Journal of Southeast University (English Edition) Vol.19 No.3 Sept. 2003 ISSN 1003—7985

A packet loss avoidance handoff scheme

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Abstract: The basic mobile IP protocol is simple but only suitable for wide area and low speed networks. In this paper, we propose a novel micro-mobile IP handoff scheme, that is the packet loss avoidance handoff scheme. By using an additional cache at the base station and distinguishing packets with packet IDs, the proposed scheme minimizes the number of lost packets during handoff. Network architecture and detailed handoff procedures are given. We also analyze the cache size at the base station, the associated network load with the handoff procedure, and the handoff delay. The scheme is investigated by computer simulations. Simulation results show that the proposed scheme is suitable for environments with fast mobility and frequent handoff.

Key words: handoff; mobile IP; domain; analysis and handoff delay; packet loss

With the development of wireless technologies, the demand for wireless access to the Internet continues to increase. Mobile users expect to get the same service quality as fixed users. IETF mobile IP standard provides a simple way to solve the global mobility problem[1], but it cannot satisfy the service demands under the rapid mobility and frequent handoff environment due to the high round-trip delay and heavy control overheads. At the same time, with smaller cells, the wireless network can take advantage of higher data throughput, better frequency reuse, and lower power transceivers[2]. For these reasons micro-mobility protocols are proposed that perform registration and handoff locally. Compared with micro-mobility protocols, the protocol described in Ref.[1] is also called a macro-mobility protocol. There are many micro-mobility protocols, such as Cellular IP from Columbia University[3], HAWAII from the Lucent Bell Labs[4], EMA from University of Maryland[5]. These protocols have their weaknesses and cannot support large real-time IP-based wireless networks efficiently[6]. In this paper we propose a fast micro-mobile handoff scheme, named "packet loss avoidance handoff scheme" (PLAHS), which supports mobile nodes crossing the wireless cells frequently. The results show that PLAHS effectively reduces handoff delay and packet loss.

This article is organized as follows. In section 1, we give an overview of the network architecture. Section 2 presents the handoff procedure of our scheme. Section 3 calculates the buffer size at the base station (BS). We investigate the performance of PLAHS in section 4, including network cost, handoff delay, and packet loss. Finally, section 5 presents our conclusions.

1 Network Architecture

A generalized trend of future network architecture is the all-IP-based network in which IP is used end to end no matter what the core networks or access networks are. Here, the access networks are hierarchical as shown in Fig.1.

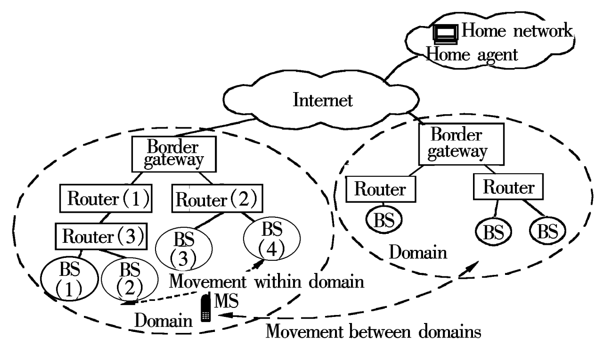

Fig.1 All-IP-based hierarchical network architecture

The domain is composed of three types of nodes.

1) Border gateway (BG) It is a router at the upper layer of a domain. A wireless access network is connected with the Internet by at least one of the BG packets arriving from the Internet to the mobile node, which are decapsulated and forwarded to the next router by route cache mapping.

2) Router It is at the middle layer of a domain. Routers forward IP packets according to routing information in soft-state route caches. Soft-state means

Received 2002-11-05.

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that the routing information, if not refreshed, will be removed automatically after a certain period of time.

3) Base station (BS) It is at the bottom layer of a domain. BS communicates with mobile nodes by a wireless interface and can save the packets with buffers. BS is also referenced as access point (AP) in WLAN.

2 Handoff Processing

In this section, the new scheme PLAHS is described. If a handoff occurs between domains, the macro-mobility protocol is adopted. When a mobile node moves inside a given domain, the mobile node sends a regular mobile IP registration message with network access identifier (NAI) extensions[7] and IP ID extensions. The IP ID in the registration message is used to identify the last packet received by the mobile node from the old BS. The fixed length fields of a mobile IP registration request message are shown in Fig.2.

0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1

Type = 1	S	B	D	M	G	V	H	rsv	Lifetime
Mobile node's home address									
Home agent address									
Care-of address									
Identification									

Fig.2 The fixed length fields of a registration message

Fig.3 presents a message sequence chart of the handoff process in this scheme when a mobile node receives data from a correspondent node (CN).

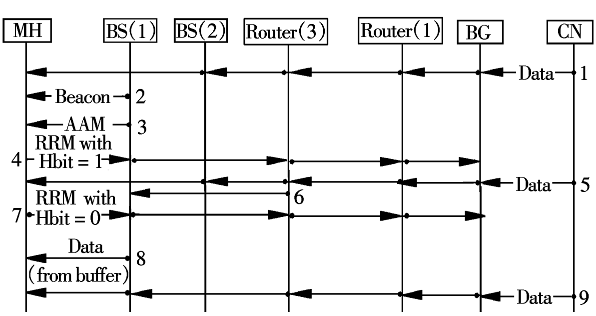

Fig.3 Message sequences of handoff in PLAHS

Similar to the semi-handoff in Ref.[3], the mobile node listens to the agent advertisement from BS and initiates the handoff based on signal strength measurement. The mobile node receives data from CN through BS (2) (the old BS) (step 1) and moves towards BS (1) (the new BS). It will scan the neighbor frequency band and choose a new BS by the comparing the beacon signal strengths (step 2). Then the mobile node tunes to BS (1). After receiving the advertisement agent message (AAM) (step 3), it sends a registration request message (RRM) with "H" bit set (step 4), indicating that BS (1) should buffer packets to the mobile node. BS (1) then creates a new mapping in its route cache and forwards the registration message to the next router on the way to BG. All the routers on the way from new BS to a crossover router (router (3)) which is the intersection of old and new paths will add entries of the mobile node in their route caches, including IP-address timestamp, forwarding port, etc. Routers on the way from the crossover router to the BG, except the crossover router itself, will update the entries of the node. After sending the RRM, the mobile node returns to the BS (2) and still receives packets form it (step 5). At the same time, the packets will also be sent to the BS (1) by a new route entry and buffered (step 6). After a delay T_D, the mobile node will switch to the BS (1) and send a registration message with an "H" bit set to zero. The BS (1) then abstracts the IP ID from the registration message, which is the identity of the last packet received by the mobile node from the old BS. After that BS (1) forwards packets to the mobile node, beginning with the packet having IP ID immediately after the abstracted IP ID (step 8). The registration message will trigger another route setup process and the old route mapping associated with the BS (2) will be cleared after the time limit. Packets from the Internet will be forwarded to mobile node by new route (step 9).

3 Buffer Size

Buffer size at the BS should be equivalent to the maximum number of packet losses due to the handoff without a buffer. With this handoff scheme, if the transmission time from the BG to the new BS T_N is shorter than that of the old BS T_O, then some packets sent to the mobile node will be lost. The number of lost packets is

$$P_{loss} = \left[\frac{T_O - T_N}{T_P} \right] + 1 \tag{1}$$

where T_P is the average arrival time of packets sent to the mobile node. The maximal difference value between T_O and T_N is T_{OMAX}, which can be set to the passing time of a packet from the BG to the farthest BS. So the buffer size M at the BS can be given as

$$M \geqslant \left[\frac{T_{OMAX}}{T_P} \right] + 1 \tag{2}$$

It shows that the buffer size is related to the topology of networks and the distance between a BS and the BG. The longer the distance between the BS and

BG, the bigger the buffer size.

4 Performance Analysis and Simulation Results

Assume every T_R, the mobile node, sends a registration message to renew route caches. We define αT_R the route-timeout value where α is a small integer to avoid the route invalidation by the loss of the route update message. During time T, the cost of the transmitting registration messages is NT/T_R where N is the size of the registration message in bits.

After receiving the registration message in which "H" bit is zero, the new BS forwards packets to the mobile node. At the same time, these packets are still sent to the old BS until the old routing cache mappings become invalid. During time T, the mean cost of sending packets along the old route after handoff is $TR[(\alpha - 1/2)T_R - T_D]/T_H$, where R (bit/s) is the average packet receiving rate of the mobile node, and T_H is the average time that the mobile node stays in a cell.

During the handoff, the cost of network in time T is calculated as

$$C_{load} = \frac{NT}{T_R} + \frac{TR\left[\left(\alpha - \frac{1}{2}\right)T_R - T_D\right]}{T_H} \tag{3}$$

The optimal route-update time $\hat{T}_R$ is the one that minimizes the overhead of the network. It can be calculated as

$$\hat{T}_R = \sqrt{\frac{NT_H}{R\left(\alpha - \frac{1}{2}\right)}} \tag{4}$$

According to $\hat{T}_R$, the overhead of the network is

$$\hat{C} = 2\sqrt{\frac{NT^2 R\left(\alpha - \frac{1}{2}\right)}{T_H}} - \frac{TRT_D}{T_H} \tag{5}$$

We simulated the handoff procedure using a discrete-event simulator. In our simulations, the domain is an extended service area (ESA) of wireless local area networks (WLAN). The mobile node receives data at a rate of 1 Mbit/s and performs handoff every 30 s. The size of the registration message is 112 bytes, $\alpha = 3$ and $T_D = 140$ ms. Theoretical results and simulation results are plotted in Fig.4. Curves in Fig.4 show that the optimal registration cycle time is about 100 ms. When T_R takes the optimum value as given in Eq.(4), the relation between the average handoff time and the cost of network is plotted in Fig.5. In Fig.4, there are some simulated points with costs values lower than the theoretical one. This is caused by loss of registration messages. Because in this scheme, the BS need not send the reply to the mobile node after receiving the registration from this node. If the old BS does not receive the registration message from the mobile node, the mobile node will not resend this message immediately. As a result, the timer in the route tables will not be refreshed and the amount of time of the old BS receiving redundancy packets will be reduced. Besides WLAN, this scheme is also suitable for other wireless communication systems, such as 3G wireless communication systems.

The curve in Fig.5 is mainly determined by the first term of the right hand expression in Eq.(5), which is proportional to the square root of the migration rate. The expression shows that the cost increases not so fast with the increase of the migration rate. Therefore, this scheme is suitable for high speed mobile nodes.

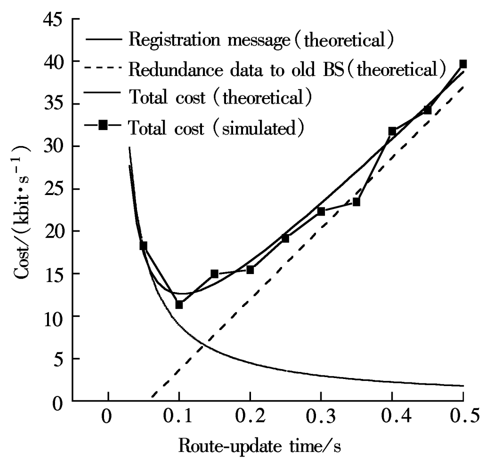

Fig.4 The relation between network cost and route-update time during handoff

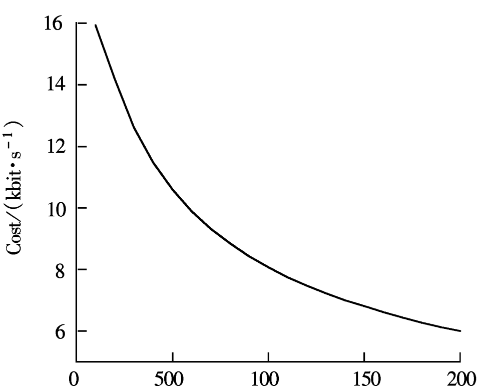

Fig.5 The relation between average handoff time and cost of network

Handoff delay is the time needed to complete a handoff inside the network. It is composed of rendezvous time and protocol time[8]. Rendezvous time is the time from a mobile node leaving the old BS cell to the mobile node receiving the broadcast message from the new BS. Protocol time is the time taken to restore the connection after receiving the broadcast message. We assume that, compared with protocol time, rendezvous time is small and can be ignored. The handoff delay in this scheme is

$$\tau = T_D + T_G + T_1 \tag{6}$$

where T_G is the time taken for a registration message transmitting from a mobile node to BG, and T_1 is the time that the mobile node spends to tune to the new BS and then return to the old BS.

When the mobile node can communicate with more than one transceiver (e.g. in a WCDMA system), the packet loss will be reduced to zero. When the mobile node can only communicate with one transceiver (e.g. in a GPRS system), the packets sent to the mobile node will be lost during T_1. Let T_i be the average packet inter-arrival time, the maximum number of packet losses of handoff is

$$P_{loss} = \left[\frac{T_1}{T_i}\right] + 1 \tag{7}$$

In general, the ratio of T_1 and T_i is less than 1, so the maximum value of P_{loss} is 2.

In either case, the number of packet losses is very small, so we call this scheme the packet-loss-avoidance handoff-scheme (PLAHS).

5 Conclusion

PLAHS is compatible with macro-mobility protocol. It adopts the standard mobile IP registration message[1] so that the mobile node need not specifically support the micro-mobility protocol. The use of buffer and IP ID reduces the packet loss and avoids receiving the duplicated data. In the registration process, the mobile node still receives the packets and packets loss is minimized. Therefore, the scheme works well under high mobility and frequent handoff environment. We have analyzed and simulated the performance of PLAHS and reached the conclusion that it adapts to not only data services, such as FTP and E-mail, but also delay sensitive services, such as Internet phone and video conferencing.

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避免分组丢失切换方法

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摘　要　针对基本移动 IP 协议虽然简单但只适用于大范围、低速的情况,提出了一种新的微观移动 IP 切换方法——避免分组丢失切换方法.该切换方法通过在基站处增加缓存以及利用 IP 分组的标识,将切换过程中分组丢失减少至最小.并给出了该切换方法所适用的分层全 IP 网络结构及其切换过程,对基站缓存的大小、切换带来的网络负荷、切换延时等也进行了分析.仿真和分析结果表明最小分组丢失切换方法适用于快速移动、频繁切换的环境.

关键词　切换; 移动 IP; 域; 切换延时; 分组丢失

中图分类号　TN929.533