A Simple Path Prediction Scheme to Improve Handoff Efficiency in All-IP Wireless Networks

Huamin Zhu* ***Associate Member***, Kyung-sup Kwak*** ***Regular Member***

ABSTRACT

Mobile IP maintains Internet connectivity while Mobile Hosts moving from one Internet attachment point to another. However, Mobile IP is not appropriate for seamless mobility. Some micromobility protocols were proposed to complement Mobile IP by offering fast and seamless handoff control in limited geographical areas. In this paper, a new scheme, based on path prediction and resource reservation, is proposed to reduce the handoff latency by trying to eliminate the link setup time for fast handoff in all-IP wireless networks. Analytical results show that the proposed scheme offers shorter handoff delay and can improve the handoff efficiency.

Ⅰ. Introduction

It is clear that support for seamless mobility will be needed in order to provide good service quality for mobile users, particularly in pico-cellular environments where the rate of handoff and associated signaling load grows rapidly. Mobile IP [1] maintains Internet connectivity while MHs (Mobile Hosts) moving from one Internet attachment point to another. However, Mobile IP is not appropriate for seamless mobile because after each migration a local address must be obtained and communicated to a possibly distant location directory or Home Agent (HA). Micromobility protocols [2]-[5] complement Mobile IP by offering fast and seamless handoff control in limited geographical areas and IP paging in support of scalability and power conservation. These protocols have the benefit of reducing delay and packet loss during handoff, and eliminating registration between MHs and distant Home Agents (HAs) when MHs remain inside their local coverage areas. Eliminating registration in this manner is necessary for the wireless Internet to scale to support very large volumes of wireless subscribers. It is proposed in [6] that the main idea for fast handoff is to make sure that the new access router has everything ready and waiting for the MH before it arrives. In this paper, we try to achieve this purpose by path prediction and resource reservation [7].

The rest of the paper is organized as follows. In section Ⅱ, network model is described for the all-IP wireless network. The proposed path prediction scheme is presented in Section Ⅲ. Results are discussed in Section Ⅳ, followed by our conclusions in Section Ⅴ.

Ⅱ. Network Model

Our network model is on the basis of Cellular IP network [3], shown in Figure 1.

This is a hierarchical network, the high layer of the network is the Mobile IP enabled Internet, and the low part is the local Cellular IP access network. In our network model, the MSC (mobile switching center) and all its BSs (base stations) form the local cellular IP access network where the MSC is the FA (foreign agent). We assume that handoff is taken in the local network in this

---

* Telecommunication Lab, Graduate School of IT and Telecommunications, Inha University (zhm@telecom.inha.ac.kr)
** Senior Manager, Core Network Development Team, SK Telecom (hskim@sktelecom.com)
*** Professor, Graduate School of Information Technology and Telecommunications, Inha University (kskwak@inha.ac.kr)

논문번호 : 040015-0010, 접수일자 : 2004년 1월 12일

paper.

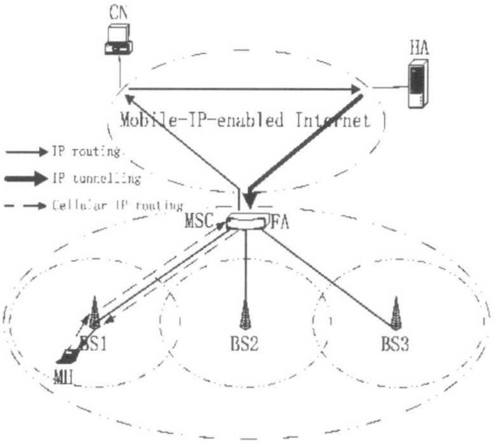

Fig 1. The network mode

Let T_l be the handoff latency, which is the time that elapses between handoff initiation and the arrival of the first packet along the new route. We can get

$$T_l = T_{up} + T_{setup} + T_{down}, \qquad (1)$$

where

T_{up}: the packet transmission time from the MH to MSC,

T_{setup}: the link establishment time,

T_{down}: the packet transmission time from the MSC to MH.

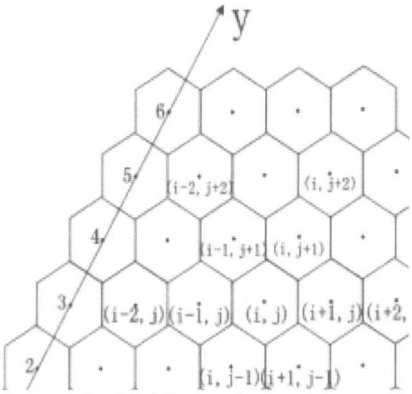

Fig 2. Cell mapping

Ⅲ. Prediction Method

We can define a one-to-one mapping, which maps each base stations belonging to one MSC into a pair of integer, the coordinates of the cell, as shown in the Figure 2.

Assume the MH moves from the current cell (i, j) to the new cell (x, y), we use the following equation to compute the coordinates of the predicted cell (u, v).

$$\begin{cases} u = i + 2(x - i) \\ v = j + 2(y - j). \end{cases} \qquad (2)$$

Then the link from the MSC to the MH by the predicted BS is established and reserved for the MH till the next handoff.

The handoff procedure is shown in Figure 3.

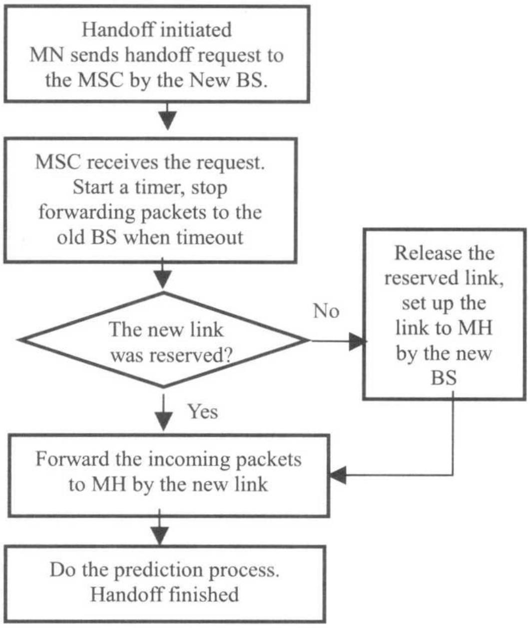

Fig 3. The handoff procedure

Ⅳ. Results

If the prediction is correct, we can get

$$T_l = T_{up} + T_{down}. \qquad (3)$$

If the prediction is not correct, we have the same T_l as (1).

Let p be the probability of correct prediction, the average handoff latency of our scheme is given by

$$E[T_l] = T_{up} + (1 - E[p])T_{setup} + T_{down}\,. \tag{4}$$

where ***E[ ]*** means the mean value. The larger ***E[p]***, the smaller the average handoff latency and the better the performance.

For the normal case, we can get =1/6 because there are six cells around each cell.

If we assume that the MH moves along a line, we can get better results. We assume that the entire cells are absolutely uniform and the position of the MH is uniformly distributed in the cell. Without loss of generality, we can let the radius of the cell be unit. Let the original coordinate of the MH be ***(u,v)***, which is denoted by point A in the figure. And let ***p(u,v)*** be the probability of correct prediction when the MH is at ***(u,v)***. As shown in Figure 4, the MH moves from Cell 1 to Cell 2 directly. At this time, ***p(u,v)*** is the probability that the MH will move from Cell 2 to Cell 3 directly. Thanks to the symmetry of the cell, we need only consider the case that A is on the low part of the cell ($\wedge$), i.e., v<0. Subdivide this part into two sub-parts for further analysis.

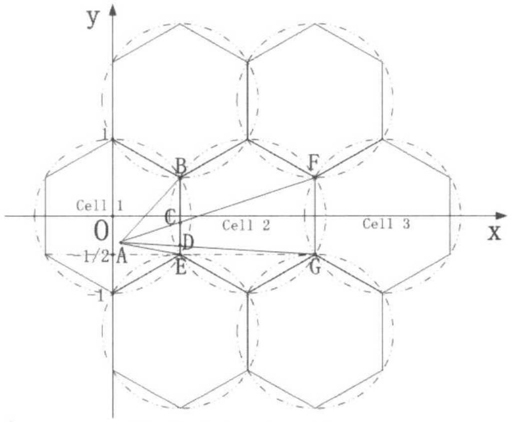

Fig 4. A in sub-part 1

Sub-part 1 ($\wedge_1$):

$$\begin{cases} -1/2 \le v \le 0 \\ -\sqrt{3}/2 \le u \le \sqrt{3}/2\,, \end{cases}$$

shown in Figure 4.

We have

$$p(u,v) = \frac{\angle CAD}{\angle BAE}\,. \tag{5}$$

Line ***AF*** can be represented by

$$y = \frac{1/2 - v}{3\sqrt{3}/2 - u}\left(x - \frac{3\sqrt{3}}{2}\right) + \frac{1}{2}\,. \tag{6}$$

Line ***AG*** can be represented by

$$y = \frac{-1/2 - v}{3\sqrt{3}/2 - u}\left(x - \frac{3\sqrt{3}}{2}\right) - \frac{1}{2}\,. \tag{7}$$

Since

$$S_{\Delta ABE} = \frac{1}{2}|BE| \cdot h_{BE} = \frac{1}{2}|AB| \cdot |AE| \cdot \sin(\angle BAE)\,, \tag{8}$$

where $S_{\Delta ABE}$ means ΔABE's area, $|\cdot|$ means the length, and $\boldsymbol{h_{BE}}$ is the height on ***BE***, we can easily get

$$\sin(\angle BAE) = \frac{|BE| \cdot h_{BE}}{|AB| \cdot |AE|}\,, \tag{9}$$

$$\sin(\angle CAD) = \frac{|FG| \cdot h_{FG}}{|AF| \cdot |AG|}\,. \tag{10}$$

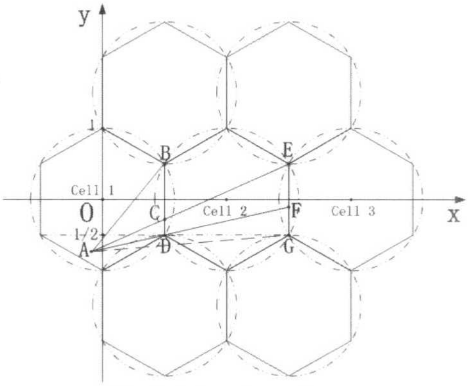

Fig 5. A in sub-part 2

Sub-part 2 ($\wedge_2$):

$$\begin{cases} -1 \le v \le -1/2 \\ -\sqrt{3}(1+v) \le u \le \sqrt{3}(1+v), \end{cases}$$

shown in Figure 5.

We have

$$p(u,v) = \frac{\angle CAD}{\angle BAD}. \qquad (11)$$

Line ***AE*** can be represented by (6).

By the same way, we can derive $\sin(\angle BAD)$ from (9) and

$$\sin(\angle CAD) = \frac{|CD| \cdot h_{CD}}{|AC| \cdot |AD|}. \qquad (12)$$

So,

$$E[p] = \iint_{\Lambda} \frac{1}{S_{\Lambda}} p(u,v)dudv = \iint_{\Lambda} \frac{4}{3\sqrt{3}} p(u,v)dudv. \qquad (13)$$

By using the midpoint rule to approximate the integration, we have ***E[p]***=0.3, shown in Figure 6.

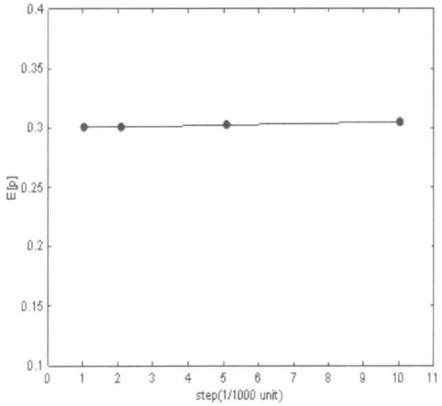

Fig 6. Numerical results of one-reserved-cell scheme

If we increase the reserved cell to three, the prediction method is shown in Figure 7, where we assume the current cell is cell ***(i,j)***. We have ***E[p]***=1/2 for the normal case because there are six cells around each cell, and ***E[p]***=0.74 if the MH moves along a line, shown in Figure 8.

New cell	Predicted cells
(i+1, j)	(i+2, j-1), (i+2, j), (i+1, j+1)
(i, j+1)	(i+1, j+1), (i, j+2), (i-1, j+2)
(i-1, j+1)	(i-1, j+2), (i-2, j+2), (i-2, j+1)
(i-1, j)	(i-2, j+1), (i-2, j), (i-1, j-1)
(i, j-1)	(i-1, j-1), (i, j-2), (i+1, j-2)
(i+1, j-1)	(i+1, j-2), (i+2, j-2), (i+2, j-1)

Fig 7. Prediction method for three-reserved-cell scheme

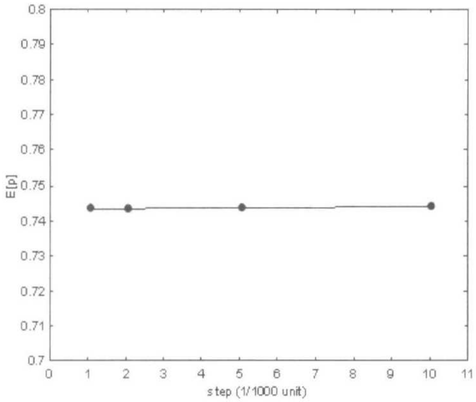

Fig 8. Numerical results of three-reserved-cell scheme

The cost for three-reserved-cell scheme is that the overhead also increases. Compared with one-reserved-cell scheme, the cost for three-reserved-cell scheme is that the overhead increases because it needs to reserve two more neighbor cells. If we consider the reserved cells only, it achieves 2.5 (0.74/0.3) times of prediction accuracy by using 3 times of reserved cells; If we consider both current cell and the reserved cells, it achieves 2.5 times of prediction accuracy by using 2 (4/2) times of cells. So the three-reserved-cell scheme is reasonable. This implies a design tradeoff for the wireless network.

For the extreme case, we can reserve all the cells surrounding the new cell, i.e., six-reserved-cell scheme. In this case, we can get ***E[p]***=1 regardless of the movement of the MH, i.e., we can eliminate the link setup time completely. The cost for this scheme is also the increased overhead.

V. Conclusions

Analytical results show that the path prediction scheme can reduce the handoff delay for micromobility of mobile hosts in an all-IP wireless network. The overhead of our scheme is the reserved link. However, there is no packet sent by the BS of the reversed link during the reserved period, so it doesn't add interference to the wireless network. As far as the CDMA wireless network is concerned, it doesn't affect the system capacity of the wireless part of the network in theory. Our scheme only requires little computation overhead on MSC, and it is very easy to implement. Recently, GPS (global position system) has been widely used in the 3G wireless communication system. With the help of GPS we can work out better algorithms to improve the accuracy of the path prediction of the MH. Then we can improve the performance of our path prediction scheme further and decrease the overhead of the reversed link in the wireless network.

References

[1] Perkins, C.E., "Mobile IP," IEEE Communications Magazine, vol. 11, pp. 84-99, May 1997.

[2] Chiussi, F.M.; Khotimsky, D.A.; Krishnan, S.: "Mobility management in third-generation all-IP networks," IEEE Communications Magazine, vol. 40, pp. 124-135, Sep. 2002.

[3] Campbell A. T. et al., "Design, Implementation and Evaluation of Cellular IP," IEEE Pers. Commun., pp. 42-49, Aug. 2000.

[4] Han-Chieh Chao; Yen-Ming Chu; Mu-Tai Lin, "The implication of the next-generation wireless network design: cellular mobile IPv6," Consumer Electronics, IEEE Transactions on, vol. 46, pp. 656-663, Aug. 2000.

[5] I-Wei Wu; Wen-Shiung Chen; Ho-En Liao; Young, F.F, "A seamless handoff approach of Mobile IP protocol for mobile wireless data networks," Consumer Electronics, IEEE Transactions on, vol. 48, pp. 335-344, May 2002.

[6] Perkins, C.E., "Mobile IP," IEEE Communications Magazine, vol. 40, pp. 66-82, May 2002.

[7] William Stallings, High-Speed Networks: TCP/IP and ATM Design Principles. pp. 444-457, New Jersey: Prentice-Hall, 1998.

주 화 민 (Huamin Zhu) 준회원

1999년 7월 : 중국 남경대학 수학과 졸업 학사
1999년 9월~2001년 2월: 남경대학 수학과 석사
2001년 3월~현재 : 인하대학교 정보통신대학원 정보통신공학과 석박사 통합과정
<주관심분야> 이동통신, 무선통신네트워크

곽 경 섭(Kyungsup Kwak) 정회원

1977년 2월: 인하공대(학사)
1981년 2월: 미국 University of Southern California 대학원(EE석사)
1988년2월 미국 University of California, San Diego (통신이론 및 시스템 박사)
1988년~1989년: 미국 Hughes Network Systems 연구원
1989년~1990년: 미국 IBM 연구원
2000년 3월~2002년 2월: 인하대학교 정보통신대학원 초대원장
1990년 3월~현재: 인하대정보통신공학부 교수
2002년 1월~2003년 12월: 한국통신학회 부회장
2003년 3월~현재: IT신기술연구소 소장/ 초광대역무선통신연구센터장
<주관심분야> 위성/이동통신, 무선통신네트워크, UWB Radio, 무선 인터넷