A Fast Handoff Scheme Between PDSNs in 3G Network

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Abstract. This paper proposes a fast handoff scheme between PDSNs (Packet Data Serving Nodes) which provide packet services to a mobile node. The proposed handoff scheme does not require reestablishment of a PPP connection that may occur in the process of performing handoff between PDSNs. The handoff method between PDSNs requires that the PDSNs should receive subscribers' information about mobile nodes from their neighbor PDSNs forming a communication network. When the PDSN recognizes the mobile node moving into its coverage area, it can quickly establish a communication channel with the mobile node based on the subscriber information received already. As a result, the handoff is performed without reestablishing PPP. Therefore, the handoff between PDSNs can be performed faster removing time needed for establishing a PPP session with a terminal and for terminating a previously set up PPP session.

Keywords: Handoff, Packet Data Serving Node, PPP connection.

1 Introduction

The number of users accessing the Internet through a mobile phone or a Personal Data Assistant (PDA) is increasing rapidly. And CDMA2000 is one of the leading technologies for the third-generation (3G) wireless communications and is being standardized by the 3G Partnership Project 2 (3GPP2)[1]. The CDMA 2000 network can provide both circuit-switched and packet-switched data services [2]. While the circuit-oriented data service is suitable for applications that need bulk data transfer, most data applications will be more efficiently provided by the packet-switched data service.

Since mobile subscribers of a wireless network can roam and move from one cell to another, there is a need for handoff support. Depending on channel usage, there are three types of handoff in the CDMA 2000 system, namely, hard handoff, soft handoff, and softer handoff. A hard handoff requires the MS (Mobile Station) to reestablish synchronization when it enters a new cell. It requires a complex signaling operation between an MS and a network node in order to reestablish a radio channel in the new

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cell. Moreover, after the cellular handoff stage is completed, the MS needs to perform Mobile IP signaling if the care-of-address is changed due to the cellular handoff.

The CDMA2000 works with Mobile IP protocol [3] to provide mobility in the IP layer. For packet data service in the CDMA network, the Mobile IP supports the handoff of the mobile station moving from one cell to another. The Mobile IP is standardized by the IETF, allows a mobile station to transparently access the Internet without changing its IP address when the mobile station moves to another IP domain [3]. The data packets that are destined to the MS cannot reach the MS if the MS has changed its attachment from one PDSN in the CDMA 2000 system to another. A fast moving MS will require a timely completion of the handoff operation so that little data is lost during handoff. Therefore, handoff performance in terms of completion time and data loss prevention has been the key to improving the quality of service [11]. While the CDMA 2000 handoff scheme [2, 4] may be suitable for a packet-switched data service for moderate speed mobile users, there is considerable room for improvement such that the system can provide better performance to fast moving users that can benefit from low handoff latency.

This paper proposes a fast handoff scheme between PDSNs (Packet Data Serving Nodes) for a mobile node that can reduce signaling latency and user data loss during handoff. This improvement is achieved by exchanging subscribers' information about mobile nodes among their neighbor PDSNs forming a communication network.

A number of suggestions have been made so far to improve handoff performance. [5] has suggested the use of a previous foreign agent notification extension allowing data packets in flight to the MS's previous foreign agent to be forwarded to its new location. This reduces the packet loss during the Mobile IP handoff stage. In [6], the authors suggest hierarchical domains of Internet routers in which the Mobile IP registration to the home network can be avoided when the MS hands off regionally within the domain thereby reducing the frequency of access to the home network. This approach reduces the time delay of Mobile IP handoff made within the same domain, but it is not effective when the handoff takes place between different domains. Similar concepts of hierarchy of Internet routers and regional registration have been used in [7, 8, 9].

Our scheme, on the other hand, does not rely on the domain concept and yet it yields less delay regardless of which router the MS hands off to. In addition to the above efforts to improve the performance of Mobile IP handoff, [10] suggests a cellular handoff scheme for CDMA 2000 that replaces a part of the signaling steps carried out by Mobile IP packets with link level signaling messages, thereby reducing message processing delay in the Mobile IP layer.

[11] proposes an improved hard handoff scheme by making a part of the signaling procedure carried out concurrently with other parts in an effort to reduce the total time that it takes to complete the signaling. Our scheme gives better performance than other schemes as shown in Section 4.

The remainder of the paper is organized as follows. A brief introduction to the current CDMA 2000 handoff scheme is given in Section 2. The proposed fast handoff scheme is described in Section 3. Section 4 presents performance evaluation of the proposed signaling scheme with the standard one, and some concluding remarks are given in Section 5.

2 Handoff Scheme of CDMA2000 System

The CDMA2000 consists of radio networks and IP core networks. Figure 1 shows the architecture of the CDMA2000 network. In the radio network, a Base Station Controller (BSC) communicates with a packet data serving node (PDSN) through the packet control function (PCF), which is responsible for handling a logical link between the BSC and the PDSN. Mobile Switching Center (MSC) controls user traffic channels in the radio network.

Fig. 1. Architecture of the CDMA2000 Network

The functional elements for the packet data service in the IP core network consist of PDSN, home agent (HA) for Mobile IP service, HLR/HSS and Authentication, Authorization and Accounting (AAA) server. The PDSN provides the interface between the radio network and the IP core network, and performs foreign agent (FA) functions of the Mobile IP protocol. It is responsible for point-to-point protocol (PPP) connection to the mobile station and for logical link (R-P session) to the PCF. It is also responsible for the mapping between the PPP connection and the R-P session. For Mobile IP service, the PDSN is a default router for the mobile station. The mobile station registers with its home agent via the PDSN. After successful registering, the PDSN de-encapsulates data packets which are sent by a correspondent node to the mobile station and are tunneled from the HA. And the PDSN forwards them to the mobile station.

The AAA server supports both the Challenge Handshake Authentication Protocol (CHAP) and the Password Authentication Protocol (PAP) based authentication while a mobile station establishes a PPP connection to the PDSN and requests the Mobile IP registering to the PDSN. The HA maintains the current location of a registered mobile station in its binding table. It is also responsible for the delivery of data to a registered mobile station based on its binding table. The binding table includes home address assigned to a mobile station and COA, which is the address of PDSN that a mobile station has connected on the PPP link.

Handoff methods in CDMA 2000 based wireless data communications can be broken down into handoff between PCFs (Packet Control Functions) and handoff between PDSNs. The handoff between PCFs occurs in a case where the movement of a mobile node between PCFs happens, and PCFs gets changed before and after the moving but are in an identical PDSN area. In this case, care-of-address used by the mobile node does not change so that the mobility is guaranteed.

The handoff between PDSNs occurs in a case where a mobile node moves to another PDSN area. In this case, since care-of-address changes, the IP protocol of the mobile node should be reset. For this, by using a FA (Foreign Agent) function of the PDSN, an IP should be reassigned to the mobile node, and the mobile node should register in a new FA. Only after this, the moving of the mobile node is completed. In other words, when a mobile node moves to another PCF in a PDSN area in a state where the mobile node is registered for Mobile IP in the PDSN. The PCF traces the mobility. A packet transmitted from an IP network to the mobile node, is transmitted to the PDSN through a HA (Home Agent) according to the IP address of the mobile node. Then, the PDSN transfers the newly registered packet to the PCF through a radio and packet (R-P) interface and the PCF transfers it to the mobile node.

However, when a mobile node moves into another PDSN area, the MIP is registered in the new PDSN. This registration informs the new PDSN of the mobile node's IP address moving. In this case, since a new FA registers in an HA, an IP packet to be transferred to the mobile node is transferred to the new PDSN from the HA and then transferred to the mobile node. Accordingly, loss of the user packets occurs during the delay time because this PPP re-registration cannot be prevented.

That is, generally a contact point corresponding to the PPP of an MS is a PDSN and since the MS has moved into a new PDSN, a process which reestablishes a PPP session should be performed in order to obtain a new PPP contact point.

Fig. 2. Standard CDMA2000 call process for a mobile node to initially connect a call

Fig. 2 is a schematic diagram of a signal flow showing a standard CDMA2000 call process for a mobile node to initially connect a call. Referring to Fig. 2, when a mobile node first connects a call, the mobile node transfers a calling message containing a data service request to a PCF. When a call is established, a PCF plays a role to exchange signals and traffic information between an AP (Access Point) and a PDSN. The PCF receiving the message transmits this information to a PDSN to establish RP connection and performs a PPP connection setup procedure. Here, RP

connection means an interface connection between a PCF and a PDSN for signaling (A11) and user traffic (A10). The PDSN performs a FA function in an MIP and an NAS (Network Access Server) function for setting up a PPP with a terminal. At this time, after the PDSN allocates an address to the mobile node, the mobile node completes PPP setup. The PDSN transmits an advertisement message to the mobile node periodically. Through this message, the mobile node can confirm its current Internet contact point.

Meanwhile, when the mobile node receives this advertisement message and transmits a mobile IP registration request (MIP RRQ) to the PDSN, the PDSN and the HA determine whether or not the subscriber is one of those subscribers who are qualified for the MIP support, and then perform authentication. If the subscriber cannot be authenticated, the PDSN includes an error in the mobile IP registration reply (MIP RPL) code, transmits the code to the mobile node and terminates the call. However, if the subscriber is authenticated to perform normal MIP, the PDSN maintains visitor information and by informing it to the mobile node, the registration procedure is finished. Thus, if a PPP is set up and a call is effectively established, actual data communications between the mobile node and a host are performed.

Fig. 3. Handoff procedure of standard CDMA2000 network

A handoff example will now be explained referring to Fig. 3. Fig. 3 is a schematic diagram showing a process to support mobility of a mobile node in which the process of Fig. 2 is performed twice. For the following explanation, a couple of terms is defined. A tPDSN (target PDSN) is a PDSN providing packet services to a newly connected mobile node which is moved into its concerned area. An sPDSN (source PDSN) is a PDSN to which, before moving, the mobile node was connected. It is assumed that at present a mobile node receives data services through sPCF (source PCF) and sPDSN after connected to the Internet. Since the subscriber moves and handoff between sPCF and tPCF (target PCF), and tPDSN occurs, a new RP session and PPP session should be set up. Here, a target PCF and a target PDSN mean a PCF

and a PDSN of a network to which the subscriber should be connected because of the moving. This process will now be explained in detail. First, tPCF transmits A11 RRQ message to tPDSN, and according to this, tPDSN responds to PCF with an RLP message. If this process is successful, a PPP session is reestablished between the mobile node and tPDSN. Then, tPDSN transmits an MIP advertisement message to the mobile node, and according to this, the mobile node transmits an MIP registration request to tPDSN. In response to this, tPDSN again transmits an MIP registration reply to the mobile node, and by doing so, a new MIP is set up. Then, A11 interface for signaling between sPCF and sPDSN is performed and the existing PPP session is terminated. Thus, when handoff between PDSNs is performed, processes for setting up a new PPP session and terminating an existing PPP session are needed such that unnecessary time and resources may be expended.

In this situation, the proposed method can perform handoff in a short time without performing unnecessary PPP reestablishment that may occur in handoff between PDSNs.

3 Proposed Fast Handoff Scheme

A preferred embodiment of the proposed scheme to remove this problem will now be explained referring to Fig. 4. Fig. 4 is a schematic diagram showing a detailed process such that the additional PPP connection process in the handoff method of Fig. 3 can be omitted when a mobile node moved.

Fig. 4. Signal flow of proposed handoff scheme

Let's consider a situation where a mobile node performs data communications with sPDSN before moving and then moves to another network, so the handoff is needed. When the mobile node is first trying to connect a packet call, the sPDSN makes subscriber information which the subscriber sets initially, shared by all PDSN neighboring the sPDSN. Here, subscriber information indicates an IP address of the subscriber, options defined when ICP and IPCP are tried, and so on. In this state, if subscriber movement occurs, the tPDSN senses that the subscriber moved into its concerned area and transfers the subscriber number and IP address of the mobile node to the sPDSN to which the subscriber was connected before the moving. Upon receiving this, the sPDSN transfers all information on the subscriber to the tPDSN. Upon receiving the information, the tPDSN stores the subscriber information as database items, and performs a procedure related to MIP with the mobile node.

Referring to Fig. 4, the embodiment will now be explained in detail as a signal flow between the mobile node and apparatuses in the wireless data communications network. PCF transmits A11 registration request message to tPDSN, and according to this, tPDSN transmits A11 registration response message to tPCF. Thus, the process for RP setup is the same as in Fig. 3. However, instead of the PPP session setup procedure as shown in Fig. 3, the PPP session related data – e.g., MN IP address, MRU, protocol control field compression (PFC), async. control character map (ACCM), address control field compression (AFC) – are received from sPDSN, to which the mobile node was connected before the moving, and utilized as PPP setup resources of the mobile node. The tPDSN transmits an MIP advertisement message to the mobile node which has moved into its concerned area, and according to this, the mobile node transmits an MIP registration request to tPDSN. In response to this, tPDSN again transmits an MIP registration reply to the mobile node, and by doing so, a new MIP is set up. Then, A11 interface for signaling between sPCF, to which the mobile node belonged before the moving, and sPDSN is updated.

Meanwhile, when the MIP setup is normally allocated, the PPP resources set to sPDSN may request termination or reestablishment by itself without negotiation with the mobile node, and accordingly, to the extent that the information is managed, the information is retained.

4 Performance Evaluation

According to the method for handoff between PDSNs of the proposed scheme as described above, handoff is performed without reestablishing PPP and accordingly handoff between PDSNs can be performed faster by a time (T_s) needed for establishing a PPP session with a terminal and a time (T_t) for terminating a previously set up PPP session. Here, since at least 10 messages are transmitted and received during LCP and IPCP negotiation for establishing and terminating PPP session according to the standard, T_s and T_t are given, respectively, by

$$T_s = 2T_{Lcp_ConfigReq} + 2T_{Lcp_ConfigAck} + 2T_{Ipcp_ConfigReq} + 2T_{Ipcp_ConfigAck} \quad (1)$$

$$T_t = T_{Lcp_TermReq} + T_{Lcp_TermAck} \quad (2)$$

The time reduction (T_r) effect can be achieved as follow.

$$T_r = T_s + T_t + T_{nl} \quad (3)$$

Where, T_{nl} means the network latency time. It depends on processing capacity of network nodes and network traffic loads.

We measured the delay performance of the proposed scheme on our testbed [12]. Fig.5. shows the comparison results of connection time. When the normalized traffic load is 0.5, we can save over 1.1 seconds. Generally, two cases don't show a big difference under the lower traffic load. But under the higher traffic load, our proposed scheme has the better performance by skipping PPP reestablishment and also reducing packet loss during handoff.

Fig. 5. Comparison of connection delay between the conventional scheme(*diamond*) and the proposed scheme(*square*)

5 Conclusions

In this paper, we have proposed a method for handoff between PDSNs which can reduce signaling latency and user data loss during handoff. This improvement is achieved by exchanging subscribers' information about mobile nodes among their neighbor PDSNs forming a communication network.

When a PDSN recognizes a mobile node moving into its coverage area, it can quickly establish a communication channel with the mobile node based on the received subscriber information. As a result, handoff is performed without reestablishing PPP. Therefore, handoff between PDSNs can be performed faster, removing time needed for establishing a PPP session with a terminal and for terminating a previously set up PPP session.

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