Impact of Soft Handoff on TCP Throughput over CDMA Wireless Cellular Networks

Masashi Sugano
Osaka Prefecture College of Health Sciences
3-7-30, Habikino, Habikino, Osaka 583-8555, Japan
Tel: +81-729-50-2111, Fax: +81-729-502131
E-mail: sugano@osaka-hsu.ac.jp

Liwei Kou, Takayuki Yamamoto and Masayuki Murata
Department of Information Networking,
Graduate School of Information Science and Technology,
Osaka University
1-3, Machikaneyama, Toyonaka, Osaka 560-8531, Japan
Tel: +81-6-6850-6863, Fax: +81-6-6850-6868

I. Introduction

In CDMA (Code Division Multiple Access) cellular networks, the soft handoff technique allows a mobile host to communicate with multiple base stations simultaneously, improving the transmission quality of the wireless channel and avoiding disconnection upon to base station switching. It is obvious that using soft handoff provide better performance than hard handoff as it can avoid interruptions and frequent switching. Nevertheless, when the number of MHs (Mobile Hosts) at the boundary of a cell increases, if the soft handoff is adopted, the number of connections to the BS (Base Station) also increases, and the wired channel resources will be consumed and the load on the wired channel will become heavier. Moreover, since one MH can communicate with two BSs simultaneously, if the area of soft handoff is too large, interference may be generated and obstruct the data transmission of other MHs in downlink. For these reason, optimal soft handoff control is required to enhance the system performance. Over the past few years, however, most research has focused on evaluating the performance of voice communication in CDMA cellular networks

On the other hand, due to rapid technological advances in wireless communications and the Internet, the interconnections between wireless and wired networks have to be considered. TCP (Transmission Control Protocol) is a reliable end-to-end transport protocol and can be tuned to perform well in wired networks. However, in the wireless channel, because of the characteristic of high FER (Frame Error Rate), the performance of TCP is severely affected [1].

The purpose of our research is to integrate the TCP performance in the wired and wireless channels over the CDMA cellular networks with soft handoff. It is because soft handoff affects both the wired portion of a network, and the wireless portion. In this paper, we propose a model for the simulation of the RLP (Radio Link Protocol) of data link layer in wireless channel and the method to decide the transmission delay of a packet from TCP layer. We perform simulation experiments and according to the result it can be clarified which parameters have an influence on the TCP performance when soft handoff is adopted. First, we simulate the case when varying the soft handoff margin and the MH density, and investigate the relationship between the position of MH and the TCP performance. We then obtain the effective range of soft handoff margin. Furthermore, the use of soft handoff has the advantage it can avoid the cut off of communication during the handoff. We also simulate the case of a MH moving randomly with frequent handoff to investigate this effect.

II. System Description

The logical elements of typical CDMA cellular networks are a FH (Fixed Host), a BSC (Base Station Controller), some BSs and a number of MHs. Communication between MH and BS is wireless and the BSC is wired to a FH and two or more BSs. When a MH performs the TCP transmission, the BSC receives the TCP packet from the FH via the Internet. The TCP packet is transmitted by RLP frames from the BSC to the BS which is connected to the destination MH, and the destination MH also receives the data as RLP frames from BS. Taking into consideration the TCP data packets transmission in the CDMA cellular networks, the simple protocol stack is depicted in Figure 1. We assume that a FH in a wired part of network will transmit TCP packets to a MH in a wireless channel. In the FH side, the TCP layer passes the packets over to the IP layer and sends them to the BSC/BS via the physical layer. The BSC/BS takes over the packets and partitions the received packets into smaller sized frames in the RLP layer and then sends the frames to the destination MH.

In a wireless channel, because of the fading effect and the characteristics of the spectrum, the probability of transmission error is higher than in a wired channel. To provide shielding from receiving error frames, the use of NAK (Negative Acknowledgment) based RLP in CDMA cellular networks has been proposed [2]. With NAK based RLP, whenever the RLP receiver detects a missing frame, the NAK frame that has the same specified sequence number as the missing frame is sent back to RLP sender. When the RLP sender receives the NAK frame, the missing frame is retransmitted. Furthermore, due to the fact that a MH can communicate with plural BSs in the soft handoff, the calculation of SIR (Signal to Interference Ratio) in the soft handoff state is different from that in the hard handoff state [3].

III. Simulation Model

We propose that the topology of evaluation consists of FH, BSC, BS_0, BS_1, and many MHs. If it is assumed that the multiple communication of a MH is with two BSs at most by soft handoff, it can be divided into three zones: the single communication zone of BS_0, the single communication zone of BS_1 and the multiple communication zone in which

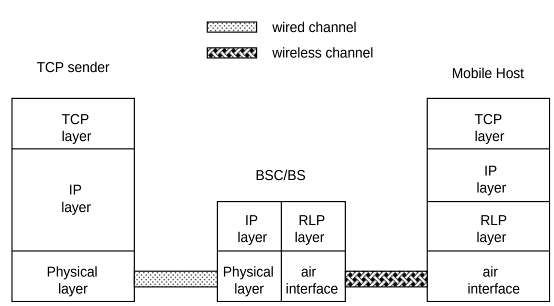

Fig. 1. Protocol stack in CDMA cellular networks

TABLE I

PARAMETER SETTINGS

Cell Radius	2 km
Bandwidth in Wireless Channel	192 kbps
Bandwidth in Wired Channel	1000 Mbps
Propagation Delay in Wireless Channel	50 ms
Propagation Delay in Wired Channel	100 ms

the MH communicates with both of them. Among all of MHs, we assume that some are in the single communication area (communicate with BS_0 or BS_1) and others are in the multiple communication area (communicate with BS_0 and BS_1 simultaneously) as in a real CDMA cellular networks environment. In this paper, we used the ns-2 [4] for simulation. However, there were no utilizable CDMA modules available for RLP on the data link layer in ns-2, so we make the RLP modules and introduce some assumptions to derive the packet delay.

In this simulation, we derive the frame error rate of RLP according to SIR. Here we make the assumption that one TCP packet is divided into four RLP frames. The probability of retransmission for each frame can be calculated by FER. The transmission delay of TCP packet in the wireless channel must be considered with the retransmission of each frame in a TCP packet. As a description of RLP3, the first and second retransmissions can be performed in the first round, and the third, fourth and fifth retransmissions can be performed in the second round. Then we calculate the transmission delay of a frame based on the retransmission of the first round or second round. Due to lack of space we do not present the formulation of analysis.

IV. SIMULATION RESULTS AND DISCUSSIONS

In this section, we show our proposal for evaluating CDMA cellular networks. Here, we define the position of the MH as the ratio of the actual position of the MH to the distance between the BSs. Assuming BS_0 and BS_1 are in the CDMA cellular networks, the MH is in the same position as BS_0 if the position of the MH is equal to 0, and in the same position as BS_1 if the MH position is equal to 1. Similarly, when the MH position is equal to 0.5, this indicates that the MH is in the center, between BS_0 and BS_1. We also define the MH density as the number of MHs per unit area (of one cell). Parameters used for the numerical examples are summarized in Table I.

We first show the effect of soft handoff margin on FER at the terminal located in the border of a cell in Figure 2. We can see the FER is better when the soft handoff margin is increased from 2 dB to 4 dB. However, FER becomes much worse when

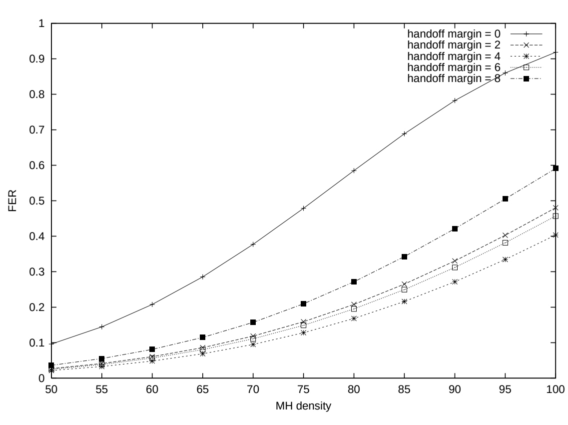

Fig. 2. Relationship between FER and MH density

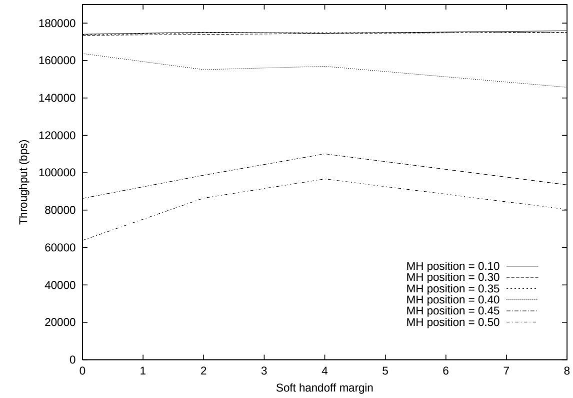

Fig. 3. Effect of soft handoff margin (MH density = 50)

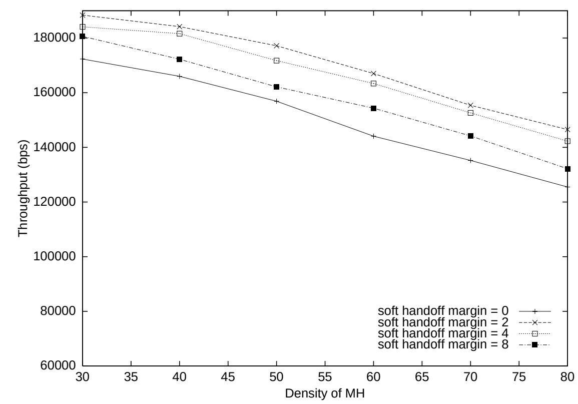

Fig. 4. Average Throughput in case of MH moving randomly

the soft handoff margin is further increased to 8 dB. When the soft handoff margin was set to 8 dB, it caused the number of MHs communicating with one BS to increase too much. This generates huge interference and the effect of the soft handoff is suppressed.

Figure 3 expresses the throughput by the position of a MT for every soft handoff margin. In this figure, it turns out that the case where a soft handoff margin is 4dB is the optimum at the MT located near the border of a cell (MH position = 0.45 and 0.5). However, it is shown in the terminal near the center of a cell that it is almost uninfluential.

We next show the simulation result in the case of a MH moving at random between cells and repeating handoff many times. We set up the initial MH position to be random and the average time of MH stay in a cell is 100 second. The influence on TCP performance of using the hard and soft handoff can be shown as Figure 4. We can observe the effect of prevention of disconnection by the soft handoff has the largest case where a soft handoff margin is 2dB. That is, even if it performs a soft handoff more than it, a throughput deteriorates by the increase of interference or the load of wired portion.

REFERENCES

[1] A. Chockalingam and G. Bao, "Performance of TCP/RLP protocol stack on correlated fading DS-CDMA wireless links," *IEEE Transactions on Vehicular Technology*, vol. 49, pp. 28–33, Jan. 2000.

[2] F. Khan, S. Kumar, K. Medepalli, and S. Nanda, "TCP performance over cdama2000 RLP," in *Proceedings of IEEE VTC 2000 Spring*, May 2000.

[3] C. Mihailescu, X. Lagrange, and Ph. Godlewski, "Soft handover analysis in downlink UMTS WCDMA system," in *Proceedings of MOMUC '99*, Nov. 1999.

[4] "The network simulator - ns-2," available at http://www.isi.edu/nsnam/ns/.