Pre-selection Algorithm of Access Points in a Handover Management Scheme

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***Abstract*—Recently, wireless networks and mobile terminals are rapidly evolving. Wireless networks are evolving towards heterogeneous overlaying environment, while the mobile terminals evolve towards having multi-interface functionality in order to face seamless service continuity. Traditional horizontal handover management schemes that mainly depend on signal strength for decision making are unable to fulfill ubiquitous and seamless mobility across heterogeneous networks. Vertical handover is more related to convenient criteria such as user preferences or application requirements. The use of location information in decision making would certainly enhance horizontal or vertical handover mechanisms by supporting optimized handover management. For that, using the location information and the mobile terminal movement can participate to a handover decision improving the handover execution procedure. For example, when a mobile terminal is moving with a certain velocity, it can perform handover execution uselessly that affects handover performance. This paper proposes and describes a pre-selecting access points algorithm in a location-aided handover management scheme in order to reduce unnecessary handovers in a moderate mobility scenario. It shows by simulation the feasibility of the proposed algorithm applied to a random mobility and a dense environment.**

***Keywords*–Handover management ; Location information ; Polar coordinates ; Access Points selection.**

I. Introduction

Handover management is the key aspect in the development of solutions supporting mobility scenarios. It is the process by which a Mobile Terminal (MT) maintains its connection active while moving from one point of attachment (access point or base station or access router) to another. Handover management issues include mobility scenarios, metrics, decision algorithms and procedures. Mobility scenarios can be classified into horizontal (between different cells of the same network) and vertical (between different types of networks, for example, Cellular Networks and Wireless Local Area Networks (WLAN)). In homogeneous networks, horizontal handovers are typically required when the serving access point becomes unavailable due to MT's movement. In heterogeneous networks, the need for vertical handovers can be initiated for convenience rather than connectivity reasons (e.g., according to user choice for a particular service).

Conventional handover management techniques consider usually the link quality parameters (received signal level, reliability, etc.) and user parameters. In low mobility scenarios, this solution is quite efficient because MT always selects the best access network according to link and service quality. However, when MT moves at a moderate speed, the frequency of handovers increases, and thus the time of connection to each cell decreases. Despite of the recent improvements in levels 2 and 3 handover technology, packet loss is always performed and therefore, a slight temporary service degradation can be observed in each handover executed. In a moderate mobility scenario, MT should choose the network or the cell that provides the maximum connection time, especially in a dense environment. Such choices would allow MT to remain over time in each cell and reduce the number of unnecessary handovers and thus service degradation. For that, a location-assisted handover can be used in such scenarios. More specifically, the location information can be added to the link quality parameters in the handover decision process performed before selecting the best access network.

In our paper, we propose the use of location information of moving MT and Access Points (APs) in the choice of the target AP for the handover process. According to several measurements of the MT's position over time, it is possible to estimate the direction of its movement. Furthermore, if this information is increased with its context (e.g., the user moves on a highway between two towns), it is possible to predict its future position. In this contribution, we only focus on an outdoor moderate mobility scenario in a way that high mobility has to consider more parameters such as cellular connectivity parameters. The cell type concerned by our proposal covers picocell (range of $\approx$ 200 m or less) or femtocell (range of $\approx$ 10 m) in cellular networks and WiFi hotspots cell (e.g., WiFi range of $\approx$ 100 m). In our scenario, thanks to the location information of each detected AP, it is possible to give more weight to the nearest APs of the MT's future position. These APs will be in the coverage of MT longer than those whose MT rolls away. Then, we can choose among APs in MT movement direction the one that gives the best link quality parameters thanks to a multi-criteria decision method. Each AP knows the position of its neighboring access points. This information can be obtained in two ways: (i) from agreements between operators, which provide the location of their access points; (ii) cooperation between users, which record the APs, their location and their Quality of Service (QoS) parameters. Location information can be collected with other technologies: Global Positioning System (GPS), Radio-Frequency IDentification (RFID), WiFi,

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Bluetooth, etc. In our paper, we gather location information from GPS as geographic/cartesian coordinates and we convert it to polar coordinates in order to pre-select the nearest APs in the MT movement direction.

Based on a location-assisted solution, we propose an intelligent handover management scheme. Our solution considers a pre-selection algorithm of access points, an important phase in our handover process in order to reduce unnecessary handovers that can affect handover performance in a moderate mobility scenario. After this phase, an access network selection can be processed based on user preferences. In this paper, we focus on the feasibility of our algorithm in a dense environment and with a random mobility by simulation results. Here, we define a dense environment as an area in which the APs are deployed such that MT always detects the overlapping of more than two APs.

Our paper is organized as follows. Section II presents the related work. Section III describes the whole handover management scheme. Section IV introduces the proposed algorithm for pre-selecting access points in the handover management scheme. Section V gives the simulation results. Finally, Section VI concludes our work.

II. Related Work

The handover management process is described in three phases [1][2][3]:
(1) the handover information gathering: used to collect all the information, through monitoring and measurements, required to identify the need for handover and to apply handover decision policies. It can be called also ”handover initiation” phase or ”system discovery”.
(2) the handover decision: used to determine whether and how to perform the handover by selecting the most suitable access network (taking into account some criteria such as user preferences) and by giving instructions to the execution phase. It is also called ”network selection” or ”system selection”.
(3) the handover execution: used to change channels and addressing conforming to the details resolved during the decision phase.

A handover management process can be enhanced by adding location information. Localization techniques use different technologies. GPS gives a more precise location information in outdoor environments. Signal quality based techniques such as the quality or a mapping of the Signal Strength (SS) received are used to estimate MT position. These techniques give a position with a margin of error of several meters. Otherwise, they can be useful and sufficient to deduce MT direction movement. Connectivity based techniques can also be used in a way that MT can estimate its position using the location of all the APs detected in its vicinity (i.e., intersection of all the APs coverage). Hybrid techniques use GPS and the cellular network (such as Global System for Mobile Communications (GSM)) for Assisted-GPS. Here, the cell coverage information is used to enhance the precision of the estimated location especially in poor satellite signal conditions.

In the literature, many works propose a location-based handover management process [4][5][6][7]. In [4], the authors propose a location-assisted handover (LAH) which is the use of position information to aid and optimize handover and interface selection decisions within the multimode MT. LAH supports more intelligent handover services that ensure optimized MT operation. They have developed a novel multimode MT architecture in order to realize LAH for such terminals. Depending upon velocity, direction and on-going traffic of MTs, it can estimate the time when a handover is needed. The authors proposed an architecture with no evaluation performance results. Otherwise, Yu et al. [5] shows that a proposed 3G-WLAN heterogeneous network handover algorithm based on location information has effectively reduced the number of handovers, limited the ping-pong effect, improved the handover performance compared to a traditional vertical handover. But, the simulation experiments were made only on two cells, one cell of 3G cellular network and one of WiFi hotspot and on an MT moving with a fixed velocity and direction. In the same cellular-WLAN scenario, Nielsen et al. [6] contribution performs two proactive handover decision algorithms by using movement prediction to determine the right time and the right place for a user terminal to handover. But, the authors do not give precision on the positioning system used in their solutions. For more accurate results, Folstad and Helvik [7] proposes a reliability model of a trajectory (defined as the series of APs) based on measurement reports and signaling from networks (i.e., extension of Media Independent Handover (MIH)) in order to find the optimal AP selection and handovers for a dual homed service.

GPS can be used in location-based handover solutions [8][9]. In [8], the handover latency is reduced by reducing the number of APs scanned by MT during the handover process by using GPS. It is a pre-authentication mechanism to the most potential selected AP in order to reduce the scanning delay. In [9], another scheme is based on a GPS pre-selective scanning to reduce the scanning delay which is 90 percent of whole handover delay.

Other works proposed handover algorithms considering MT movement in low to moderate mobility scenario. Jeong et al. [10] exploits a mobility prediction scheme with a relatively low velocity in order to propose an optimized handover decision algorithm in hierarchical femto/macro cell networks. Dam et al. [11] proposes a vertical handover algorithm considering the user movement prediction, energy consumption and QoS parameters for the end-to-end connections. It considers a peer-to-peer scheme in a WLAN connection between devices and a server bounce mechanism. Both works [10][11] use a centralized component such as a server to gather terminal mobility and network related information.

Our proposal is based on a location-aided handover management. It does not use the location information to estimate the right time to handover like in [4] (i.e. that is fulfilled by the handover initiation), but to do the right handover by pre-selecting the candidate APs in MT movement. Our solution collects the location information related to MT trajectory like in [7] and uses it to calculate the speed and the direction. Our experiments were made on a coverage of various cells with a random movement but not only two cells compared to [5] that fixed the speed and the direction values. For that, it uses a GPS like in [8][9] but the location information is integrated in a more sophisticated handover management scheme. We give more intelligence to our handover management scheme like the works in [10] and [11] but without a centralized component to store location information.

III. Our Handover Management Scheme

Our handover management scheme is composed of four phases :

(1) Handover initiation,
(2) Pre-selection of access points,
(3) Multi-criteria handover decision for network selection,
(4) Handover execution.

First of all, we need to collect all the necessary handover criteria such as the phase defined previously (Section II). These latter are required to be context-aware in the sense that it should be conscious of possibilities offered by each access network, MT movement and QoS requirements for the demanding service. In traditional handover decision, only one criteria is used, the Received Signal Strength (RSS). For a vertical handover decision, it is not sufficient. Context information are relevant in a way that they are useful enough to avoid false decisions, therefore, bad performances. They can be relative to the network, the terminal, the service and the user. Here, we group it into two parts as in [12]: all the information related to the network on one side and all the information that may exist at the terminal on the other side. There are: (i) *Network context*: QoS parameters (bandwidth, delay, jitter, packet loss), Coverage, Monetary cost, AP location information ; (ii) *Terminal context*: User preferences, Service capabilities (real-time and non real-time), Terminal Status (battery and network interfaces), Priority given to interfaces, Location information (velocity, direction).
The third phase concerns the selection of the best available network. This phase is aided by the second phase which reduces the number of target access networks in order to avoid the ping-pong effect (i.e., number of unnecessary handovers). These two phases can be defined as the handover decision phase as defined in Section II. The pre-selection phase is more related to the MT movement (slow, moderate or high mobility).

Our handover management process is given in Figure 1, highlighting the pre-selection phase concerned by this paper. Our process begins with the handover initiation (*Phase (1)*). It is mainly based on connectivity criteria in a way that performs if a handover is needed or not. While MT uses a running application and a handover is needed due to connectivity reasons, a phase of pre-selection of access points (*Phase (2)*) is triggered according to the location information (velocity, direction, position). The decision to initiate a handover to the best access point or network among those pre-selected according to user preferences is performed at the *Phase (3)*. Here, we consider a decision in which all the available alternatives (access points or networks) have to be evaluated according to given objectives. For that, the AHP (Analytic Hierarchy Process) method is used to assign scores to these networks (network scores). It carries only the calculation of the final decision, *Decision Making*, when all parameters (scores) are already available. Before applying it directly, two steps must be performed: (i) assigning scores to criteria, *Criteria Scoring*, a pre-configuration step in which the importance of each objective is evaluated according to user preferences; (ii) assigning scores to networks, *Scoring Network*, where available networks are evaluated and compared according to each objective. The last phase is the handover execution (*Phase (4)*) that establishes the IP connectivity through the selected

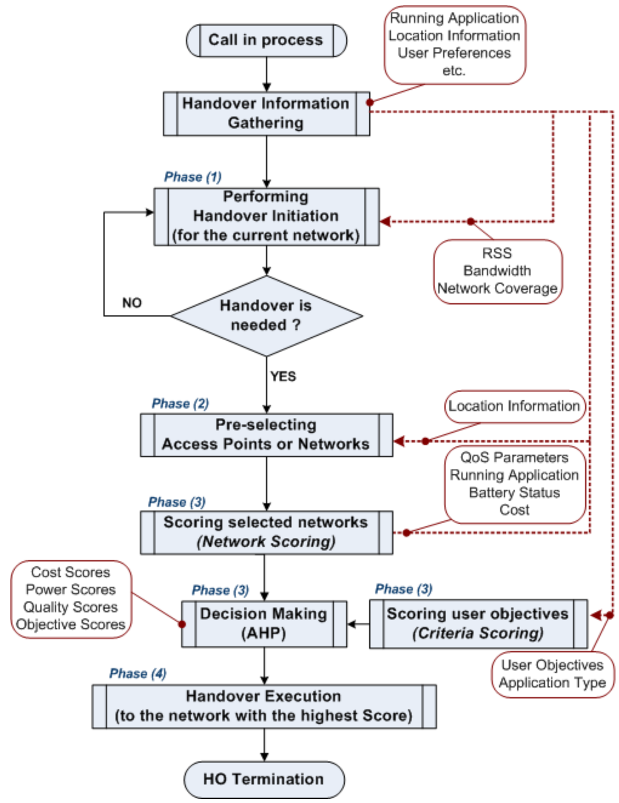


Figure 1. Our Handover Management Scheme

access network. Details on the phases 1, 3 and 4 are given in [12].

IV. Our AP pre-selection Algorithm

Our pre-selection algorithm has to retrieve the location information given by GPS and to convert the coordinates in order to compute an area of selected APs according to the direction and the velocity of MT movement.

A. Location information gathering and processing

Before any processing, we have to retrieve the MT position. This latter can be obtained via GPS that gives geographic coordinates (longitude, latitude and elevation in degrees). For more simplicity, these coordinates have to be converted to cartesian/geocentric coordinates (x, y, z in meters) such as in [13]. Once MT position obtained, we have to define periodically the MT velocity and direction. These two parameters are computed by the equations 1 and 2.

$$v = \frac{\sqrt{(x_{k-1} - x_k)^2 + (y_{k-1} - y_k)^2 + (z_{k-1} - z_k)^2}}{\Delta t} \quad (1)$$

$$\overrightarrow{\alpha} = arctan\left(\frac{|y_{k-1} - y_k|}{|x_{k-1} - x_k|}\right) \quad (2)$$

Here, the indexes k and $k-1$ are the last two successive samples of location information (the most recent values) between two times t_{k-1} and t_k. Δt is the sampling period. These parameters are computed in order to allow a periodic update of MT velocity and direction. In order to choose Δt value, we have to consider the transmission period of the beacon message. The beacon is a frame transmitted periodically by an AP to announce the presence of a wireless access network containing all the necessary information such as the beacon interval, SSID or the supported data rates. The default value of the beacon interval is $0.1sec$. Because GPS data is updated every second, it is more advisable to choose one second for Δt.

MT receives the location information of all APs that surround it. Once APs localized, the algorithm converts the cartesian coordinates of all detected APs into polar coordinates. Here, each AP can be characterized by a distance (d) and an angle (α). These two parameters allow to localize the APs in a coordinate system whose origin is MT. The distance and the angle between MT and AP are given by the equations 3 and 4.

$$d = \sqrt{(x_{MT} - x_A)^2 + (y_{MT} - y_A)^2 + (z_{MT} - z_A)^2} \quad (3)$$

$$\alpha = arctan\left(\frac{|y_{MT} - y_A|}{|x_{MT} - x_A|}\right) \quad (4)$$

where x_{MT}, y_{MT} and z_{MT} are the cartesian coordinates of MT and x_A, y_A, z_A are those of an access point A.

B. Pre-selection algorithm description

According to the location information as polar coordinates obtained in the previous section, the pre-selection algorithm restricts the set of the available access points to which MT can connect. It selects only the access points in MT's direction (limited by an angle of tolerance X). If we consider A as a set of the available access points, the pre-selection consists of getting a sub-set A^* defined by :

$$A^* = \{(d_i, \alpha_i) \in A | \overrightarrow{\alpha} - X \leq \alpha_i \leq \overrightarrow{\alpha} + X\} \quad (5)$$

where the couple (d_i, α_i) is the distance and the angle of the pre-selected access point i. The vector $\overrightarrow{\alpha}$ represents the MT direction and X is the tolerance angle. An AP is selected if it is in MT proximity, it means that it has to belong to the area limited by the tolerance angle X. The selection is given at the Figure 2 where the stars are the selected access points and the squares are the rejected ones.

We have to consider some criteria in order to determine the tolerance angle in AP selection. The criteria that have to be satisfied are :

- An AP has to be in the coverage area of MT movement.
- The number of candidate APs has to exceed a minimum threshold ($Min\_threshold$). If the number of the candidate APs is under the value 2, our algorithm is not useful. The handover will be executed to the unique available AP.
- The number of selected APs does not exceed a maximum threshold ($Max\_threshold$).

We notice that the conversion to the polar coordinates system can be imprecise in a way that the computing is realized every Δt seconds. The precision can be increased while Δt is decreased. Therefore, we can increase the location information precision by relaxing our method constraints, i.e., by increasing the tolerance angle X in order to select more candidate APs. In this case, the disadvantage of our method will be the time calculation and a high number of possible handovers.

In order to propose a precise AP pre-selection algorithm that fulfills the mentioned criteria, we opt for this process :

(1) A first selection is based on APs position. We choose the APs in the coverage area of MT at the time t_k. It means that we initialize the tolerance angle to $X = 90°$. We choose this X value because we have to consider the maximum value of the available APs that can be detected in MT direction. We obtain a first subset A^* as given in the Figure 2(a).

(2) A second selection has to limit the number of preselected APs in order to be comprised between the two fixed thresholds. For that, we have to eliminate the farthest APs until obtaining a number of APs in the interval $[Min\_Threshold, Max\_Threshold]$

In the second selection of our process, here are the steps to obtain the final number of pre-selected APs.

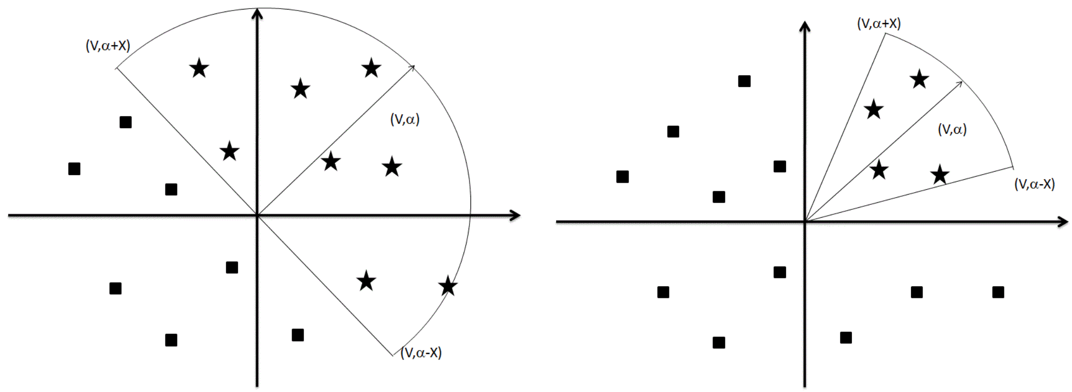
- X takes the value of the angle of the farthest selected AP from MT. If the number of APs in the set A^* are not included in the $[Min\_Threshold, Max\_Threshold]$, we eliminate this AP. After the change of the set A^*, we affect to X the value of the angle of the farthest AP.
- This first step will be repeated until we obtain a number of APs less or equal to $Max\_Threshold$. We notice that we can face the case in which two APs are symmetric according to MT, i.e., one AP has an angle $\alpha_i = \alpha_T + X$ and the other $\alpha_i = \alpha_T - X$. Here, we have to choose to eliminate one of them and keep the other.
- Finally, we can decrease the value of the $Max\_Threshold$ in order to obtain a more precise pre-selection if MT velocity is very high. As we mentioned previously, the precision is closely related to the final value of the tolerance angle X. In our work, we choose a value of $Max\_Threshold$ equal to 5. This value is sufficient in a way that we will get enough access points to perform a network selection for convenience reasons (i.e., according to user preferences).

Figure 2(b) gives the result of the second pre-selection for an interval $[Min\_Threshold, Max\_Threshold] = [2, 4]$.

The different steps of AP pre-selection are summarized in Algorithm 1.

Algorithm 1 AP Pre-selection algorithm

1. Retrieving MT position (x, y, z)
2. Computing MT direction ($\overrightarrow{\alpha}$) and velocity (v)
3. Converting each available AP $\in A$ coordinates into polar coordinates (d, α)
4. Defining $A^* = \{(d_i, \alpha_i) \in A | \overrightarrow{\alpha} - X \leq \alpha_i \leq \overrightarrow{\alpha} + X\}$
5. First selection: $X = 90°$
selecting the candidate APs in the coverage area of MT direction.
6. Second selection:
repeat Evaluating A^* with $X = X_{farthestAP}$
if $\alpha_{iM} = \alpha_t + X$ of an access point M and $\alpha_{iN} = \alpha_t - X$ of an access point N **then** M or N is eliminated.
until $N_{selectedAPs} \in [Min\_Threshold, Max\_Threshold]$



(a) First Selection (b) Second Selection

Figure 2. Our AP pre-selection process results

V. Simulation Results

In this paper, we focus our work on the feasibility of our pre-selection algorithm in a specific scenario. In order to evaluate our proposed algorithm, we use a Java-based event-driven simulator. We choose SIDnet-SWANS (Simulator and Integrated Development Platform for Sensor Networks Applications), a project developed by the Electrical and Computer Engineering department of Northwestern University [14]. SIDnet-SWANS is the GUI (Graphical User Interface) implemented in Java of the network simulator JIST/SWANS. JIST (Java in Simulation Time) is a discrete event-driven simulation environment and SWANS (Scalable Wireless Ad hoc Network Simulator) is the extension to simulate wireless ad hoc networks. JIST/SWANS has the same functionalities as the network simulator NS2 or GloMoSim (Global Mobile Information System Simulator). In our simulation scenario, MT (a node represented by a black point) has a random mobility in which the new position and the velocity are computed using a random direction. The cell coverage used concerns the same type of nodes. We used IEEE 802.11 MAC and PHY layers for each node. The AP/nodes are randomly deployed in a square simulation area of $1000 * 1000$ m.

Our simulation results are presented in the next Figures 3, 4, 5 and 6. In the simulation tests represented by Figure 3 and 4, we use 100 AP/nodes in order to highlight the two selection phases of the proposed AP pre-selection process. Firstly, MT direction and velocity are determined according to its initial position (represented by the black point). The pink point represents the MT current position. Secondly, our implemented algorithm pre-selects the candidate APs in the coverage area of MT movement (represented by the green points) using the tolerance angle $X = 90°$ (see Figure 3). Finally, it selects a fixed number ($Max\_Threshold = 5$) of APs (represented by the yellow points) while reducing the tolerance angle ($X = 15°$) until it answers the second selection criteria (see Figure 4). In Figure 5, we see that when the number of deployed AP/nodes is reduced (equal to 30 nodes), the tolerance angle is adapted to $X = 45°$ to respect the $Max\_Threshold$. If we reduce more the number of deployed AP/nodes until 10 nodes, the first selection criteria are matching the second selection criteria (see Figure 6).

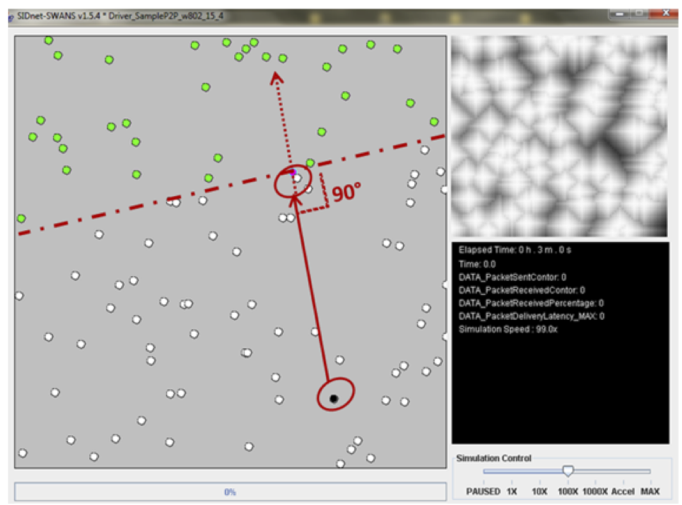


Figure 3. First Selection ($X = 90°$)

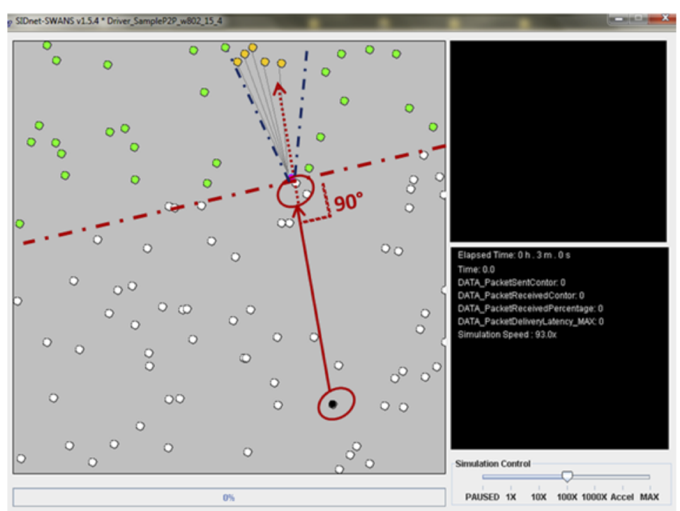


Figure 4. Second Selection ($X = 15°$)

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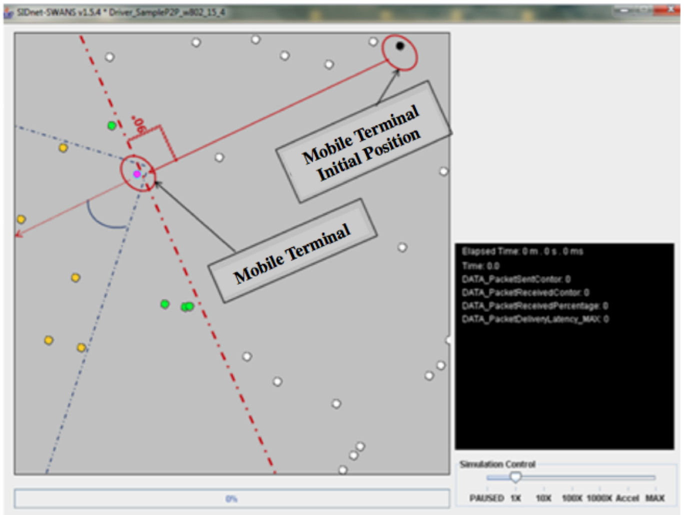

Figure 5. Second Selection ($X = 45°$)

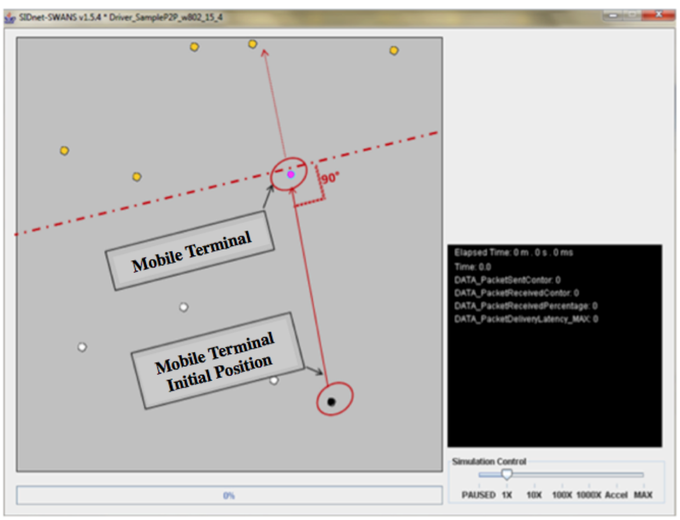

Figure 6. 1^{st}Selection Criteria = 2^{nd} Selection Criteria

VI. Conclusion & Future Work

In this paper, we proposed a pre-selection algorithm of access points in an intelligent handover management scheme. Our proposal converts cartesian coordinates of MT and the APs in MT coverage to polar coordinates in order to retrieve APs position in MT direction. It selects a fixed number of candidate APs according to a tolerance angle that can be reduced until we obtain a minimum value. We showed that our algorithm is feasible in a dense environment and with a random mobility. It will be interesting to test this algorithm with another existing type of mobility, implemented in JIST/SWANS, such as STRAW (STreetRAndom Waypoint) that provides more accurate simulation results by using a vehicular mobility model or GMMM (Gauss-Markov Mobility Model). Here, we can also consider different types of cells (macrocell) for high mobility scenario. Hence, it will be interesting to analyze the mobile speed effect on MT connection time to the network. Our algorithm is involved in a location-assisted handover. It helps the network selection phase in a way that it selects the candidate APs (i.e., access networks) according to MT movement (i.e., direction and velocity). Such a location-assisted handover can reduce the ping-pong effect (i.e., the number of unnecessary handovers) and therefore, a better handover can be performed. More simulation results will be proposed in a near future work that integrates the implemented algorithm to the proposed handover management scheme. Hence, the handover performance of our scheme will be compared to traditional vertical handover management schemes such as RSS or Bandwidth based vertical handover decision schemes. In a future work, we intend to add to our outdoor solution (using GPS) an indoor localization-based solution using WiFi or femtocell coverage.

References

[1] P. Chan, R. Sheriff, Y. Hu, P. Conforto, and C. Tocci, “Mobility Management Incorporating Fuzzy Logic for a Heterogeneous IP Environment,” IEEE Communications Magazine., vol. 39, no. 12, December 2001, pp. 42–51.

[2] H. Wang, R. Katz, and J. Giese, “Policy-enabled Handoffs across Heterogeneous Wireless Networks,” Second IEEE Workshop on Mobile Computing Systems and Applications, 1999. Proceedings. WMCSA’99., February 1999, pp. 51–60.

[3] M. Kassar, B. Kervella, and G. Pujolle, “An overview of vertical handover decision strategies in heterogeneous wireless networks,” Computer Communications, vol. 31, no. 10, 2008, pp. 2607–2620.

[4] T. Ahmed, K. Kyamakya, M. Ludwig, M. Schielein, S. McCann, E. Hepworth, and A. Surtees, “Location-assisted handover for multimode mobile terminals,” Proc. of the IEEE/ACM Euro American Conference on Telematics and Information Systems (EATIS), February 2016.

[5] Q. Yu, W. Jiang, and Z. Xiao, “3g and wlan heterogeneous network handover based on the location information,” International Conference on Communications, Circuits and Systems (ICCCAS), vol. 2, 2013, pp. 50–54.

[6] J. J. Nielsen, T. K. Madsen, and H.-P. Schwefel, “Location assisted handover optimization for heterogeneous wireless networks,” 11th European Wireless Conference 2011-Sustainable Wireless Technologies (European Wireless), 2011, pp. 1–8.

[7] E. L. Folstad and B. E. Helvik, “Reliability modelling of access point selection and handovers in heterogeneous wireless environments,” Design of Reliable Communication Networks (DRCN), 2013 9th International Conference on the, 2013, pp. 103–110.

[8] D. Sarddar, J. Banerjee, T. Jana, S. K. Saha, U. Biswas, and M. Naskar, “Minimization of handoff latency by angular displacement method using gps based map,” International Journal of Computer Science Issues (IJCSI), vol. 7, no. 3, 2010, pp. 29–37.

[9] D. Sarddar, J. Banerjee, J. G. Chowdhury, R. Jana, K. K. Nundy, U. Biswas, and M. Naskar, “Reducing handover delay by pre-selective scanning using gps,” International Journal of Distributed and Parallel systems (IJDPS), vol. 1, no. 2, 2010.

[10] B. Jeong, S. Shin, I. Jang, N. W. Sung, and H. Yoon, “A smart handover decision algorithm using location prediction for hierarchical macro/femto-cell networks,” IEEE Vehicular Technology Conference (VTC Fall), 2011, pp. 1–5.

[11] M. S. Dam, S. R. Christensen, L. M. Mikkelsen, and R. L. Olesen, “Location assisted vertical handover algorithm for qos optimization in end-to-end connections,” IEEE 11th International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom), 2012, pp. 1632–1640.

[12] M. Kassar, B. Kervella, and G. Pujolle, “An intelligent handover management system for future generation wireless networks,” EURASIP Journal on Wireless Communications and Networking, vol. 2008, 2008, p. 6.

[13] “Transformation geographic to geocentric,” http://www.ngi.be, last access 14/04/2016.

[14] O. C. Ghica, G. Trajcevski, P. Scheuermann, Z. Bischof, and N. Valtchanov, “Sidnet-swans: A simulator and integrated development platform for sensor networks applications,” 2008, pp. 385–386.