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New approach to eliminate the latency in handoff schema for mobile node

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An important and challenging issue in the next-generation wireless systems (NGWS) is to support seamless handoff while moving between different integrated networks. This paper presents a location aided fast handoff protocol which is an improvement over the pre-registration low latency handoff proposed by the IETF. Pre-registration requires layer 2 information that might not be present in the access technology being used. By processing geographical data information acquired through GPS related to mobile node movement and the coverage area of each foreign agent intelligent handoff decisions can be made, allowing more control over the actual handoff latency and buffering requirements.

Key words: Mobile IP, seamless handoff, fast-handoff (low latency handoff), location information, GPS.

INTRODUCTION

In the integrated next-generation wireless systems, users are always connected to the best available networks and switch between different networks based on their service needs. It is an important and challenging issue to support seamless mobility management in the NGWS. Mobility management contains two components: location management and handoff management [Akyildiz et al.,1999]. Location management enables the system to track the locations of mobile users between consecutive communications. On the other hand, handoff management is the process by which users keep their connections active when they move from one base station (BS) to another. There exist efficient location management techniques in the literature for NGWS [Xie and Akyildiz, 2002; Xie, 2004]. However, seamless support of handoff management in NGWS is still an open research issue. Mobile IP (MIP) [Perkins, 2002] is one of the most successful solutions that support host mobility management for a large set of applications and devices on the Internet. In Internet when a mobile node (MN) moves and attaches itself to another network, it needs to obtain a new IP address. This changing of the IP address

requires all existing IP connections to the mobile node be terminated and then re-connected. With MIP, each mobile node is identified by a static home network address from its home network, regardless of the point of attachment, and a care-of address (CoA), an IP address to identify the MN's current point of attachment to the Internet when it is in a foreign network. While a mobile node is away from its home network, it updates its (CoA) to its home agent (HA).

The home agent intercepts any packets destined to the mobile node, and tunnels them to the mobile node's current location. Thus, it is necessary for a mobile node to register its location at the home agent whenever it moves to a new network. The time taken for this registration process combined with the time taken for a mobile node to detect handoff and configure a new network care-of address in the visiting network, amounts to the overall handoff latency. Packets are not delivered to the MN at the new location until the registration request is accepted by the HA and the registration reply is sent back. Therefore, packets on the fly may be lost due to the handoff delay.

In this paper we introduce a new fast handoff protocol, which relies on geographical information acquired through GPS of the MN location related to the serving foreign agent coverage area, to reduce the overall handoff latency.

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MOBILE IP HANDOFF DELAY

Mobile IP handoff delay is divided into two elements; one is caused by movement detection and the other is caused by signaling for registrations [Perkins, 1996]. The proposed hierarchical Mobile IP and micromobility solutions [Ramjee et al., 2002, Valko, 1999] particularly achieve reduction in registration signaling delay, but fail to address the problem of handoff requirement detection delay. Therefore, recently, the use of link layer information to reduce the handoff requirement detection delay has gained attention. The basic idea behind this approach is to use the link layer information to anticipate the possibility of handoff in advance so that the handoff procedures can be carried out successfully before the MN moves out of the coverage area of the serving foreign agent (FA). In the IETF, three methods have been proposed for low latency handoffs by EI [2001]:

1. Pre-registration handoff method: This method allows the mobile IP handoff to be made prior to the L2 handoff. The old FA, which resides in the network to which the MN has been attached, obtains router advertisements from the new FA which resides in the network to which the MN is expected to move, and advertises them in the old network. The MN detects movement by way of this information and completes a mobile IP registration via the new FA before the L2 handoff.
2. Post-registration handoff method: This method makes the mobile IP handoff after the L2 handoff. The old FA and the new FA establish a temporary tunnel by receiving source or target triggers from the link layer. Packets originated from or destined for the MN are transmitted to the new or old FAs by way of this tunnel. This method defines handoff request/reply messages to notify handoff from the old FA to the new FA.
3. Combined handoff method: This method combines the above two methods. It attempts the pre-registration handoff method before the L2 handoff, and if it fails, the old FA attempts the post-registration handoff method. The pre-registration method has two requirements, the first is next movement FA detection, and the second is handoff initiation decision, that should not be too early causing large buffering and packet delay, and not late for layer3 HO not to be completed before MN moves out from OFA coverage area. Traditionally, a MN decides to handoff to a new network based on the signal-to-noise ratio of the neighboring network. However, many modern mobile wireless devices are equipped with global positioning system (GPS) service provided by the vendors and service providers. Location-based services, GPS-based routing [Koodli, 2005] and GPS-assisted handoff [EI, 2001] are some of the common mechanisms that can take advantage of the MNs GPS coordinates. GPS co-ordinates can also be used to discover the relative location of the MN with respect to the neighboring networks. This paper introduces a location aided fast

handoff protocol (LAFH) variant of pre-registration, where the GPS co-ordinates of the MN combined with its velocity measurement, and the handoff signaling delay estimation are used to make intelligent handoff initiation decision to the nearest (geographically) neighboring network. We hope that by implementing our solution the problem of handoff will be confronted.

RELATED WORK

The importance of location based handoff techniques is well understood. In [Hamad. H 2008] in this paper We have studied the random movement of mobile node from any point, the GPS read the coordinate the velocity and the direction every second and it was expected to determine the direction through which the region is expected. In EI [2001] there is a study to use RSS to track the MNs and then use their trajectory information to support low latency mobile IP handoff. Dutta [2007] discuss how a combination of location information and SNR can provide better performance by reducing unnecessary handoff. Tom [2005] discuss how a protocol assisted by location information from a vehicle can predict the handoff (thereby enhancing the overall handoff performance). However using GPS to acquire location information to track the MN will make it easier and more practical. Julien and Thomas [2006] describe an experimental system that demonstrates how handover performance is improved by using geo-location information provided by a GPS system. They suggest using MIPv6 in combination with GPS coordinates to provide fast-handoff. In Media Independent Handover Services February [2007]; they introduced the idea of taking advantage of the geographical area covered by a network to achieve better handoff; they kept measuring the distance between the MN and the terminals of the area covered by the serving FA, and initiated handoff if the distance was less than fixed threshold value. However there has been no consideration to the velocity of the MN and the handoff signaling delay in the handoff initiation decision. In this paper, we provide a new handover protocol LAFH that takes into account the GPS coordinates of the MN, its velocity measurement, and the handoff signaling delay estimation to make intelligent handoff initiation decision.

ARCHITECTURE AND PROTOCOL

Reference network

The reference network is illustrated in Figure 1. For sake of simplicity the 802.11 AP and MIP FA functionalities are combined within one access router. Each network has a single wireless access point. The coverage area of each wireless access point is a circle with radius R and the

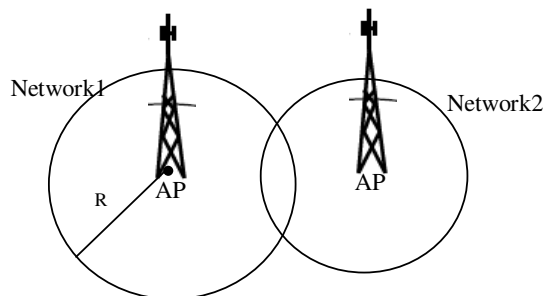


Figure 1. Reference network.

wireless access point is located at the center of the coverage area. It is not necessary that both coverage areas are equal. A MN of certain location coordinates $p = (x, y)$ is said to be in the coverage area of the FA1 with center $c = (x', y')$ and radius R if the distance d between the two points p and c is smaller than R , that is:

$$d = \sqrt{(x - x')^2 + (y - y')^2} \quad \text{and} \quad d \leq R$$

A FA that supports mobile nodes must advertise apart from its network prefix its location GPS coordinates and the radius of the region that it covers. The mobile node can combine these information with its GPS values of location, velocity and direction to determine whether it will continue to be connected to the current network or it must try to connect to a new network because it will soon be out of the current network's covered region.

The mobile node repeats periodically this check with a frequency relative to its velocity.

Detailed description

Neighborhood discovery

When entering new domain MN, it learns about its neighboring FAs that may be visited by the MN in case of handoff. Using the neighbor discovery protocol, the MN also learns the details of its neighboring FAs, such as the regional coverage area of each FA. It also knows about its serving FA coverage area through router advertisement message.

Handoff signaling delay estimation

The handoff signaling delay is the total time elapsed since the MN sends a registration request to a new FA until it receives back a registration reply. If the handoff signaling delay estimated is t_0 , then for the handoff pre-registration procedures to be successfully carried out, handoff triggering should starts at time equal t_0 before leaving the coverage area of its serving FA. To estimate

the handoff signaling delay one of the existing algorithms in [Dutta, 2007; Imielinski and Navas, 1999] can be used.

MN movement tracking

The purpose of movement tracking is to use a GPS receiver to periodically track the position of the MN while moving in the coverage area of the current serving FA to check if it needs to switch to a new network or not. The MN will switch to the next estimated cell which is close to the boundary by a certain interval equal to the handoff delay t_0 . To achieve this, the location coordinates of a three different positions of the MN p_1 , p_2 and p_3 are initially recorded, where $p = (x, y, t)$ with sampling time of one second assuming velocity of 1 m/s, and repeatedly track the movement, after each one second, a new position p_n is recorded such that $p_1 = p_2$, $p_2 = p_3$, and $p_3 = p_n$. A function f is found to describe the MN movement trajectory according to its previous locations and speed. The trajectory describing function could be linear, cubic, or five degree polynomial. Using this function, the expected position of the MN after time interval of t_0 is calculated to be p_4 .

Handoff initiation

In this step the coordinates of p_4 calculated in the previous section is used to detect the next FA to which the MN will move. If the next movement of the MN (p_4) is located in the coverage area of the current serving network there will be no handoff requirement and the system is required to keep tracking of the MN movement. On the other hand, if the coordinates of p_4 are not in the coverage area of the current network, the MN will select the nFA of the coverage area where its next expected movement p_4 is located. Thus handoff triggering should be initiated to the new network selected. To check under which FA coverage area p_4 is, we check the distance d between p_4 and the center of the coverage area of each neighboring FA, then compare d with the radius R of the coverage area of that FA, and if $d \leq R$ then p_4 is said to be in the coverage area of that FA. If p_4 is located in the

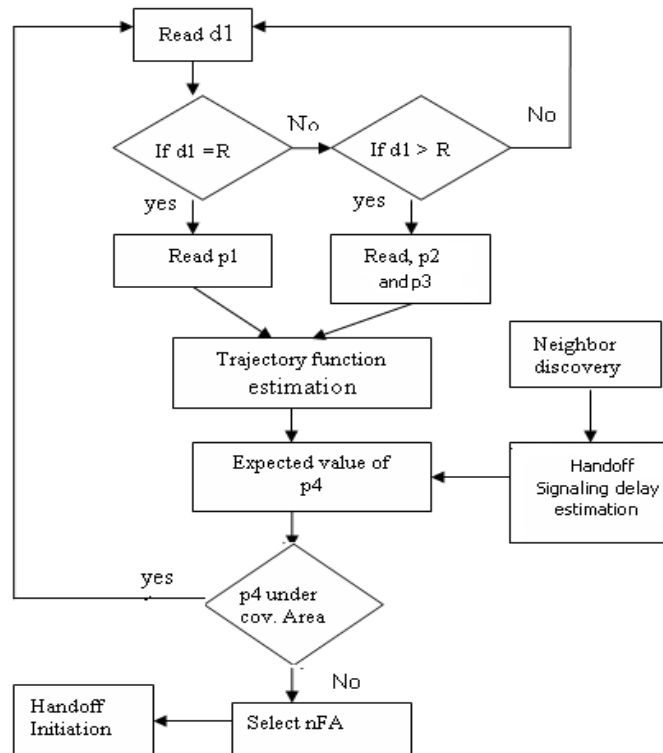


Figure 2. The flow chart of LAFH operation

coverage area of many over lay ping FA, then there would be a simultaneous pending update option of MIP protocol, where the MN binds the CoAs of the FAs that contains the coordinates of p_4 under their coverage area as well as the CoA of the oFA for a specified time interval, therefore, the home agent HA forwards packets destined for the MN to the specified CoAs during this time interval. The MN keeps its connection with the old network in this way to avoid the ping pong effect during handoff, that is if the MN returns to the old FA during this time period, there is no need to carry out the MIP handoff procedures again. The operation of our new protocol (LAFH) is summarized in Figure 2.

NEXT MOVEMENT DETECTION

The basic idea in mobile networks is the fact that the user moves from one place to another with the survival of contacting the other party the same. For the realization of this, idea has been divided into geographical coverage area to the number of cells that have the form of hexagonal.

In our protocol we studied the movement of MN from cell in the estimated direction to the other cell. When the cell is a hexagon form, it can be represented with two circles: interior circle takes the form of internal points in the hexagon and the outer circle is surrounded by the

edge of hexagon. This MN is considered moving randomly if the distance between MN and the center of the hexagonal is small than the radius of a small circle then this distance is not taken in the account. When this distance become equals to radius of small circle, which means that it is far from becoming hand off, we start reading the position and speed each time to detect the direction of MN and the new region.

The system coordinate divide the earth surface into horizontal and vertical parts called latitude and longitude respectively, and by using these coordinates we can locate any object on the earth. The GPS is used to determine the geographic coordinates, speed, and time of any mobile in any place on the earth. We suppose that mobile motion is nonlinear as shown in Figure 3. Where d_1 is the distance between the MN and center of circle, R is the radius of circle.

When the MN reaches near the boundary, it means $d_1 = R$, so it reads three coordinates in the path of movement at a constant time interval, then it estimate the next coordinate (P_4) which represent the direction to which the region MN will go after handoff .

- If the MN goes straight, it will make a pre-registration with the calculated new base station (new B.S).
- If the MN goes left or right it will make a pre-registration with the calculated new B.S or supposing that MN is returning back to it's current region, its old B.S in

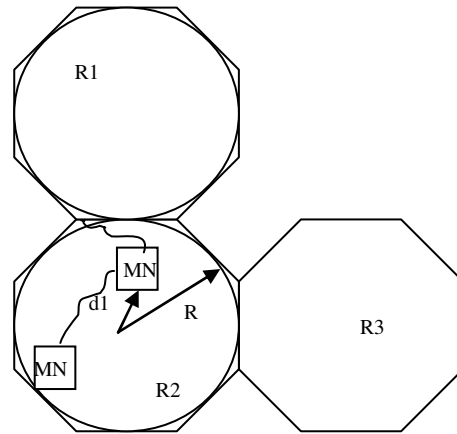


Figure 3. The trajectory of MN.

this case is kept and a new point P5 is taken to detect the correct direction and determine the new B.S that MN will make pre-registration with it. Our proposed algorithm to detect the coordinates of the next position is shown in Figure 4.

Procedures to predict the forth position

Step 1. First enter $p1(x1, y1, t1)$, $p2(x2, y2, t2)$, $p3(x3, y3, t3)$.

Step 2. Compute the function that describes the trajectory through the three points. In genera, the function of the path is given by $f(x) = a0 + a1x + a2x^2 + a3x^3 + a4x^4$ and $x(t) = vt + x0$; where: t is the time, $t = t4 - t3$, ($a0, a1, a2, a3, a4$) are the polynomial function parameters, v is the velocity, $x0$: is the initial position. Since the three points were taken in small distance, it is clear that the best path approximation function is a linear one.

Step 3. Compute the estimated direction: $\alpha = \tan(y/x)$ where $y = y4 - y3$ and $x = x4 - x3$. And we compute the distance $d34$:

$$d34 = \sqrt{(x2-x1)^2 + (y2-y1)^2}.$$

Step 4. If $p4$ is in the straight direction, compute $p4(x4, y4, t4)$.

Else if $p4$ is in the right position, compute $\theta1$, $p4(x4, y4, t4)$;

Where; $\theta1 = \theta - \alpha$, $x4 = x3 + d34 \cdot \cos\theta1$, $y4 = y3 + d34 \cdot \sin\theta1$

If $p4$ is in the left position compute $\theta2$, $p4(x4, y4, t4)$;

Where; $\theta2 = \theta + \alpha$, $x4 = x3 + d34 \cdot \cos\theta2$, $y4 = y3 + d34 \cdot \sin\theta2$.

Practical example

Suppose that we have three positions $p(x, y, t)$ as in Figure 5, $p1 = (10, 15, 1)$, $p2 = (20, 30, 3)$, $p3 = (30, 45,$

6), $t = 3$ s so by applying the algorithm in Figure 4 we can obtain the estimate coordinate $p4(x4, y4, t = 9)$.

First we compute the path function for different polynomial order:

Linear function

a. $y = 1.5 \cdot x + -4.3512e-015$.

b. Norm of residuals = $1.7764e-015$.

Quadratic function

a. $y = 2.2659e-017 \cdot x^2 + 1.5 \cdot x + 9.8903e-015$.

b. Norm of residuals = $8.1403e-015$.

Cubic function

a. $y = -1.4687e-018 \cdot x^3 + 8.5823e-017 \cdot x^2 + 1.5 \cdot x$.

b. Norm of residuals = $7.9441e-015$.

4th degree polynomial

a. $y = -2.3573e-019 \cdot x^4 + 1.7374e-017 \cdot x^3 - 3.6253e-016 \cdot x^2 + 1.5 \cdot x$.

b. Norm of residuals = $1.0658e-014$.

The results are shown in Figures 6a and b.

From the result shown in Figures 6a and b, we find out that the best estimated path function in a small distance is a linear function that has the lowest residue.

The results of calculating the next position's coordinates corresponding to the selected directions are shown in figures 7, and 8.

PERFORMANCE ANALYSIS

In the performance analysis we assume that:

- 1) Mobile nodes are allowed to move away from the starting point in any direction.
- 2) The probability of the variation of the mobile direction along its path is random.

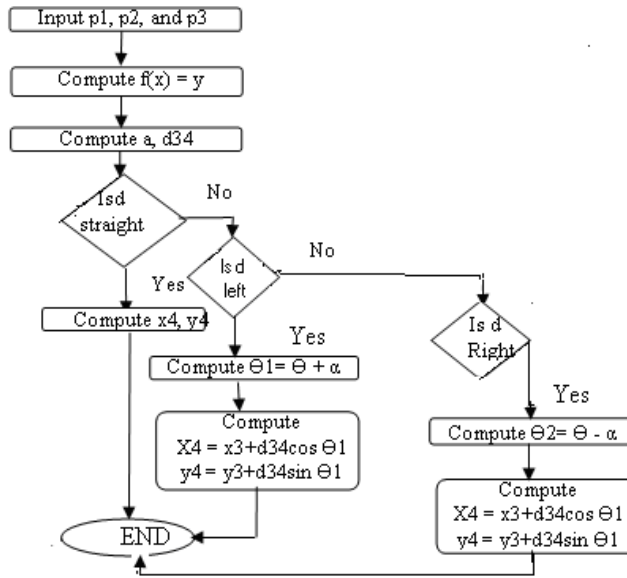


Figure 4. Detection of the next position coordinate flow char.

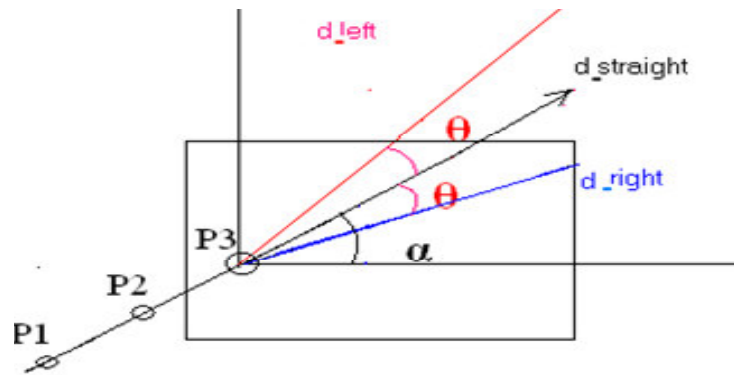


Figure 5. The direction of p4.

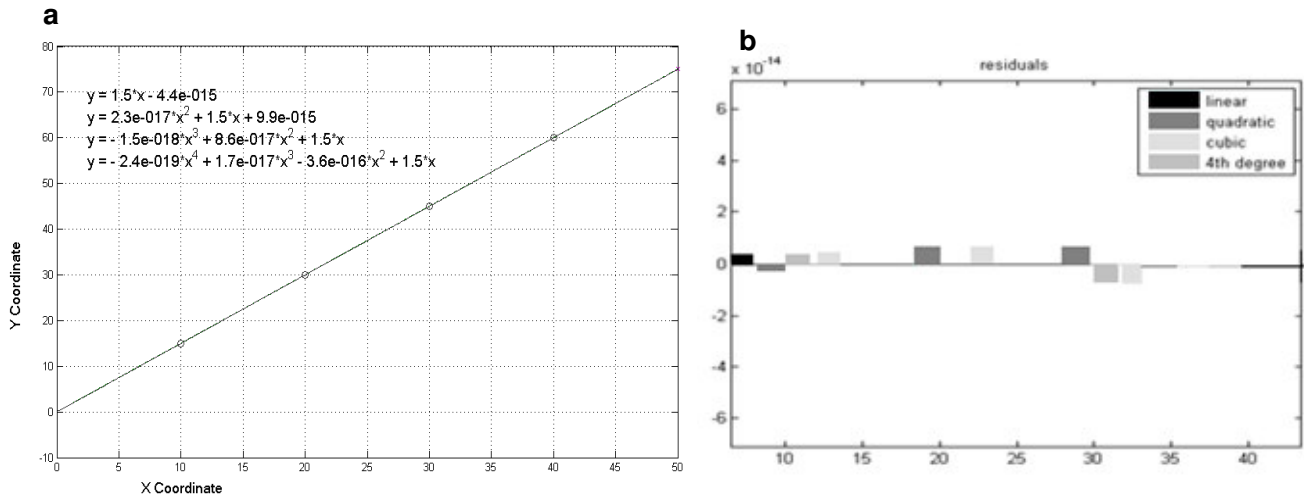


Figure 6. a: The function of the path with residue. b: The histogram of path function with residue.

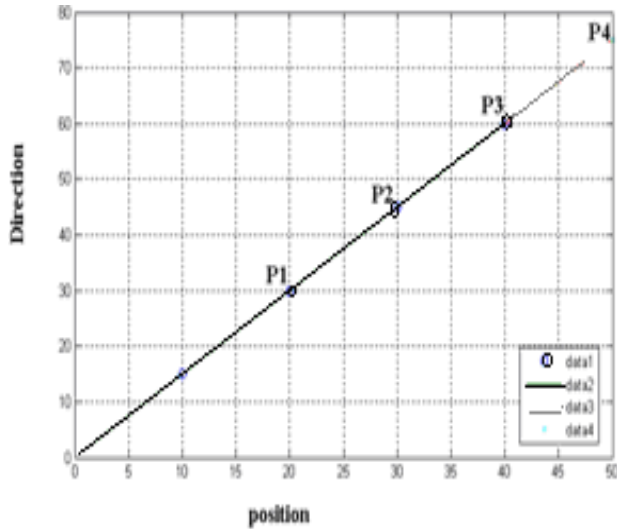


Figure 7. Direction straight.

3) The velocity of the mobile stations is assumed to be constant in small distance and small time.

The probability density function pdf of the directions of all mobile stations is given by:

$$Pdf = \begin{cases} \frac{1}{2} \cos(\alpha_0), & -\frac{\pi}{2} \leq \alpha_0 \leq \frac{\pi}{2} \\ 0, & \text{otherwise.} \end{cases}$$

then;

$$pr = \int_{-\infty}^{+\infty} pdf = 1.$$

$$pr(\alpha_0) = \begin{cases} \int_{-\pi/2}^{+\pi/2} 1/2 \cos(\alpha_0) = 1 \\ 0, & \text{otherwise.} \end{cases}$$

$$\text{If } -\theta < \alpha_0 < +\theta$$

$$Pr(\alpha_0) = \int_{-\theta}^{\theta} c \cos(\alpha_0) = 1$$

$$Pr(\alpha_0) = [c \sin(\theta) + d] - [c \sin(-\theta) - d] = 1. \\ \Rightarrow 2 c \sin(\theta) = 1, c = 1/(2 * \sin(\theta)).$$

$$Pr(d_{right}) = \int_{\alpha-\theta}^{\alpha} c \cos(\alpha_0) = c [\sin(\alpha) - \sin(\alpha - \theta)]$$

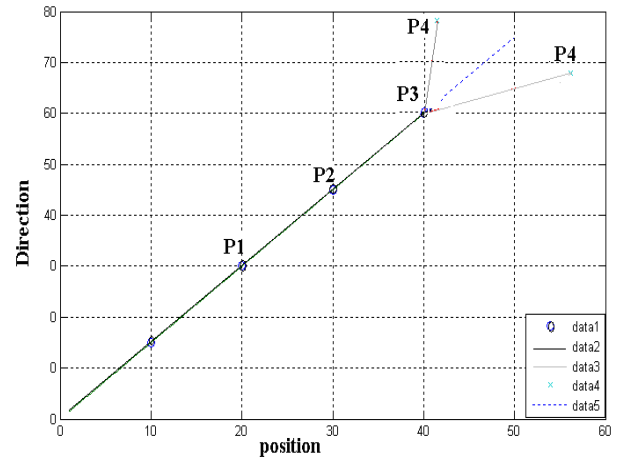


Figure 8. Direction right or left.

$$Pr(d_{left}) = \int_{\alpha}^{\alpha + \theta} c \cos(\alpha_0) = c [\sin(\alpha + \theta) - \sin(\alpha)]$$

$$pr(d_{straight}) = 1 - Pr(d_{right}) - Pr(d_{left})$$

where: d_right is the direction of moving right, d_left is the direction of moving left, d_straight is the direction of moving straight.

NUMERICAL RESULTS

By using the previous example, we compute the angle α :

$$\begin{aligned} \tan(\alpha) = y/x = 1.5 \rightarrow \alpha = 56.3, \text{ suppose } \theta = 15. \\ \text{So, } pr(d_{right}) = c [\sin(56.3) - \sin(41.3)] = 14.82\%. \\ Pr(d_{left}) = 1.93[\sin(71.3) - \sin(56.3)] = 22.12\%. \\ Pr(d_{straight}) = 100 - 5.75 - 8.59 = 63.05\%. \end{aligned}$$

This means that the next position is in the straight direction because it has the highest probability

Table 1 shows the results of direction probabilities for different values of α . From Table 1, it is clear that as α increase the probability of straight direction movement increases and our estimation that the MN will go straight will be more accurate. Table 2 shows the direction probability for different values of θ . From Table 2, it is clear that changing the angle θ has small effect to the estimated straight direction. Figures 9 and 10 summarize the previous results. From Figure 9, as we fix α and vary θ the $Pr(d_{straight})$ remains constant and this constant value is proportional to α . Also we can see that the probability to go right increases as the angle θ increases and this is opposite to going left. From Figure 10 it is shown that as we change α and fix θ , the probability to go straight is the highest probability and increase by increasing α . Also we can conclude that the probability to go in the direction right decreased when α increased

and the same thing for the direction left; α decreased with a higher amount than going in the direction right.

Conclusion

In this paper we have presented a new fast handoff location aided protocol variant of pre-registration method. We have shown that using location information acquired from GPS receivers, handoff initiation decision and the next movement detection can be made more successfully. From our results it has been shown that using movement tracking of the MN its next movement direction can be estimated with high accuracy and its new position coordinates can be predicted. Using information about the coverage area of each foreign network, the next network to which the MN will move in a certain time interval can be selected successfully. We believe that our solution in combination with pre-registration provides a reliable solution to the handoff problem that appears in mobile networks.

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