Performance Improvements of Mobile Data Protocol in Wire and Wireless Interworking Environments

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Abstract. In this paper, efficient data transmission methods in wire and wireless interworking environments are studied in the case of handover occurring. In the wire and wireless interworking equipment, handover adaptation methods as well as various transmission characteristics of wire and wireless channel must be considered. To provide efficient mobile data service based on TCP, the wire and wireless interworking module with analysis function of TCP segment header protects the duplicated transmission of TCP frames. Also, by using the forwarding mechanism of status information and buffered data in the interworking module, it is possible to recover frame loss occurring in handover quickly. According to simulation results, proposed method has better performance than conventional method in view of throughput and delay. The reason is due to the fact that duplicated transmission is prevented and data recover is performed very quickly because buffered data is forwarded without loss in the case of handover.

I. Introduction

Recently, for a past few years, the progress of personal communication technology has been changed from voice based service into multimedia communication service that includes data and moving picture. To offer mobile multimedia service, development of a multiple access mechanism which controls multimedia traffic efficiently, guarantee of sufficient bandwidth which can support multimedia data, and development of a high speed transmission technique which can handle real time traffic must be performed. Also, the interworking between high speed wire network using ATM technique and low speed wireless network should be considered.

The general multiple access methods in wireless channel environments are FDMA, TDMA and CDMA. Also, the hybrid methods of CDMA and TDMA are proposed[1],[2]. These methods have improved channel utilization. To offer packet data service, access methods such as ALOHA, slotted-ALOHA, CSMA and PRMA are used. Also, the researches to improve performance for multimedia service are in progress [3]. In multimedia service, properties of service such as transmission delay, signal to noise ratio, and receiving information quality must meet some criteria with which customers are satisfied. When we consider mixture environments of data and voice with simple multimedia applications, voice service requires realtime property with a tolerate of 1 - 3% data loss. However, data service can not tolerate data loss, but some delay time can be allowed. Thus, for voice traffic transmission, error recovery based on retransmission mechanism is not performed for real time processing and only FEC is used. But, data traffic uses retransmission mechanism and FEC method to guarantee data transmission reliability. Also, coding rate is changed according to the channel environments in order to maximize transmission performance[4].

Wireless multimedia service is based on conventional mobile communication systems such as cellular phone and PCS. Actually, a study on improvement method of data transmission performance in voice and data integration environments has been done[5]. However, most of researches consider only mobile network, and do not consider the wire and wireless interworking environments. Also, a study on handover and location registration to support terminal and user mobility has been performed by many researchers[6], but little research has been done in the aspect of data transmission protocol.

The present TCP/IP protocol of wire network supports various internet application services such as HTTP, FTP and TELNET. To support mobile environments, a standard mobile-IP protocol is being set up. Thus, to support general internet service and mobile data service, a mechanism that supports TCP protocol must be studied.

In this paper, performance improvements of data service protocol in interworking environments of wire and wireless networks is studied in the consideration of duplicated transmission and handover. Following this introduction, we describe conventional studies for wireless data service in section II. A handover mechanism which supports mobility service is described...
II. Data Service Protocol in Mobile Wireless Environments

1. Wireless Link Protocol in CDMA PCS

The RLP (radio link protocol) wireless link protocol is proposed to support asynchronous circuit data service [7]. RLP is used by forward and backward traffic channel of IS-95A protocol, and performs bit error recovery operation based on retransmission mechanisms.

The transmission of RLP data frame through primary traffic channel and secondary traffic channel uses multiplex option 1 of IS-95A. RLP data frame has data burst message format in signaling traffic transmission. RLP frame consists of control frame, unsegmented data frame, segmented data frame and full rate format B data frame as shown in Figure 1.

![Figure 1] RLP frame format

The SEQ field is used to indicate RLP data frame sequence number, which operates according to modulo 256 mechanism. The CTL field is used to indicate RLP frame type such as SYNC, ACK and SYN/C/ACK. When sender RLP is initiated, RLP SYNC frames should be transmitted continuously. Receiver RLP layer replies with a SYNC/ACK frame for received SYNC frames, and transmits a SYNC/ACK frame until SYNC frames are not received any more. When sender RLP receives SYN/C/ACK frame, it ceases transmission of RLP SYN/C/ACK frame, and replies with RLP ACK frame. Then, the sender RLP should transmit ACK frame until SYN/C/ACK frame is no more received from receiver RLP continuously. If receiver RLP receives ACK frame, initiation procedure is completed, and data transmission phase is activated. The error recovery mechanism for data transmission uses retransmission mechanism based on NAK response. To reply with NAK frame, receiver RLP sets CTL field in RLP control frame. The FIRST field has SEQ value of the first data frame which needs to be retransmitted, and LAST field has SEQ value of the last data frame which needs to be retransmitted.

RLP data frame is transmitted by using unsegmented frame format, and its length is presented in LEN field. The unsegmented data frame could be separated into three frames, and transmitted respectively. As upper layer protocols of RLP layer, there are TCP which is described in RFC 793, IP which is described in RFC 791 and ICMP which is described in RFC 792.

2. CDMA PCS Network Architecture for Data Service

The CDMA PCS network elements for wireless packet/circuit data services consist of terminal equipments, mobile stations, base stations and IWF (interworking function). The interface between a terminal equipment and an IWF is defined as Rm, Um and L interface. Figure 2 shows protocol architecture for data service in CDMA PCS network architecture.

![Figure 2] The protocol architecture for packet/circuit data service

The terminal equipment provides one or more Rm interface, and each Rm interface could support only one service at the same time. Then, Rm interface supports RS-232 control function, AT command set, and PPP data transmission function. Um interface is a relay layer interface, and it consists of RLP and IS-95A physical layer. Also, Um interface includes a traffic channel management function. On the other hand, L interface provides data and signaling path as well as interface between BS and IWF.

The link layer protocol performs data transmission between terminal equipment and IWF. Also, it provides header compression and protocol discrimination for network layer protocols. Teleservice layer includes network and upper layer protocols, and supports communication function for application layer entities between terminal equipments and remote terminal equipments. Also, terminal equipment provides a user interface, and mobile station controls wireless communication between MS and BS. On the other hand, IWF is located at MSC or special network equipments, and it performs circuit establishment and release control between wire and wireless network.

III. Handover Mechanism for CDMA PCS

The handover of mobile station can be classified into idle handover that occurs in idle state and traffic channel handover which occurs in traffic channel control state. During idle state, in the case that mobile station moves...
from one base station area to another base station area, idle handover occurs. When mobile station detects another pilot channel signal except pilot channel signal of current base station, mobile station requests handover. In order to perform idle handover, mobile station maintains three pilot sets such as active set, neighbor set, and remaining set. The active set means forward pilot channels for current paging channel. The element of neighbor set is described by neighbor list message, and remaining set means all possible pilot offsets except neighbor and active set.

When mobile station stays in the traffic channel control state, mobile station supports three type handover such as hard handover, seamless handover and soft handover. A soft handover provides communication link between old and new base station without interruption of current call. This soft handover is performed between the same frequency CDMA channel, and provides diversity of forward traffic channel paths and reverse traffic channel paths between old and new base stations. CDMA-CDMA hard handover occurs between two base stations which have different frequency or different frame offset. If soft handover is impossible, CDMA-CDMA hard handover is performed. If another pilot signal strength is larger than threshold, mobile station sends pilot measurement message to base station. The base station allocates forward traffic channel to mobile station for handover. In order to support handover mechanism in traffic channel control state, mobile station maintains four pilot channel set such as active set, candidate set, neighbor set and remaining set. The active set indicates pilots related with forward traffic channels. The candidate set indicates pilot that is not included in active set, and receiving strength of pilot is sufficient to recover forward traffic channels by mobile station. The neighbor set includes pilots which could be under the candidate set for handover except active set and candidate set.

Figure 3 shows the general procedure of handover in digital CDMA cellular system.

IV. Improvement method of mobile data service protocol based on duplicated transmission detection and handover supporting mechanism

Because data services do not permit information loss, error control and flow control according to bit error are considered. Especially, error control and flow control have to be applied to mobile data service limitedly because quality of wireless link is much worse than that of wire link. Also, effective recovery mechanisms have to be applied in the case that burst error occurs in the course of handover.

1. The problem of duplicated transmission

To provide mobile data service, interworking for data service in wire link is needed. The wire link guarantees higher reliability for data transport than wireless link. Then, to apply TCP/IP protocol for wireless link, much consideration must be taken into due to high error ratio and limited bandwidth. Then, TCP protocol used in the wire environments must be adjusted in wireless environment. TCP segment length in wire link leads to frame error extremely in wireless link. Thus, in TCP protocol for IS-99, largest segment size is reduced to fitfulness size, so excessive frame errors at wireless link layer are reduced[7]. However, this method increases transmission overhead of wireless link, and does not guarantee performance in wire and wireless interworking environments.

To solve these problems, we propose the method that improves the interworking performance by adding simple protocol analysis function in interworking module between the wire and wireless link[8]. This method uses TCP of wire network already established without modification, and removes duplicated frame through frame header analysis in interworking module. Therefore, suggested interworking module prevents duplicated TCP frame transmission due to different transmission characteristics of wire and wireless link. Thus, fast retransmission could be achieved. However, when handover happens through movement of mobile terminal, a frame loss is recovered through end to end error control in upper layer.
2. Performance impairments during handover
The handover mechanism of PCS is designed in consideration of voice service. Then, to support future mobile data service, handover mechanism must consider data transmission mechanism which minimizes data loss and recovers error frame fastly.

In the handover procedure, channel is released when quality of channel is dropped relatively compared with normal situation. Thus, during handover, data loss occurs. Although loss of frame is admitted for voice traffic, but loss of data traffic is not admitted. Thus, retransmission mechanism is performed to recover data. During handover processing, to minimize data loss, it could use the method that designates both present connection node and near connection node for group and announces data information through multicast. In the method to apply multicast for wireless connection node with fixed IP address, activated wireless connection node uses unicast transmission, and near connection node manages relative data through multicast. The transmission in wireless area is done specially in connection node activated, and IP packet is saved at fixed buffer in case of connection node being inactivated. If activated connection node is changed due to mobile terminal movement, new activated connection node receives data frame through unicast. Then, old connection node receives and stores multicast data frame. However, as near connection node increases, much buffering is necessary at connective point, and overload between interchange node and connection node is increased radically.

3. Performance improvements of mobile data service
To improve mobile data service performance, the method that could recover data loss during handover of mobile terminal and compensate for different channel characteristics in wire and wireless interworking environments must be considered.

The transmission performance of TCP used for end to end control falls radically because of different transmission characteristics of wire and wireless channel. The error characteristics in wire and wireless channel are different each other. Thus, TCP in wire networking makes duplicated transmission of data packet and unnecessary transmission in wireless link is increased. To solve these problems, we suggest an improvement mechanism, in which through analyzing header information of TCP frame, duplicate transmission is removed in interworking module. This operation of interworking module is described in Figure 4.

When handover happens in the course of terminal movement, relative status information and data are buffered through end to end control of TCP. If there occurs excess of response timer for transmitted frame, TCP reduces credit scale of TCP frame, and performs retransmission. Only if it receives response frame, TCP increases credit value. Therefore, data transmission performance is reduced during handover processing time.

In this paper, it is suggested that status information and data saved at interworking module during handover should be forwarded to new connection node, for the purpose of quick recovery of data frame. The information flow for handover is presented in Figure 5.

![Figure 4: TCP frame control in interworking module](image)

![Figure 5: Information flow of interworking module for handover](image)
handover command, it performs data forwarding to new base station. Then, buffered traffics and status information in interworking module related with data service is transmitted at the same time. These procedure makes it possible that data transmission of new base station is the same as that of old base station.

If handover is completed, mobile station transmits handover completion message to new base station. If new base station receiving information of interworking module receives handover completion message, new base station is getting to retransmit data saved at buffer of interworking module, to recover data loss during handover procedure.

V. Simulation and Results Analysis

1. Simulation Environments

Figure 6 shows the network architecture for performance evaluation of data service protocol in the case that duplicated transmission and handover occur.

The interface between BS and mobile node supports PCS CAI protocols, and we assume that wire network is high-speed network, based on IP. Thus, overhead for data transmission in wire network is considered as TCP/IP protocol overhead and delay time for IP packet transmission. Then, propagation delay is ignored. The hard handover to perform frequency allocation among BS is considered. The maximum handover time is assumed to be 80msec. Also, during handover, we assume that burst error occurs. BS performs interworking between wire and wireless network protocol. For performance evaluation of data service, non-modified TCP protocol in wire network is adapted. TCP protocol performs end-to-end control for data communication between fixed host and mobile node. In the wireless link, transmission rate is assumed to be 9600bps, and data link layer protocol is assumed to be RLP protocol. Then, data loss occurs only in wireless link.

Wireless channel has burst error due to signal fading, multipath and interference of transmission. This error degrades data transmission quality. We use 2-state markov error model that describes wireless channel quality between mobile node and base station as shown in Figure 7[9].

The bit error ratio of bad and good state is assumed to be 10 : 1, and the value of Pbad and Pgood is decided according to mean bit error rate.

2. Results Analysis

For performance analysis of data transmission protocol in wire and wireless interworking environments, we compare and analyze the performance of conventional and proposed methods. Figure 8 shows TCP frame transmission performance as channel error rate increases without handover. The FER is frame error rate of RLP protocol that is used for wireless link. In proposed method, interworking module performs the analysis of TCP frame header, and detects duplication transmission. Then, interworking module discards duplicated TCP frames to prevent unnecessary transmission. However, in conventional IWF, interworking module does not recognize whether current TCP frame duplicates TCP frame or not. Thus, the duplicated TCP frame is transmitted to mobile station through wireless link. Then, throughput is decreased severely as frame error rate increases.

The transmission performance of TCP frame according to channel error rate in non-handover environments is presented in Figure 9. The handover period is assumed to be 10% of transmission period.
time. The transmission performance of the proposed IWF is mainly influenced from channel error rate except performance reduction by interruption of transmission during handover period. However, in conventional IWF, data transmission is interrupted by handover, and data recovery mechanism for lost TCP frame is performed by end-to-end control of TCP. Thus, TCP frame loss and retransmission are increased as channel error rate increases. Therefore, data transmission performance of proposed IWF is better than that of conventional IWF.

![Figure 9](The transmission performance vs. channel error rate in handover environments)

Figure 10 shows the transmission performance of TCP frame vs handover ratio. As handover ratio increases, transmission performance of TCP frame is getting to be decreased. Then, the performance of proposed IWF is better than that of conventional IWF. Because TCP frame retransmission for data recovery is performed at interworking module instead of sending node in proposed IWF.

![Figure 10](The transmission performance of TCP frame vs handover ratio)

**VI. Conclusions**

In this paper, we propose an effective mobile data protocol in interworking environments between PCS and wire internet.

In the case of using conventional TCP protocol for data service in wire and wireless interworking environments without protocol modification, data transmission performance without protocol modification, data transmission performance is decreased. To improve this phenomenon, we propose the interworking module with TCP header analyzing function as well as handover supporting mechanism. If handover request occurs, interworking module forwards data information and status variables to new base station. Then, new base station which receives forwarding data from old base station transmits TCP frame data in sequence. These mechanisms provide very faster recovery of lost data than conventional interworking module with simple protocol conversion and buffering function. Because, analyzing function prevents duplicated transmission of TCP frame, and handover supporting mechanism minimizes data loss occurring in the case of handover. According to simulation results, proposed mechanism has better performance than conventional interworking module in view of transmission throughput.

**References**


