff, so are the PNs (PILOT-INC). However, different pilots have different time migrations for mobile stations to classify different pilots. These time migrations are all several times of one known standard migration so that mobile stations can search pilots. In all status of a mobile station, it keeps on searching pilots, but does not report to base stations. In normal case, it only searches pilots in its working frequency, and just under base station's demand, it may search other pilots in other frequencies.

The process of soft handoff acts as follows. First, the mobile station searches all pilots and measures the signal intensity of each pilot. If the intensity of some pilot is higher than the pilot intensity add-threshold (T-ADD), the mobile station will consider the intensity enough for communication but before establishing connection with new pilot, it will send a message of measuring pilot intensity to the old base station for informing this situation. Then the old base station will forward mobile station's report to the mobile switching center (MSC), and the MSC will notify the new base station to arrange a channel for the mobile station. After the above have done, the old base station will send a message to the mobile station that it can take actions to process its handoff.

The mobile station brings the pilot into its available pilot set after getting the message and begins to demodulate the old and new pilot channels simultaneously. Then it send a message to inform the base station that it has finished the process of handoff and been the status of demodulating two pilot channels. With the moving of the mobile station continuing, one of two pilot intensities will be lower than the pilot intensity drop-threshold (T-DROP). At that time, the mobile station will start a countdown timer. When the timer has finished its time T-TDROP, the mobile station sends the message of measuring pilot intensity again. Since the mobile station is communicating with the two stations, old and new, simultaneously, they will both receive the message and forward it to the MSC. The MSC then returns the corresponding handoff instruction and the base stations forward it to the mobile station. The mobile station brings the old mature pilot out of its available pilot set. Now the mobile station is communicating with the new base station and after it sends the message that it has accomplished the handoff process to the base station, the soft handoff ends.

The process can be illustrated from figure 2 below.

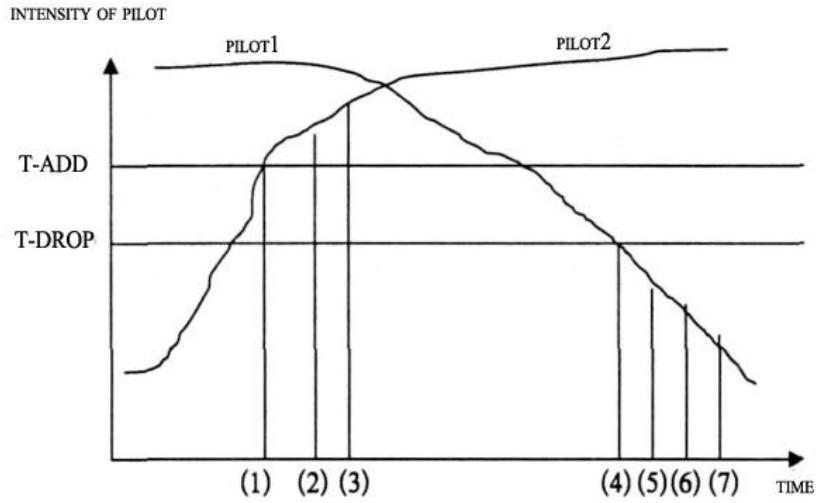

Figure 2

- At the time of (1), the mobile station has detected the intensity of pilot2 higher than T-ADD and it sends a message of measuring intensity to the old base station.
- At the time of (2), the base station sends handoff instruction.
- At the time of (3), the mobile station brings pilot2 into its available pilot set and sends the message that it has finished this step.
- At the time of (4), the intensity of pilot1 is lower than T-DROP, and the countdown timer begins.
- At the time of (5), the timer ends and then the mobile station sends the message of measuring intensity.
- At the time of (6), the base station sends the handoff instruction.
- At the time of (7), pilot1 is brought out from the mobile station's available pilot set and the mobile station sends the message that it has accomplished the soft handoff.

IV. THE PARAMETER SETTING OF SOFT HANDOFF

The process of soft handoff in CDMA cellular networks is the process of comparing the pilot signal intensity and different handoff parameters such as T-ADD (the pilot intensity add-threshold), T-DROP (the pilot intensity drop-threshold) and T-TDROP (the time of the countdown timer). So a good parameter setting is very important to soft handoff's capability.[3] We will discuss the settings of the three parameters below and show how they affect the networks.

1. **T-ADD parameter**
   When the intensity of some pilot is higher than T-ADD, the pilot is added into the available pilot set of the mobile station and the process of soft handoff begins. The setting of T-ADD parameter should be low so that pilots can be added into available pilot set quickly. It should be also high enough to avoid wrong alert caused by noise. If it is set too low, there will be many measuring and unnecessary handoff will occur, even a mobile station will occupy three or more pilots, which is a waste. In the other hand, if it is set too high, it may cause the service worse because fewer pilots are involved and the user can use fewer pilots.
2. **T-DROP parameter**
   In contrary, when the intensity of some pilot is lower than T-DROP, the pilot is removed from

the available pilot set. The setting of T-DROP should be as low as possible to prevent a good pilot from being removed. However, if it is set too low, unnecessary handoff will occur since the same pilot may be added into and removed from the available repeatedly. Besides, a too-low setting causes the coverage of one base station to expand which leads the power of base stations increase. For the mobile station, it is in several coverage areas of different base stations that leads a waste of several pilots occupied. However, if it is set too high, the handoff area is narrowed, the times of handoff is reduced, the ping-pong effects (the mobile station changes the pilots back and forth) appear more frequently and the call dropping rate is higher.

3. **T-TDROP parameter**

   When the intensity of a pilot is lower than T-DROP, the countdown timer begins to work and when it gets to T-TDROP, the pilot is removed from the available pilot set. The value of T-TDROP should be larger than the time needed to establish a connection. If the value is set too small, it may cause unnecessary handoff (since the same pilot may added and removed repeatedly). In the other hand, if the value is set too large, the mobile station may occupy too many pilot channels.

By analyzing how the parameters affect the performance of soft handoff above, we can see the settings of these parameters is very important. In realistic, there are more parameters that affect the performance and this thesis just analyze three of them for a glance. We usually set these parameters by emulation analysis or practice.

V. GLANCE AT RELAY HANDOFF

During the process of soft handoff, a mobile station is served by two or more base stations, which occupies two or more pilots wasting resources. The relay handoff technology is introduced in TD-SCDMA (Time Division-Synchronous Code Division Multiple Access). The mobile station cuts off the old connection with the old base station at the time a new connection with the new base station is established so that there is always only one connection. During the process, no information is lost and no communication is interrupted.

TD-SCDMA uses a unique smart antenna technology to get the mobile station’s direction of arrival (DOA). With the technology of synchronous CDMA, it gets the distance between the mobile stations and the base station. And then the system gets the precise location of the mobile station. With the location information of the mobile station, the system can detect if the mobile station has entered the handoff area. If so, then the new base station gets a message that a new mobile station arrives and will prepare for handoff. It is considered as a quick, reliable and efficient handoff. [4]

VI. ENDING WORDS

Handoff technology not only solves the problem how cellular networks cover seamless, but also is the key technology to promote performance of mobile communication. To discuss how soft handoff works and how its parameters affect the performance has important meaning to the construction of CDMA cellular networks. In realistic, we should consider the system load, distribution of business and the transmitting environment to design an efficient plan of soft handoff.

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