A Location Aided Fast Handoff Protocol for the Next Generation Wireless Systems

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Abstract- *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.*

Keywords: *Mobile IP, Seamless Handoff, Fast-handoff (Low Latency Handoff), Location Information, GPS.*

1. 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 [1]. 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 [18], [19]. However, seamless support of handoff management in NGWS is still an open research issue. Mobile IP (MIP) [2] 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. A general mobility model is presented in Figure 1. 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.

2. 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 [3]. The proposed hierarchical Mobile IP and micromobility solutions [4], [5] 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 El Malki et al.[7]:

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

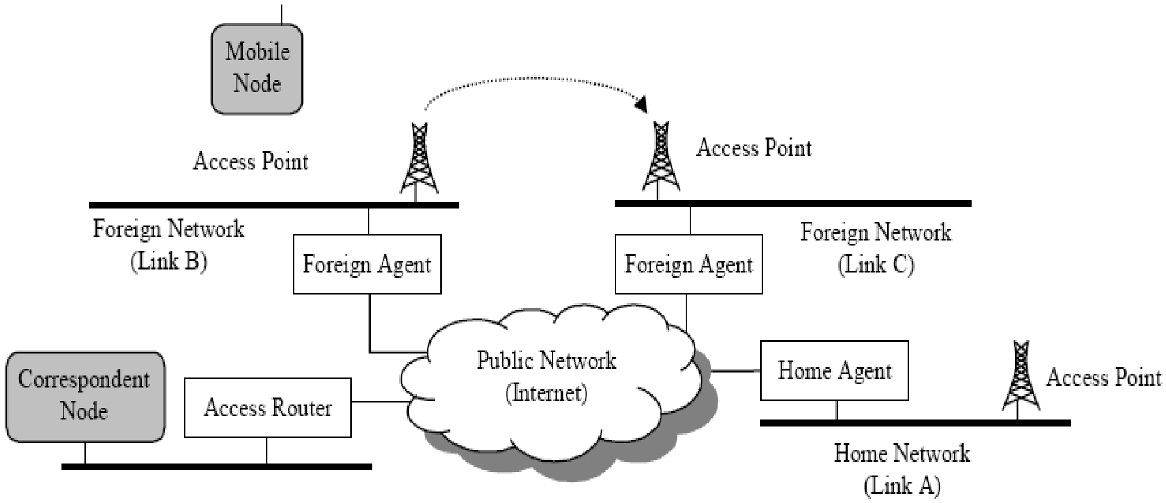

Figure 1: General mobility model.

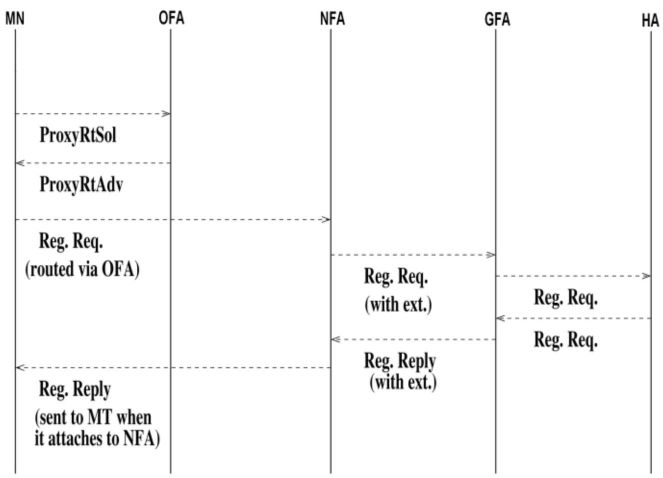

Figure 2: Timing diagram for pre-registration MIP handoff

handoff. The timing diagram for this method is shown in figure 2.

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 to be not 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 provides. Location-based services, GPS-based routing [6] and GPS-assisted handoff [7] 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.

3. Related Work

The importance of location based handoff techniques is well understood. In S-MIP [8] there is a study to use RSS to track the MNs and then use their trajectory information to support low latency mobile IP handoff. Wang and Wu [11] discuss how a combination of location information and SNR can provide better performance by reducing unnecessary handoff. Tom Van Leeuwen et al [12] 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 aquire location information to track the MN will make it easier and more practical. .Julien Montavont and Thomas Noel [13] 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 [14] they introduce the idea of taking advantage of the geographical area covered by a network to achieve better handoff; they keep measuring the distance between the MN and the terminals of the area covered by the serving FA, and initiate handoff if the distance is 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 co-ordinates of the MN, its velocity measurement, and the handoff signaling delay estimation to make intelligent handoff initiation decision.

4. Architecture and Protocol

4.1 Reference Network

The reference network is illustrated in Figure 3. 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 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:

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

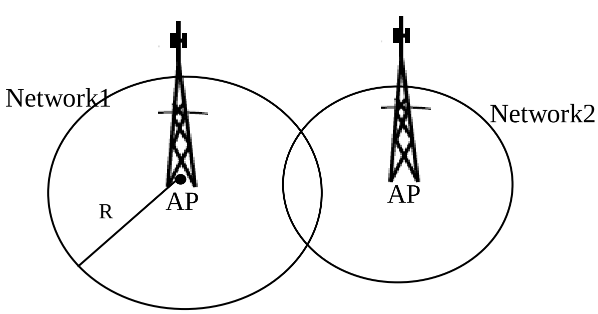

Figure 3: Reference Network

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.

4.2 Detailed Description

4.2.1 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.

4.2.2 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 t0, then for the handoff pre-registration procedures to be successfully carried out, handoff triggering should starts at time equal t0 before leaving the coverage area of its serving FA. To estimate the handoff signaling delay one of the existing algorithms in [11],[12] can be used.

4.2.3 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 basic idea is that if the MN from a certain location while traveling with a certain velocity and direction is expected to leave the coverage area of the current serving FA in time interval equals to the signaling handoff delay t0, then handoff triggering should be initiated immediately. To achieve this the location coordinates of a three different positions of the MN p1, p2 and p3 are initially recorded, where p=(x,y,t) with sampling time of one second assuming velocity of 1m/sec, and repeatedly track the movement, after each one second a new position pn is recorded such that p1=p2, p2=p3, and p3=pn. 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, the calculation of the trajectory function will be described later in section 5. Using this function the expected position of the MN after time interval of T0 is calculated to be P4.

4.2.4 Handoff Initiation

In this step the coordinates of p4 calculated in the previous section is used to check if to trigger handoff initiation or not and to detect the next FA to which the MN will move. If the next movement of the MN (p4) 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 p4 are not in the coverage area of the current network, the MN select the nFA of the coverage area where its next expected movement p4 is located. Thus handoff triggering should be initiated to the new network selected. To check under which FA coverage area p4 is, we check the distance d between p4 and the center of the coverage area of each neighboring FA d, then compare d with the radius R of the coverage area of that FA, and if $d \leq R$ then p4 is said to be in the coverage area of that FA. If p4 is supposed to be located in the coverage area of more than one FA, that is because of the overlapping in the coverag area of different networks, then we choose to use simultaneous pinding update option of the MIP protocol, where the MN binds the CoAs of the FAs that contains the coordinates of p4 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 keep 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 fig.4

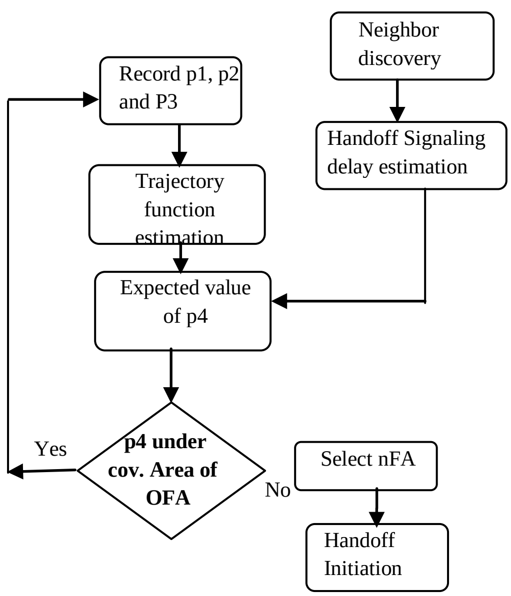

Figure 4: flow chart of LAFH operation

5. Next movement Detection

The system coordinate divide the earth surface into horizontal and vertical parts called latitude and longitude respectively, and by using this coordinate we can locate any object on the earth. The GPS is used to determine the geographic coordinate, speed, and time of any mobile in any place on the earth. We suppose that mobile motion is nonlinear as shown in fig.5.

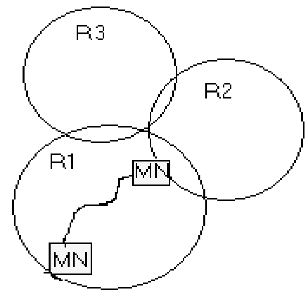

Figure 5: The trajectory of MN

When the MN reach near the boundary, we take 3 points of his path at a sequence of time T in order to determine its direction, then we calculate the coordinate of the next point (P4) by taking into consideration the probability of its new direction s.t. the probability that the MN will go straight & Pl: probability that MN will go left & Pr: probability that MN will go right). After calculating the coordinate of point P4, we can determine to which region the 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 go left or right it will make a pre-registration with the calculated new B.S or we suppose that MN is returning back to its current region so we keep its old B.S in this case we take new point P5 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 coordinate of next position is shown in figure 6.

5.1 Procedures to Predict the Forth Position

1- First enter p1(x1, y1, t1), p2(x2, y2, t2), p3 (x3, y3, t3).
2- Compute the function that describes the trajectory through the three points. In general the function of the path is given by:

$$f(x) = a0 + a1x + a2\,x^2 + a3\,x^3 + a3\,x^4 \quad \text{and} \quad x(t) = v*t + x0 \qquad (1)$$

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.
3- Compute the Estimated direction: α =tan y/x where y=y4-y3 and x=x4-x3. And we compute the distance d34 :

$$d34 = sqrt[(x2-x1)^2+(y2-y1)^2] \qquad (2)$$

4- If p4 is in the straight direction.
Compute p4(x4, y4, t4)

Else if p4 is in the right position

Compute θ1, p4(x4, y4, t4)

Where

$\theta 1 = \theta - \alpha, \quad x4 = x3 + d34 * \cos\theta 1, \; y4 = y3 + d34 * \sin\theta 1$ (3)

If p4 is in the left position

Compute θ2, p4(x4, y4, t4)

Where

$\theta 2 = \theta + \alpha, \; x4 = x3 + d34 * \cos\theta 2, \; y4 = y3 + d34 * \sin\theta 2$ (4)

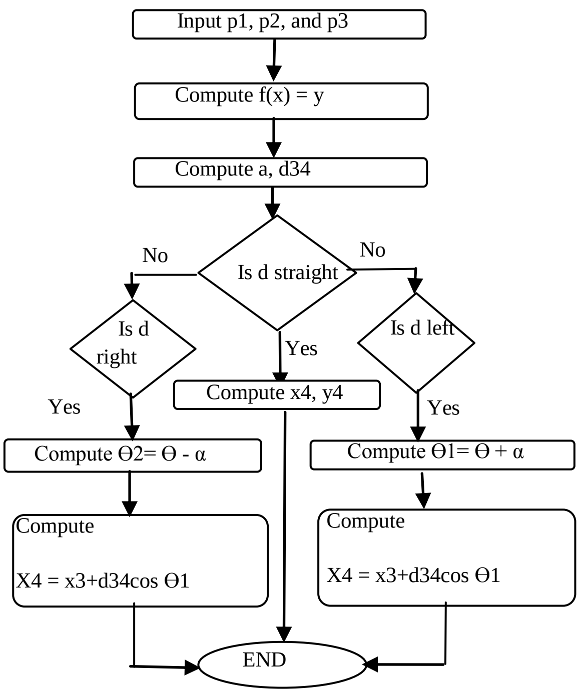

Figure 6: Detection of next position coordinates

5.2 Practical Example

Suppose that we have three positions p(x,y,t) as in figure 7 p1=(10,15,1), p2 = (20,30,3)), p3 = (30,45,6) , t = 3s so by applying the algorithm in figure 6 we can obtain the forth point p4(x4,y4,9).

First we compute the path function for different polynomial order:

Linear function

- y = 1.5*x + -4.3512e-015
- Norm of residuals = 1.7764e-015

Quadratic function

- y = 2.2659e-017 *x^2 + 1.5*x + 9.8903e-015
- Norm of residuals = 8.1403e-015

Cubic function

- y =-1.4687e-018 *x^3 + 8.5823e-017 *x^2 + 1.5*x
- Norm of residuals = 7.9441e-015

4th degree polynomial

- y = -2.3573e-019 *x^4 + 1.7374e-017 *x^3 - 3.6253 e-016 *x^2 + 1.5 *x
- Norm of residuals = 1.0658e-014

The results are shown in figure 8.From the result shown in figure 8, 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 9, and 10.

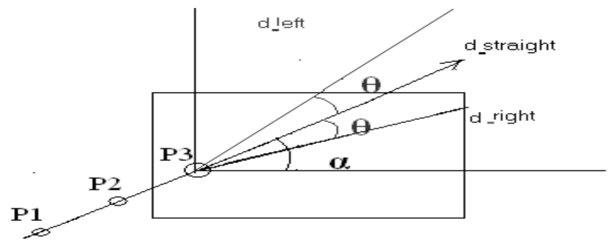

Figure 7: The direction of p4

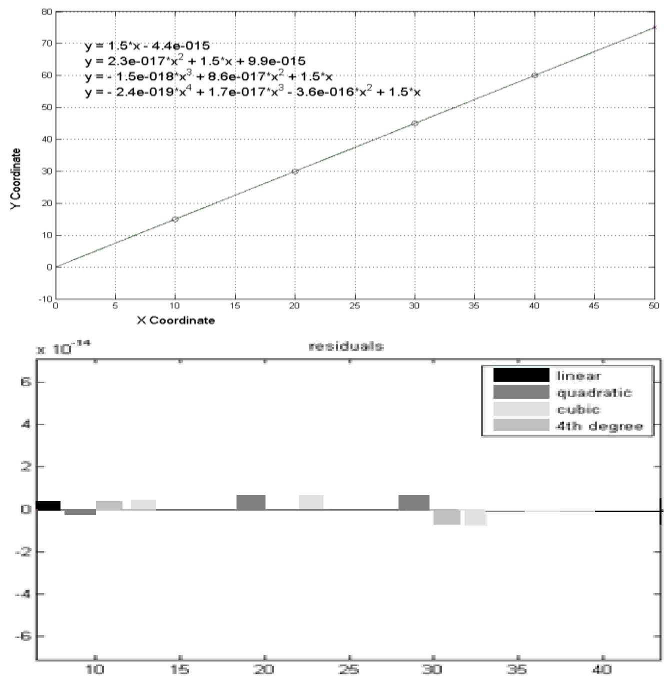

Figure 8: The function of the path with residue

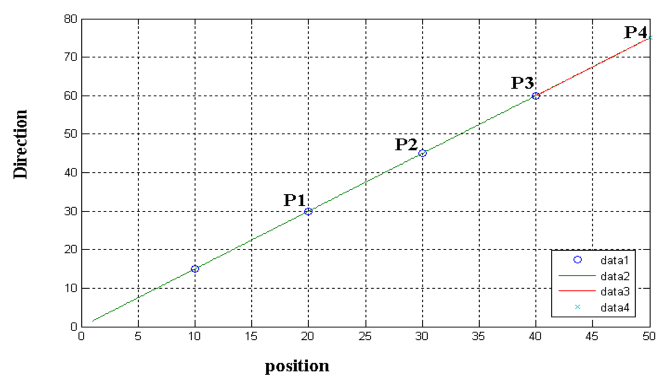

Figure 9: direction straight

6. 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.

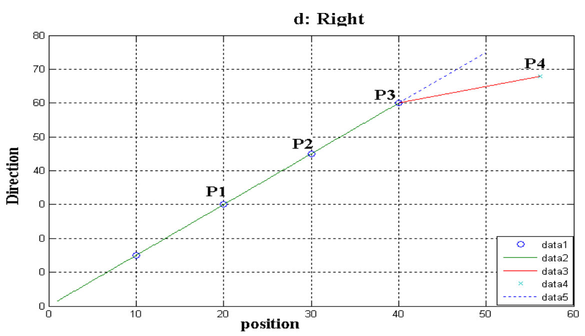

Figure 10-a : direction Right

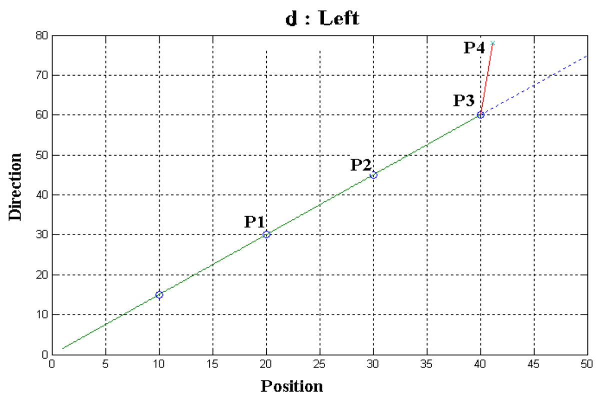

Figure 10-b: direction Left

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 given by:

$$\text{pdf} = \begin{cases} 0.5\cos(\alpha_0), & -\frac{\pi}{2} \le \alpha_0 \le \frac{\pi}{2} \\ & \text{otherwise} \end{cases} \qquad (5)$$

then

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

$$\text{pr}(\alpha 0) = \begin{cases} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} 0.5\cos(\alpha_0) = 1 \\ 0 \quad \text{otherwise} \end{cases}$$

If $-\theta < \alpha 0 < +\theta$

$$\Pr(\alpha 0) = \int_{-\theta}^{\theta} c\cos(\alpha_0) = 1$$

$$\Pr(\alpha 0) = [c\sin(\theta) + d] - [c\sin(-\theta) - d] = 1$$

$$\Rightarrow 2c\sin(\theta) = 1,\ c = 1/(2 * \sin(\theta))$$

$$\Pr(d\_right) = \int_{\alpha-\theta}^{\alpha} c\cos(\alpha_0) = c\,[\sin(\alpha) - \sin(\alpha - \theta)]$$

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

$$pr(d\_straight) = 1 - Pr(d\_right) - Pr(d\_left) \qquad (6)$$

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.

7. Numerical Results

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

Tan(α) = y/x =1.5 ➔ α = 56.3 ,suppose θ = 15

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%

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 increases the probability of straight direction movement increases and our estimation that the MN will go straight will be more accurate. Table2 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 11 and 12 summarize the previous results. From figure 11, 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 12 it is shown that as we change α and fix θ, the probability to go straight is the

Table 1: Probability of α, with θ= 15

θ	pr(d_left)%	pr(d_right)%	pr(d_straight)%
15	14.8296	22.1245	63.0458
30	11.0641	25.9255	63.0104
45	7.0069	29.9772	63.0160
60	2.4522	34.0665	63.4813
90	0.763	36.2266	63.0104

Table2: Probability of θ, with α = 56.3

α	pr(d_right)%	pr(d_left)%	pr(d_straight)
0	33.30138	33.3014	33.3972
20	32.7925	29.7936	37.4135
35	29.7935	24.7642	45.4422
50	24.76421	18.0472	57.1886
70	15.50955	7.2699	77.2205

highest probability and increase by increasing α. Also we conclude that probability to go right decrease as α increase and the same thing for going left but it decrease with a higher amount than going right.

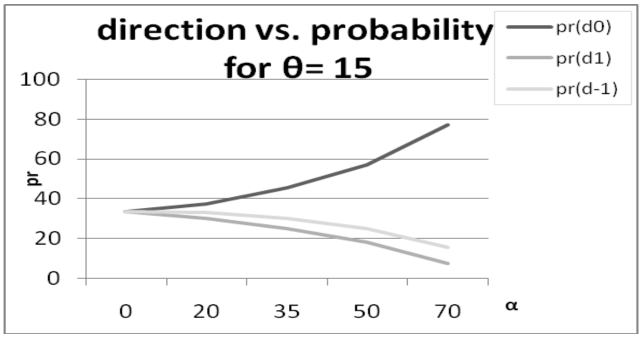

Figure 11: Probability direction of angle θ for α =563

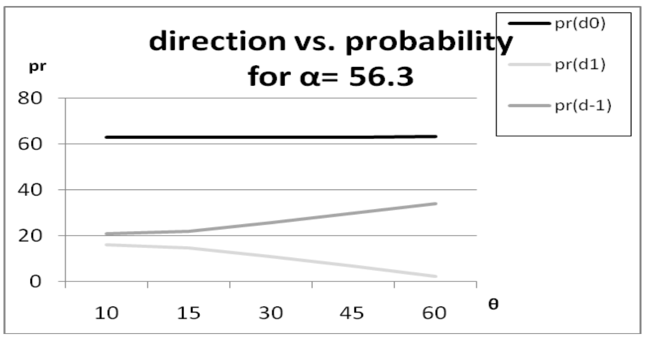

Figure 12: Probability direction of angle α for θ = 15

8. 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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