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A Proposal of Seamless Handoff Method for Cellular Internet Environments

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SUMMARY Mobile IP can provide macro mobility for a mobile node (MN) instead of the original IP communication. Since the orignal Mobile IP does not consider micro mobility, it can not avoid handoff latency. The latency causes packets loss or large variations of the delivery times. To prevent it, several methods are proposed to improve the orignal Mobile IP handoff method. In our previous work, we proposed the fast registration method which enabled an MN to have two communication routes from the home agent (HA), and realized lower latency in the handoff procedures by the doublecasting on the two communication routes. But, the simulation results also show that the proposed method still has large overhead. This paper presents a seamless handoff method, which improves the fast registration method. In the method, the MN can know the first and second suitable base stations for the communications through information from the MAC media. The control helps for seamless handoff in case that the MN must frequently change its current base station (BS). The computer simulations for Constant Bit Rate (CBR) over real-time transport protocol (RTP) flow shows that the proposed method provides no handoff latency with low overhead even if the MN must occur frequent handoffs in a second.

key words: *handoff, mobile IP, micro mobility, cellular*

1. Introduction

Recently, the Internet has been widely used as communication networks. Now, IP networks are used not only for data, but also real-time communications like voice over IP or video conference applications. These streams also go into mobile networks, instead of wired and fixed networks.

In the Internet, Mobile IP [1] has been proposed for a solution to provide macro mobility for IP. However it still suffers an interruption of the communications for real-time applications when handoff procedures are occurred, because Mobile IP can not take care of the communications during the handoff procedures.

One of the important reasons for the above problem is that Mobile IP restricts a mobile node (MN) and a home agent (HA) to deal with only one care of address of the MN. On the other hand, we proposed a fast registration method which is an improved handoff method for real-time communications using Mobile IP [2]. In the proposed method, we assume that Mobile IP and MN's MAC media can deal with two addresses in each layer to control two communication routes between an MN and a HA from IP layer. If the HA has two routes for the MN, it doublecasts data from senders to the MN through the foreign agents (FAs). Further more, when the MN receives an agent advertisement from non-primary FA for the first time, it directly sends its registration request to its HA through the primary FA. With the tactic control, the MN can finish the registration for the new FA before it can not communicate with the primary FA, and obtains the non-primary FA as a secondary FA. These controls prevent large handoff latency in the communications. But, the simulation results also show that the proposed method still has large overhead which comes from the doublecasting method and the registration method of Mobile IP.

To solve the problem, in this paper, we propose a seamless handoff method with low overhead for cellular Internet environments based on the fast registration. In the proposal, we introduce three controls, i.e., a doublecasting for only fixed networks, a fast agent solicitation control and a selection algorithm of the primary or secondary FA by radio signal strength at Mobile IP.

From the network simulation experiment, we conclude that our method can switch the MN's communication route with no packet loss and low handoff latency for CBR over RTP flow with low overhead even if the MN moves with random motions on multiple cell-overlap regions when the sufficient large overlap region, where the MN can receive an agent advertisement from the secondary FA, exists between the cells.

The rest of this paper is structured as follows. Section 2 describes a handoff method in Mobile IP, and the fast registration method. Section 3 presents a seamless handoff method extended from the fast handoff method. In Sect. 4, the simulation experiment compares with the new proposed method and the ordinal methods. Section 5 denotes the conclusion.

2. Mobile IP

2.1 Route Switching Method in Mobile IP

Mobile IP works as mobility and routing management protocol in the Internet. Under Mobile IP, an MN can

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change its connection point without modification of the original IP address. For this control, two kinds of agents (HA and FA) are needed for the functions of Mobile IP.

An MN has the Home Network (HN) and is mainly connected to the network. The HN has a HA (or HAs) which always manages all the MNs in the HN. When packets are transmitted from a sender to an MN in the HN, the MN is accessed by its IP address, and connected through its HA as the ordinary IP communication.

Suppose that the MN changes the connection point from the HN to another network which is called a Foreign Network (FN). The FN has an FA which manages the MN in cooperation with the HA. The HA intercepts every packet for the MN, and then encapsulates and forwards the packets to the FA. The FA decapsulates the forwarded packets, and transmits the original packets to the MN. From the above procedures, each MN can transparently communicate via any FNs.

Mobile IP provides macro mobility in the Internet, however, the procedure still causes the handoff latency, because Mobile IP is not considered micro mobility and the route switching control is partially dependent on MAC media. The next subsection discusses about the handoff procedures in Mobile IP.

2.2 Handoff Method in Mobile IP

In Mobile IP, a BS (HA or FA) periodically broadcasts an agent advertisement in the cell. Each agent advertisement has information for MNs to connect with the BS.

When the MN enters the overlap region between the two cells and the MN may have an opportunity to receive agent advertisements from both the old and new cells in the region. But, until the MN ensures that the MN has completely released from the old cell for reliable communications, the MN can not send a registration request, which is constructed by the agent advertisements, to register itself to the FA in the new cell. This procedure occurs handoff latency, and then many data from a sender to the MN may consume extra network resources.

To reduce this handoff latency, several methods are proposed. In [3] and [4], multicast is required for the MN to cooperate with several pre-decided FAs at any time. Thus, one of the FAs can correctly send the data to the MN, when the FA accepts a registration request from the MN. But the above methods wastes bandwidth in fixed networks between the HA and each FA because nobody can predict which FA will be selected by the MN. Further more, the FAs must have large data buffer for the MNs. Because the MN occurs the handoff procedures, it can not receive data from the previous FA. Then, the buffered data in one of the FAs can supply the data as soon as the MN connects to it.

The hierarchical BSs [5], [6] are proposed to shorten delay of registration procedures when the MN moves within the same domain due to the handoff method for Mobile IPv6 [7]. These methods also save extra packets arisen from the registration procedures.

However, the periodically broadcasted agent advertisement from the BS also causes handoff latency, because the MN should know the information of the BS at any time in order to shorten the handoff latency. Therefore, in the above method, the MN watches the link condition or the arrival intervals of packets as soon as the MN knows the link has been lost, or sends a registration request when it accepts the first agent advertisement with stronger strength of channel signal from the new cell than the one from the old cell.

All above methods succeed in shortening a handoff latency or packets losses, however, in these methods, the handoff latency can not be completely eliminated. Next subsection describes the fast registration method which we proposed to improve the handoff latency for real time communications. The method allows the MN to deal with two IP addresses and the HA can obtain the MN's two care of addresses without using the multicasting and the data buffering methods.

2.3 Fast Registration Method

Figure 1 shows the basic idea of the fast registration method when an MN changes its connection point from the FA1 to the FA2. In cellular Internet environments, there is an overlap region, where the MN can obtain agent advertisements of the new FA (FA2), between the old cell and the new cell. From these agent advertisements, the MN can recognize the care of address of the new FA.

In the method, (1) when the MN receives an agent advertisement from the FA2 in the overlap region (shown in white arrow), (2) the MN registers with the ordinal procedures in Mobile IP for the new FA. In addition, at the same time, {2} the MN also sends a

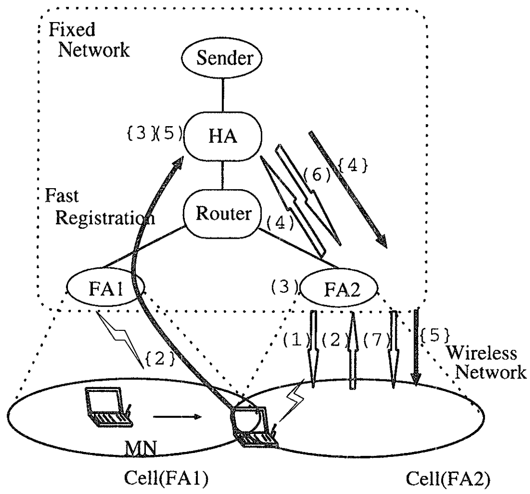

Fig. 1 An example of routing switching by the fast registration method.

registration request to the HA through the FA1 directly (shown in black arrow). Then, {3} the HA can register the MN faster than the ordinal method and establish the communication route because the registration message is accepted by the HA without the authentication of the MN at the new FA (3) and the HA (5). {4}, {5} and (6), (7) are registration replies for the MN.

The HA treats the fast registration as temporal one until it receives the registration request through the FA2 (i.e., (4)). In order to provide further reliable communications, the HA and the MN register the two care of addresses at the FA1 and the FA2, and the HA doublecasts data from the sender to the MN through the FA1 and the FA2, even if the HA does not receive a registration request through the FA2. From this doublecasting, the MN can receive data through the FA1 when it is in the overlap region, or through the FA2 as soon as finishing MN's authentication in the FA2 (3). The FA2 allows the MN to communicate at the time the FA2 receives a registration request from the MN and a registration reply from the HA (at (2) and (6), or (2) and {4}).

Our fast registration method needs to register two communication routes from the HA to the MN. We assume that Mobile IP (at the MN and the HA) and MAC media can deal with two addresses in each layer. From this assumption, Mobile IP can control two communication routes in the Internet and recognizes where the MN is going to by watching agent advertisements. These controls can prevent large handoff latency.

In the MN, the MAC media always selects at most two BSs from their signal strength and registers the both care of addresses to its HA. In the case that a HA receives more than two registration requests from an MN, we adopt a method that the HA selects two FAs of the latest two registration requests from the MN and the latest registered FA in the MN is the primary. Then, the HA doublecasts packets for the MN by using these two addresses while these addresses are being valid.

Through these procedures, a new communication route between the new FA and the HA can be constructed before the MN has completely entered the new cell. The communication route can be established within about round trip time between the MN and the HA after the registration request is sent. But the HA's doublecasting causes large overhead. This is a problem for low bandwidth wireless networks. To improves the problem, the next section proposes the seamless handoff method to reduce the overhead with no handoff latency.

3. Seamless Handoff Method

3.1 Registration Procedures

A handoff mechanism in the seamless handoff method is shown in Fig. 2 when the MN is changing its connection point from the FA1 to the FA2.

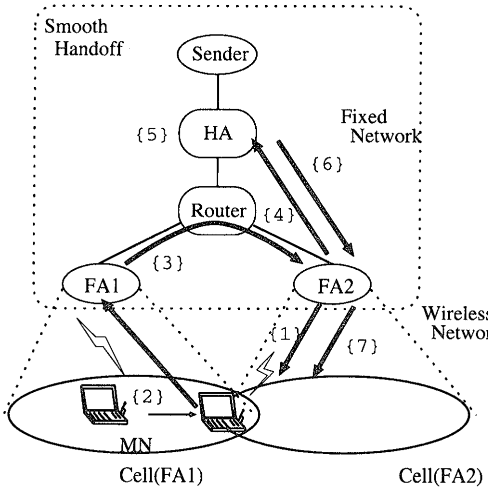

Fig. 2 An example of routing switching by the seamless handoff method.

In the new proposed, the ordinal registration procedures of (2) to (6) in Fig. 1 has completely omitted in the handoff procedures. {1} When the MN receives an agent advertisement from the FA2 in an overlap region, {2} the MN sends a registration request for the FA2 via the FA1. When the FA1 accepts the registration request, {3} it forwards the request to the FA2. {4} Then, the FA2 forwards the registration request to the HA. {5} The HA registers the care of address of the FA2, and {6}{7} it sends a registration reply to the MN through the FA2.

As the fast advertisement method, the HA and the MN register the two care of addresses of the FA1 and the FA2. The HA doublecasts data from the sender to the MN via the FA1 and the FA2. Due to this doublecasting, the MN can receive data through the FA1 or the FA2 whose signal is stronger than the other. In our proposal, the FA with stronger signal is called the primary FA, and another is the secondary FA. The MN sends a registration request to the primary FA rather than to the secondary one, because the request may not reach to the latter FA and the MN could be saved from power consumption. Note that the registration request may be through a secure communication route.

However, if no overlap region exists, the MN can not send its registration requests for the FA2 (secondary) through the FA1 (primary). In this case, the MN must send the registration request to the FA2. Next, the FA2 requests information for the FA1 to authorize the MN's request. Then, the FA2 forwards the registration request to the HA, if the authorization is successful. The above registration procedures for no overlap region are almost same with [8] which is proposed for a secure and fast handoff method.

3.2 Data Flow Controls in Seamless Handoff Method

The doublecasting in the seamless handoff method is required for reliable communication of an MN, but produces large overhead in certain conditions. For example, even if no packet loss occurs between the MN and FAs, the primary and secondary FAs forward the same data to the MN. To reduce this overhead, the secondary FA does not forward them until it directly receives a registration request from the MN. In the proposal method, the MN checks sequence number of packets in transport layer protocol (RTCP, RTP or TCP) to recognize condition of each communication route.

We also assume that each packet has information to find which FA forwards the packet. The information is constructed by the HA or the FA, and inserted to each packet's header. When the MN observes that any packet loss from the primary FA or the signal strength from the primary FA is weaker than the one from the secondary FA, it sends a registration request to the secondary FA to inform the MN's state and the both FAs start forwarding the packets to the MN. This request of the MN is notified from the secondary FA to the primary FA via the HA so as to exchange the route of primary and secondary FAs. In the method, the secondary FA always waits for forwarding the packets when the MN needs.

Suppose the MN can not receive any packets from the FAs. Then the MN needs agent advertisements from new FAs to recognize them, however, it is not always able to obtain them soon since the FAs periodically broadcast the advertisements. To overcome this problem, we proposes a fast agent solicitation method, which allows the MN to send an agent solicitation, when the MN detects a lost packet but it has one valid care of address. In proposal handoff method, the MN selects at most two FAs with the strongest signal for the primary and secondary FAs. From the above controls, we can provide good quality of communication with low overhead at the wireless link even if the MN randomly moves through multiple overlap regions.

4. Simulation Experiments for Seamless Handoff Method

To evaluate our proposed handoff method in the previous section, we experiment computer simulation by implementing our proposed methods to network simulator ns-2.1b7-current (May/15/2000) [9] and show that the seamless handoff method provides no handoff latency with low overhead in a wireless network on CBR communication over RTP.

4.1 Simulation Conditions

We simulate three handoff methods. The first is the proposed method in the previous section. The second is the fast registration method. The third method extensions of the original Mobile IP handoff method. In the non-extended Mobile IP handoff method, the MN changes its FA when it can not receive any packet from the old FA, but receives an agent advertisement from a new FA. This control causes large handoff latency. Therefore, for the third method, this section introduces an improved handoff method for the original Mobile IP to shorten the handoff latency. In the method, the MN observes every packet from the FA. When it detects any packet loss, it broadcasts an agent solicitation message to require an agent advertisement. For farther improvement, when the MN receives a stronger signal agent advertisement from a new FA than the one of the current FA, the MN switches the FA in MAC media and Mobile IP, and sends a registration request for the new FA. This control is realized by communications between the MAC media and Mobile IP.

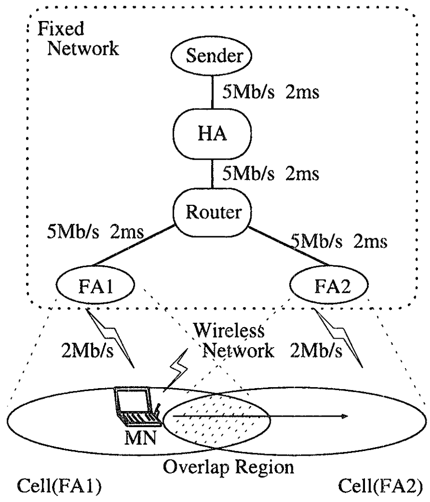

Fig. 3 Simulation model 1.

We have simulation experiments on two network models. Each model consists of fixed and wireless networks whose topology and link speed are illustrated in Fig. 3 or Fig. 6. The common conditions for all simulations are shown in below.

- The number of senders is one.
- The number of MNs in each model is also one.
- An agent advertisement from each FA is periodically broadcasted every 0.2 s within the whole cell area of the FA, including the overlap region of both cells, and the MN's registration life time [1] in each FA is 1.0 s.
- Each authentication delay for registration request in the FAs or HA is ignored.
- In the overlap region, the MN can receive packets from both FAs in the seamless handoff method and fast registration method. But, the third method in MAC media can only receive broadcasted packets from the FAs.
- In the three methods, the MN can send an agent solicitation or a fast agent solicitation message if the MN detects packet loss or packet arrival interval of more than 10 ms.

- Media access control at the wireless network in Fig. 3 and Fig. 6 is IEEE 802.11 implemented in [9].
- In the original method, the MN's MAC media is not allowed to deregister the FA for 0.1 s after it registers the FA.
- In the seamless handoff and fast registration methods, MAC media in the MN is not allowed to deregister the secondary FA for 0.1 s after it registers the FA by the latest agent advertisement from the FA.
- For wireless communication between the MN and the FA in each cell, transfer error is ignored and propagation delay is calculated as (distance between the FA and the MN)/(speed of the light).
- The sender sends data to the MN by CBR control over UDP. The IP packet size is 256 octets whose transfer rate is 384 kbps and packet interval is 5.33 ms.
- In the MN, the HA, the FAs and the router, each processing delay for routing, copying, encapsuling and decapsuling a packet is 10 μs, respectively. The one of the registration procedure for the MN is 100 μs.
- The processing delay in Logical Link Control of the FAs is 25 μs.
- Every experiment result satisfies 5% confidence interval with 95% confidence level.

The common conditions for simulation model 1 (Fig. 3) are shown in below.

- These are one HA and two FAs. Each FA has a circular cell.
- Each FA is placed at the center of the cell, and 360 m apart from each other. The MN moves straight forward from the FA1 to the FA2.

4.2 Overlap Model

At first, the radius of each cell is set to 200 m. Then, the simulation model has an overlap region. Figure 4 indicates the average handoff latency (i.e., average of packet arrival intervals when the MN switches the primary FA from which the MN receives packets) in CBR communication when the MN moves to the other cell. In this figure, the three handoff methods in the previous subsection are described as "proposal," "fast" and "original," respectively. In the rest of this paper, all simulation results will also be described in this order. In this figure, the average handoff latencies of the three handoff methods are 5.6–6.6 ms, 5.3–6.2 ms and 16.9–18.6 ms. From the results of "proposed" and "fast" each handoff latency is almost unchange with respect to movement speed of the MN. In the simulation condition, 20 m/s (= 72 km/h) is not quite fast to receive an agent advertisement from the FA2 within the overlap region. Then, the MN can execute the registration procedures for the FA2 in the overlap region before it is completely released from the FA1. Therefore, the handoff latency does not depend on the movement speed in this simulation. It is also emphasized that these results are considered as almost no handoff latency, since the packet interval of the sender is 5.33 ms and each FA also produces another latency to periodically broadcast an agent advertisement. The latter latency is estimated no less than 2 ms and should not be included in handoff latency.

The average handoff latency of "original" is at least 10 ms lager than the others because the MN can not receive data from the HA during handoff procedures which take about roundtrip time between the MN and the HA (during the period, data are flowed into the previous cell (FA1)).

Tables 1–3 show overhead (the average of the total numbers of extra or loss packets) for the three methods in the simulation. "copied in HA" is the average

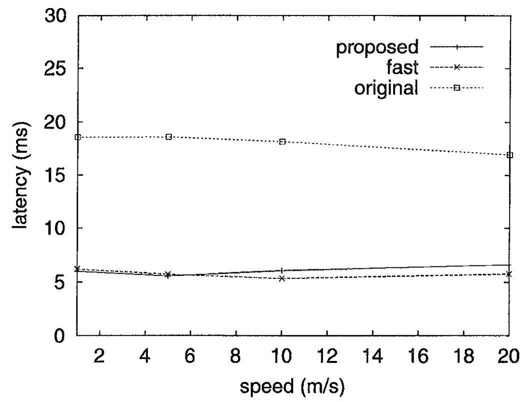

Fig. 4 Average handoff latency (overlap model).

Table 1 Average overhead of the proposed (overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	7161.3	1611.0	897.5	561.3
duplicated in wireless	15.4	16.0	14.7	16.0
duplicated in MN	14.4	15.0	13.7	15.0
lost	0.0	0.0	0.0	0.0

Table 2 Average overhead of the fast registration (overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	7158.7	1611.3	769.4	561.4
duplicated in wireless	7098.0	1550.7	709.1	501.1
duplicated in MN	6920.3	1372.7	669.3	318.7
lost	0.0	0.0	0.0	0.0

Table 3 Average overhead of the original (overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	0.0	0.0	0.0	0.0
duplicated in wireless	0.0	0.0	0.0	0.0
duplicated in MN	0.0	0.0	0.0	0.0
lost	3.4	3.4	4.3	3.1

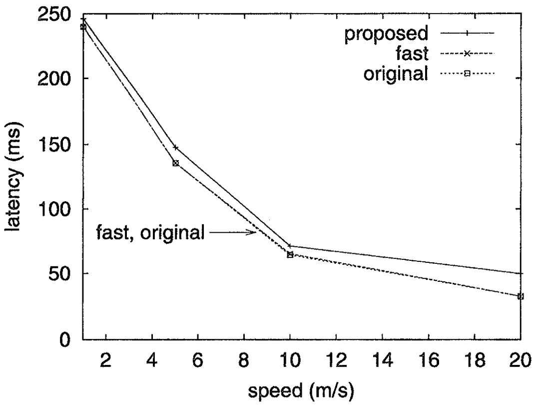

Fig. 5 Average handoff latency (no overlap model).

number of duplicated packets of doublecasting by the HA. "duplicated in wireless" is the average number of packets which is in "copied" in the HA and also flowed into the wireless network. "duplicated in MN" is the average number of packets which is received by the MN as duplication.

We obtain the average packet losses of these methods, which are 0.0, 0.0 and 3.1–4.3 packets at "lost" in the tables, respectively. Since the proposal method and fast registration method realize no packet loss, the MN can sreceive packets from the FA2 when it is departed from the overlap region.

"duplicate in wireless" of the proposed method is decreased from the one of the fast registration method, but yet arises for eliminating packet loss and carrying all packets in the correct order when the primary and secondary FAs are exchanged. However, "proposed" also has 561.3–7161.3 packets of overhead in fixed networks when the MN stays on an overlap region. This is, the packets are flowed from the HA into fixed network during 3.0–38.8 s, which is correspond to the time when the MN stays in the overlap region.

4.3 No Overlap Model

We execute the same experiment in the previous subsection again, except that the radius of the each cell is 180 m, i.e., there is no overlap region. In Fig. 5, we show that the average handoff latencies of the three methods are 49.8–246.1 ms, 32.3–240.0 ms and 32.3–240.0 ms. The results of "fast" and "original" are almost equal, since under the simulation condition, both the registration procedures are same. Since there is quite small area disconnected the connection from the both FAs, the faster speed of the MN, the lower average handoff latency. The seamless handoff method results 10 ms larger in average handoff latency than the ones of the other two methods, since no overlap region gives extra propagation delay between the FA1 and the FA2. Therefore, "lost" in Table 4 is a little larger than the ones in Tables 5 and 6. In Tables 4 and 5, "proposed" and "fast" produce 188.0–226.5 and 189.4–227.6 packets of "copied in HA," i.e., flow these extra packets during 1.0–1.2 and 1.0–1.2 s, respectively, though there is no overlap region. This is why the HA recognizes the FA1 as a valid FA of the MN during the registration life time for the FA1, and then continues to forward packets to the FA1 after the FA2 is registered.

Table 4 Average overhead of the proposed (no overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	188.0	194.9	226.5	223.1
duplicated in wireless	185.3	172.9	186.5	185.0
duplicated in MN	0.0	0.0	0.0	0.0
lost	46.1	27.3	14.4	9.3

Table 5 Average overhead of the fast registration (no overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	189.4	197.3	227.6	224.4
duplicated in wireless	130.7	136.1	166.4	160.1
duplicated in MN	0.0	0.0	0.0	0.0
lost	45.0	25.4	12.2	6.0

Table 6 Average overhead of the original (no overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	0.0	0.0	0.0	0.0
duplicated in wireless	0.0	0.0	0.0	0.0
duplicated in MN	0.0	0.0	0.0	0.0
lost	45.0	25.4	13.1	6.0

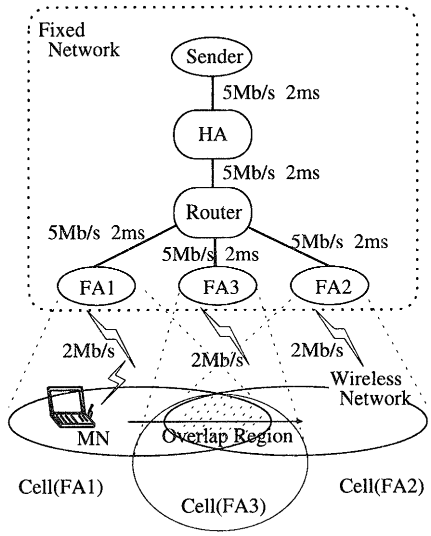

Fig. 6 Simulation model 2.

4.4 Multiple Overlap Model

Figure 6 shows simulation model with multiple overlap where the FA3 is added to Fig. 3. The common conditions for the simulation model 2 are shown in below.

- FA3 is placed in the same distance from FA1 and the FA2, and 180 m apart from the midpoint be-

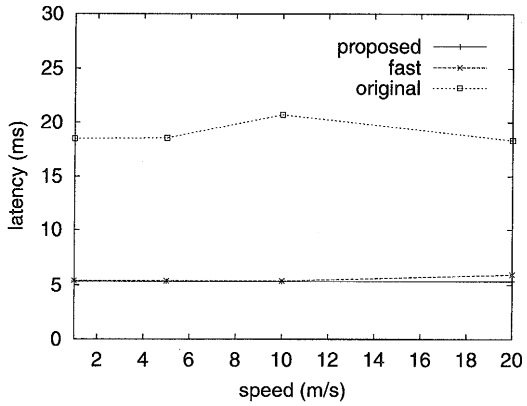

Fig. 7 Average handoff latency (multiple overlap model).

Table 7 Average overhead of the proposed (multiple overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	31600.3	6475.0	3362.9	1750.4
duplicated in wireless	12.7	12.7	23.6	23.3
duplicated in MN	10.9	11.9	21.6	22.3
lost	0.0	0.0	0.0	0.0

Table 8 Average overhead of the fast registration (multiple overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	31600.9	6475.4	3362.9	1745.8
duplicated in wireless	31537.3	6412.1	3299.1	1681.7
duplicated in MN	31357.3	6241.6	3125.5	1507.3
lost	0.0	0.0	0.0	0.0

Table 9 Average overhead of the orignal (multiple overlap model).

	1 m/s	5 m/s	10 m/s	20 m/s
copied in HA	0.0	0.0	0.0	0.0
duplicated in wireless	0.0	0.0	0.0	0.0
duplicated in MN	0.0	0.0	0.0	0.0
lost	3.4	3.4	6.7	5.3

tween the FA1 and the FA2.

- The MN moves straight forward from the FA1 to the FA2.
- The radius of the cell in each FA is 200 m.

In Fig. 7, we show that the range of the average handoff latencies of the three methods are 5.3–5.3 ms, 5.4–6.0 ms and 18.3–20.7 ms. These results are almost same with Fig. 4. Thus, the average of handoff latency does not change for each handoff method. However, from the average overheads of the three method in Tables 7–9, "copied in HA" in "proposed" and "fast" are about three times of these values in Tables 1–3, that is extra packets are flowed into fixed networks during 9.3–168.5, since the overlap region expanded by the cell of the FA3. The average number of duplicated packets is also three times in "fast," but achieves almost similar in "proposed." "last" is not changed in the two methods, though about two packets are increased at 10 and 20 ms in "original." The latter result shows that two handoff procedures are occurred when the MN moves from the FA1 to the FA3 and from the FA3 to the FA2. From these results, we can find that "proposal" provides seamless data stream with low overhead in wireless networks, even if the MN moves through multiple overlap region.

Table 10 Result of random motion in multiple overlap region (average).

	original	fast registration	proposed
handoff latency (ms)	24.8	6.9	5.6
received in HA	18750.0	18750.0	18750.0
copied in HA	0.0	18749.9	18750.0
duplicated in wireless	0.0	18749.9	904.6
duplicated in MN	0.0	18747.0	902.1
lost	134.8	0.0	0.0

4.5 Random Motion in Multiple Overlap Region

The previous subsections moves straight at constant velocity. However, actual motion of the MN is not simple. In this subsection, we let the MN move randomly within a square of sides of 400 m^2 at the multiple overlap region in Fig. 6. Additional conditions to the previous subsection for the common are shown in below.

- The center of the square is placed at the midpoint between the FA1 and the FA2. The top and bottom sides of the square are parallel with the line connected the FA1 with the FA2.
- The initial location of the MN is randomly chosen within the square. Then, the random point is selected within the square. The MN straightly moves to the point at a constant speed randomly selected among 0.0–28.3 m/s during 1 second. The above random movement is repeated without interval for 100 s.

Table 10 shows the simulation result for the random motion model. "handoff latency" means average of maximum handoff latency in each trial. "received in HA" is the the HA received from the sender for the MN. "proposed" has no packets loss, even if handoff procedures occur very often. In fact, more than 30 handoff procedures produce 134.8 average lost packets for 100 s in "original." Though, in "proposed" the average overhead in wireless networks is increased from the result in Table 7, it is just about 1/20 of the one of "fast" in the Table 10. "proposed," and "fast" flow duplicated packets during the simulation time because the MN always stays in the overlap region.

5. Conclusions

In wireless communications, handoff latency and overhead occur when an MN changes the connection point.

To reduce it, this paper improves handoff methods for cellular Internet environments using Mobile IP. The simulation experiment shows our registration method is effective for real-time communications in cellular Internet environments.

Our method is succeed in improving overhead in wireless networks, but not for fixed networks. We should improve the bad situation when the MN stays overlap region too long time. The proposed method also arises extra signaling packets for registration update to the primary and secondary FAs in overlap region. To reduce these packets, a hierarchical BS method will also be helpful for the solution.

Our simulation model is very simple. In practical, for example, many MNs exist in a cell, and may increase their average propagation delay, in the wireless network by MAC control due to congestion. In addition, more complex network topology gives large propagation delay. Such practical conditions may also occur huge handoff latency and overhead. However, large overlap region which is sufficient to be completed the registration procedures for the MN, will mitigate the above problems, and give almost same handoff latency and overhead of the simulation results in Sect. 4.

Although the doublecasting method in our proposal helps with reducing handoff latency, it consumes duplicate capacity of the fixed network. Then, heavy congestion may be caused at the routers between the HA and the FAs. However, the occurrence probability of the congestion should be quite small, since the transfer rate of the wireless network is much lower than the one of the fixed network, in general. Therefore, the router also has enough processing speed for the duplicated traffic, and then the heavy congestion should not be occurred. It should be noted that the above duplication problem is not occurred at the wireless network in our proposed method.

The seamless handoff method can also observe which FAs will be connectable to the MN by receiving registration requests. The registration request can expand for resource reservation procedures procedures, which will be useful for good quality communication in the cellular Internet environments.

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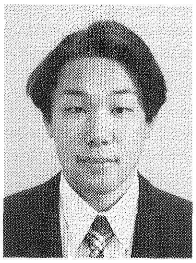

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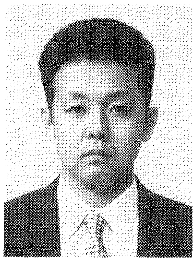

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