The Enhancement of Handover Strategy by Mobility Prediction in Broadband Wireless Access

Ardian Ulvan, Melvi Ulvan, Robert Bestak
Department of Telecommunication Engineering
Czech Technical University in Prague
Prague, 166 27, Czech Republic
ulvanard, ulvanm1, bestar1[@fel.cvut.cz]

Abstract

The IEEE802.16m provides data rates of 100 Mbps for mobile applications and 1 Gbps for fixed applications. The standard also supports high speed mobility. As a consequence, the very frequent handovers will occur. Since the system requires the very small handover interruption time (i.e. 30 ms), handover becomes a critical issue. In this paper, we consider the prediction of user's mobility to enhance the handover strategy for broadband wireless access based on IEEE802.16m. Two handover strategies, i.e. proactive and reactive handovers, are proposed. Proactive handovers tends to trigger handover before the complete loss of the origin cell signal. On the other hand, the reactive handover tends to delay handover as much as possible, so it seems effectively minimizing the number of handover. Based on our performance model and analysis, we examine the effectiveness of mobility prediction results to minimize the interruption time of handover on both handover strategies.

1. Introduction

1.1 IEEE 802.16 Wireless Broadband Systems

Wireless broadband communications system has seen a fast growth in the last years. The number of wireless user has already exceeded the number of wired line. Wireless systems have the capability to address broad geographic area without the costly infrastructure deployment. However, the main drawback resides in the bandwidth limitations and the coverage for single access point, hence the efficient utilisation of wireless network capacity is the objective of ongoing research activities.

Third generation cellular systems (3G) are rapidly spreading all over the world with the purpose to extend the service provided by the second generation cellular networks (2G). The system architecture is mainly circuit-oriented, hence voice traffic, real-time messaging and streaming are services that can be provided by means of this technology. However, they have a complex network structure and need various protocols to cover the entire system. Accordingly, the next generation wireless network or fourth generation wireless (4G) is designed to have a simple structure which based on all internet protocol (all-IP).

The performance limitations of conventional cellular wireless networks in terms of throughput and coverage are by now well recognised. IEEE 802.11 WLAN is the system that reaches the throughput of 54 Mbps, however it has limitation on service coverage. On the other hand, the network cellular has a wider coverage but has a limited cell throughput of 2 Mbps.

The foremost candidate for 4G technology is based on standards 3GPP Long Term Evolution/Long Term Evolution-Advanced (3GPP-LTE/LTE-A), IEEE802.16 and ETSI/HIPERMAN, known as WiMAX. The standards are still under developing for particular purposes.

The IEEE 802.16, at the initial stage of development, was aimed at providing high-speed Internet access in a Point-to-Multipoint (PMP) manner only. The support of Quality of Service (QoS) was embedded since the first release, which clearly stated the role of IEEE 802.16 as a leading technology for the support to advanced multimedia applications. However, Line-of-Sight (LOS) was required, because the air interface of the 2001 release was based on Single Carrier (SC) at very high frequencies, i.e. above 11 GHz [1]. This constraint could severely affect the dissemination of the technology, since it significantly increased the cost of setup of both the Base Station (BS) and Subscriber Stations (SSs).

Thus, during the subsequent years the standard has been amended so as to include support to mesh non-LOS deployment, the version that support PMP and Mesh topologies being published in 2004 as IEEE 802.16d [2]. The standard is for fixed wireless installations, it promotes bandwidths of 70 Mbps or 2-10 Mbps/user covering up to 10 Km^2 [2][1]. The standard defines both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) for channel allocation. Both channels are time slotted and composed of frames. The TDD frame composed of downlink and uplink sub frames. The duration of each of these frames can be controlled by BS whenever needed. Downlink channel is

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[1] There are assertions of up to 50 Km coverage, but these are considered highly theoretical.

broadcast channel. BS broadcast data to all SS on downlink channel. SSs accept only those packets which are destined to it.

The subsequent mobility amendment, IEEE 802.16e [6], adds support for nomadic roaming at vehicular speeds. Data rates are envisioned at 2-3 Mbps/user for portable and 1-2 Mbps/user when mobile, covering an area of 5 Km and the maximum bandwidth is up to 20 MHz. The 802.16e standard goes a step further with Orthogonal Frequency Division Multiple Access (OFDMA) [11][14], a variant of OFDM, which has the ability to assign a subset of the carriers to specific users. It is the latest 802.16 standard version which is already published.

The next version that still under finalization is 802.16j Multihop Mobile Relay (MMR) and the upcoming version of 802.16m Advance Air Interface which support the bit rate of 100Mb/s for mobile application and 1Gb/s for fixed application to fulfill the IMT-Advanced requirements (ITU-R M1645) [17]. It is clear that reaching Gbps peak throughput requires a higher spectral efficiency and much larger bandwidth. The total spectrum needed by pre-IMT-2000, IMT-2000 and IMT-advanced systems by year 2020 is estimated to range between 1.2 GHz and 1.7 GHz in (ITU-R M2078) [8].

1.2 Handover in IEEE802.16's MAC Functionalities

Handover is an integral part of all mobile wireless systems. Continuous connection during user movement among cells is allowed due to handover procedure, but on the other hand, the handover brings a significant increase of Medium Access Control (MAC) overhead and also causes an increase in delay of packet delivery to the destination user [16].

The handover procedure is introduced in the version of IEEE802.16e [6]. Based on the emerging 802.16j proposals, it is very probable that in the next versions of WiMAX recommendations (IEEE 802.16j, and IEEE 802.16m) will be defined the same types of handovers. Moreover, the general principles (with regards to the requirements of new standards) of handover will be adopted from 802.16e.

According to [6], the handover procedure can be divided in two stages (see Fig. 1). Stage that is executed before handover, called ***Network Topology Acquisition,*** contains network topology advertisement and Mobile Station (MS) scanning. In this stage, the MS investigates and collects information about neighborhood base stations of its Serving BS. During the scanning phase, the MS seeks a suitable handover to the target BS or Relay Station (RS) that are suitable to be added to the Diversity Set. The Diversity Set is a list of the BSs/RSs, which are involved in the handover procedure in case of Macro Diversity Handover (MDHO) or Fast Base Station Switching (FBSS).

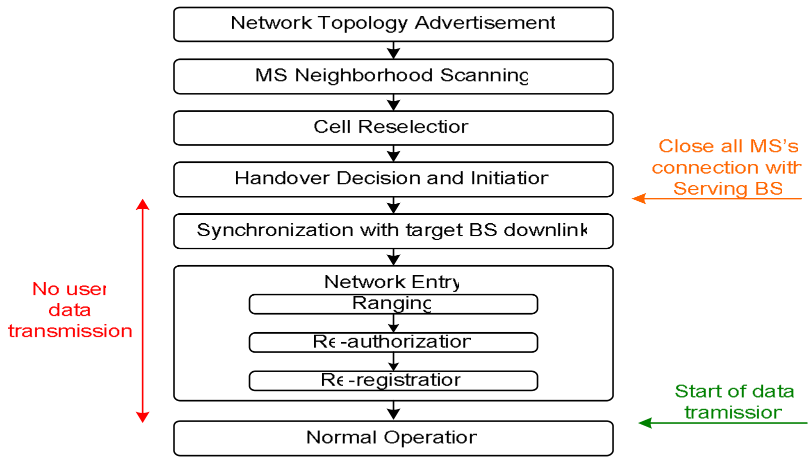


Fig.1. Two stages of Handover Procedure based on IEEE802.16e

The scanning is realized in the "scanning intervals" which interleave the normal operation of MS. Once the scanning phase is completed, the MS sends results to its serving BS. The reported results can be delivered by two report types. The first one is "event trigger report", in which MS sends reports based on a defined trigger, such as carrier-to-interference-and-noise ration (CINR), receive signal strength indicator (RSSI), relative delay, or round trip delay (RTD). In this type of report, the measurement report is sent to the Serving BS after each measurement case. In the second type of report, "periodic report", the MS sends reports periodically.

The results of scanning are used in the next stage of handover procedure called Handover Process. The first step is cell reselection. In this step, possible target BS is selected based on signal quality and offered QoS. Then, handover decision and initiation process can be initialized if all conditions and requirements for handover are met follow. The first step of handover process is ended by performing the synchronization to the new Target BS. However, before the synchronization is done the connection(s) to the serving BS has to be closed first.

As soon as the downlink synchronization is done, the MS can start the next step of handover: network re-entry procedure. The network re-entry consists of three substeps i.e. ranging, re-authorization and re-registration. In the ranging process the MS obtains information about uplink channel via Uplink MAP (UL-MAP) and Uplink Channel Descriptor (UCD) messages. The Ranging is followed by authorization and registration of MS to the target BS. After successful authorization and registration to the target BS, the MS can start normal operation.

In IEEE802.16 system all handover processes mentioned above are represented by transfer of communication among all entities (MS, serving BS and target BSs) in form of exchanging a set of Medium Access Control (MAC) messages. Fig. 2 shows the exchanges of MAC management message in the handover procedure.

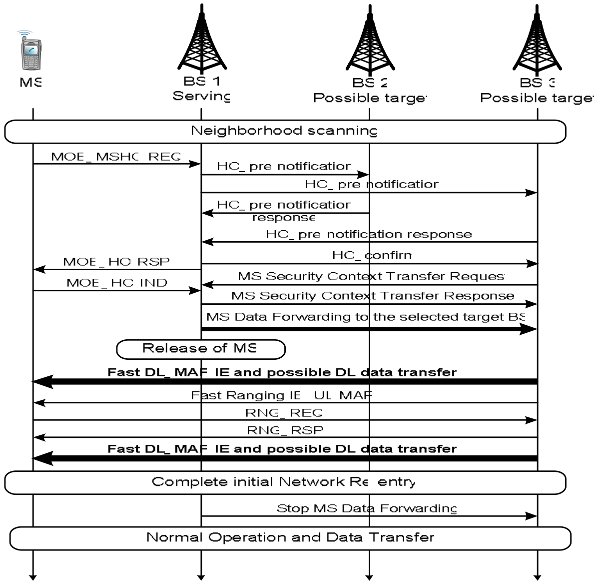


Fig.2. MAC Management Message exchanges within the handover

1.3 Issues in IEEE802.16's Handover process

In network topology acquisition stage, in fact, there is only one BS that can be selected as target BS for handover. In addition, the result obtained from the scanning process may become invalid because of the changing of neighbour BS's channel quality. Consequently, if the scan or association process occupies too many resources, the throughput significantly decreases. Furthermore, the standard does not clearly state the scanning time. If the scanning is not done

with proper timing, channel condition of neighbour BSs may be changed. That would make the scanning process results useless.

In addition, since the high speed of user mobility is supported in 806.16m, it seems the system will facing, the very frequent handover which mean the system overhead (i.e. the interruption of data transfer) due to handover will increase significantly.

In [17] we focused the analysis on scanning time and handover interruption time in network topology acquisition stage. Based on our analysis, there are some inefficient issues in 802.16e's handover procedure which is critical for 802.16m. These are redundant scanning and association process of neighbour BSs. Additionally, the defined handover strategies also contribute the overhead in handover procedure. The results suggest using the scanning process without association since it has the lowest scanning time. In addition, the handover with the fast ranging and pre-registration is favorable since it has the lowest interruption time.

The analysis of an efficient handover strategy for IEEE802.16 systems have also been carried out in several scientific papers. The fast handover in IEEE802.16e is analyzed in [18]. The single neighbor BS scanning, fast ranging and pre-registration have been proposed to reduce the handover time. To decrease hard handover, the authors in [3] propose handover modification that makes possible to receive downlink data just after synchronization with downlink channel of the target Base Station (BS). This is achieved by introducing a new MAC management message – Fast DL_MAP_IE message, which describes the fast downlink access definition in system's information element. This message is used for transmission of emergent packet (packet with payload of delay sensitive services) by target BS to mobile station (MS). In [9], the collision of connection identifiers (CIDs) in the target BS is solved by employing transport CID mapping scheme that increases the handover performance. The authors also introduce Passport handover to decrease the hard handover delay.

In this paper, we consider the prediction of user's mobility to enhance the handover strategy for broadband wireless access based on IEEE802.16m. The mobility prediction will be based on the path position prediction of the users (MSs). The Markov chain random movement modeling is used to predict the probability of user's next positions. Based on the results of user's mobility prediction, we propose two handover strategies, i.e. proactive and reactive handovers. These two strategies are used to analyze the characteristic of user's movement and to examine the handover's interruption time of the system.

The organization of this paper is as follows. In section 2 we describe the prediction of handover based on various methods. In addition, we also express the proposed handover strategies. In section 3 we propose a mobility prediction based on markov chain random movement modeling and analyze our performance model. In section 4, we investigate the prediction performance through numerical studies, and discuss the results in both handover strategies. In section 5, we give our conclusions.

2. Prediction of Handover

Knowing in advance where a MS is heading allows the system taking proactive measures, so, the unexpected impact of handovers can be mitigated.

2.1 The S-MIP Architecture

Mobility prediction often involves examining how the MSs physically move. The Seamless handover architecture for Mobile IP (S-MIP) architecture is quite typical [5]. In S-MIP, the handover is initiated by the MS which observes a poor connectivity. It informs the serving BS that it should change its current connection to other BS. It assumed that the serving BS is able to determine the next target BS based on information provided by both the candidate target BS (via backbone) and the MS it self.

The reported signal strengths are used to determine the location of the MS using a triangulation technique, more specifically, the MS is supposed located at the intersection of circle centered at BSs and whose radius is given by signal strength measurements.

Fig. 3 shows the position possibility of MS in multicells environment:

Zone I : The MH is not likely to perform a handover since it only has contacts with one BS.

Zone II : A triangulation cannot easily be done since only two BSs are reachable. The MS is known in the intersection position of two circles at two distinct points. In S-MIP, that those two points must be next to one another, or one of them can be discarded.

Zone III : The MS position can easily be found using a triangulation based on the three received signal strength.

Once the MS position has been determined, the serving BS tries to see if:

- the MS should not perform a handover,
- the MS is moving linearly towards another BS and should perform a handover,
- the MS is moving stochastically near the border of the zone covered by current serving BS.

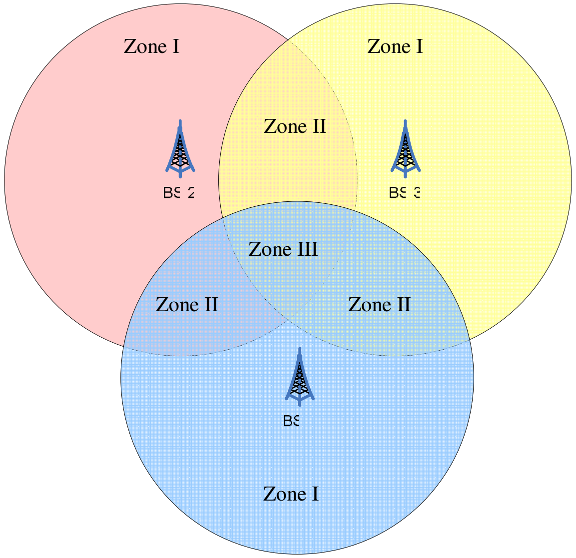


Fig. 3. Positioning based on S-MIP

The point of determining the counter-measures are likely to be different for each case. If the MS moves linearly, the handover can take place. On the other hand, if the MS moves stochastically, the target BS cannot reliably be determined yet, and the MS should stay connected to more than one BS until the serving BS decide to which target BS the MS should be attached.

2.2 Position-based Path Prediction

Knowing the position and velocity of a MS obviously can help to guess where it is heading for. The monitoring of the MS's current trajectory can be done by using GPS equipments [15] or some form of positioning method based on multilateration i.e. measuring the signal's Time Difference of Arrival (TDOA) at the neighbouring BSs, or triangulation [13].

In this prediction method, it has been assumed that the MS is moving and able to regularly send its physical position the serving BS (let say, every 1s). Each BS maintain a database of the roads within its coverage are (this information can be extracted from a digital map service). Each road is supposed linear (bends are approximated by linear segments). The BS records the average time taken to transit each road, the probability of transition from one segment to the next is modeled as a second-order Markov process. As can be shown in Fig. 4 Fig. 4, once the MSs arrives at the *E* junction, the BS computes the probabilities that MS1 and MS2 continue their way towards *D* or *F*. Since the last two roads they followed are different <*CB, BE*> and <*AB, BE*>, those probabilities are estimated independently.

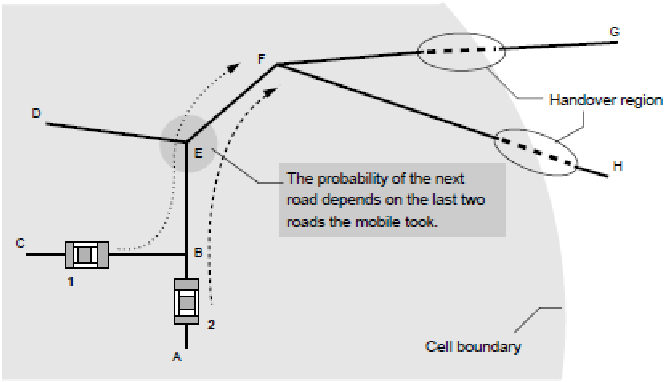


Fig. 4. Position-based prediction using road topology information

The handovers of all MSs are monitored continuously, so the roads where handovers usually appear can be flagged. Using those pieces of information, the likely path of a MS can be estimated in advance, so both the handover probability and the time remaining before this handover can easily be derived.

2.3 Handover Strategies

Work on handovers in wireless network has been going extensively. Most of the researches are in the field of cellular network and done by the mobile operators focused on network-controlled horizontal handover where handover is executed between adjacent cells of the same network. In term of IP-based wireless network, the handover research done typically in wireless local area network (WLAN) based on WiFi IEEE802.11.

With the introduction of WiMAX IEEE802.16 networks, 3GPP LTE/LTE-A as well as Mobile IPv4/IPv6, the client-based handover began to be investigated. In addition, the inter-system handover or vertical handover is going investigated intensively. The research in both L1 (physical) and L2 (MAC) is undertaken in order to achieve the most efficient handover and reduce the handover overhead.

In this paper, we focus on the handover in IEEE802.16 network. The options basically are network-controlled handover in which the decision to implement handover is taken by the BS to which the MS is currently attached. However, the standard also support the client-based handover in which initiate by the MS. This option gives the handover process in 802.16 more efficient, since any changing of necessary parameters or events (such as signal strength, coverage, the quality of service provided by the network, etc.) can be monitored by the MS from its wireless interfaces, then use them to decide to trigger the handover.

There are several possibilities of handover strategy that can be implemented in term of event used to trigger the handover. In general, it can be distinguished into two main strategy categories, i.e. proactive handover and reactive handover.

2.3.1 Proactive handover

Proactive handover strategy attempt to know the condition of various networks at a specific location before the MS reaches that location. In this strategy the MS is allowed to calculate the time before handover, and tends to trigger handover before the complete loss of the origin cell signal, for example, when the new cell Received Signal Strength Indication (RSSI) overpasses the origin one. So, it may minimize packet loss and latency experienced during handover.

2.3.2 Reactive handover

Reactive handover, on the other hand, tends to delay handover as much as possible i.e. handover starts only when the MS completely lose its serving BS/RS's signal. This responds to changes in the low-level wireless interfaces as to the availability or non availability of certain networks [13]. Reactive handovers can be further divided into anticipated and unanticipated handovers [13][12]:

- Anticipated handovers; are soft handovers which describe the situation where there are alternative base-stations to which the mobile node may handover.
- Unanticipated handover; the mobile is heading out of range of the current attachment and there is no other base-station to which to handover.

These handovers are therefore examples of hard handovers. In this paper we just consider the reactive handover in general term.

3. Prediction of User's Movements

3.1 State Probability Transition

In this work, the position-based path prediction is considered. The performing of mobility prediction is relied on Markov process. Let's consider a MS connected to its serving BS is in random motion as shown in Fig. 5 below. Based on *Markovian* characteristic, the movement may be start at a particular point (x,y) and has probability to move to any other cells/areas (states) or stay at the current position. The transition probability from *state (i)* to another state *(j)* is based on current state only rather than previous states [4].

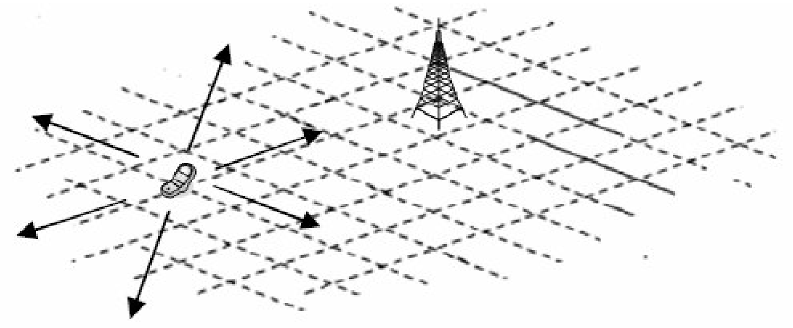
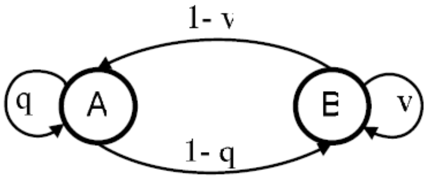


Fig. 5. Single cell environment

In single cell environment, the state probability transition can be neglected since the MS will stay connected to the same serving BS (there is no possible handover). On the other hand, in multicells environment, the handover will occur when the MS moving, so there are several cells/area to where the MS moves on. The number of cells that involve in the prediction is denoted as *N state*. If a *markov chains* process has *N state*, then the dimension of the *transition probability matrix* (**P**) will be *N* x *N*.

$$\mathrm{P} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{bmatrix}$$

The elements values of a transition probability matrix are derived from a diagram that called *state markov chains diagram*. Fig. 6 shows how a state markov chains diagram generates a transition probability matrix.



$$\begin{array}{c|cc} & A & B \\ \hline A & q & 1-q \\ B & 1-v & v \end{array} = \mathrm{P}$$

Fig. 6. State markov chains diagram and transition probability matrix

Now, let's consider the three cells (3 states) scenario of a mobile network as shown in Figure 7. The environment consists of one serving BS (A), target BS (B) and target BS (C). The MS in each BS has three state probabilities i.e. (a) the MS stays in current position $A \rightarrow A$, (b) the MS moves from $A \rightarrow B$, (c) the MS moves from $A \rightarrow C$. The total probability of (a), (b) and (c) must be equal to 1. Then we can generate the transition probability matrix of A. The same way can be done to B and C.

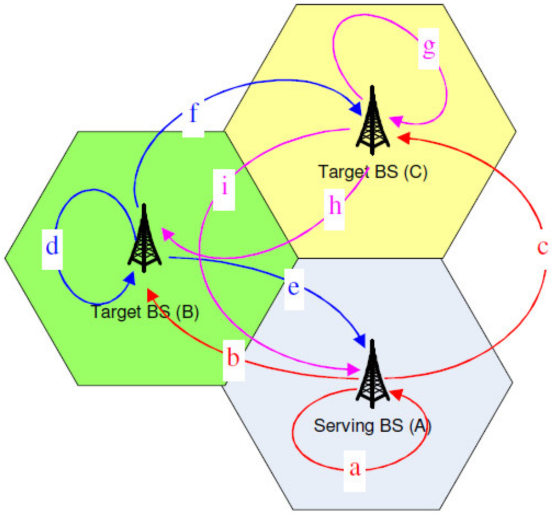


Fig. 7. The transition probability of multicells scenario

The state markov chain diagram as shown in Fig. 7 generates the transition probability matrix as:

$$P = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \tag{1}$$

The *next transition probability* ($\mathbf{P_n}$) from serving BS to target BS is calculated as:

$$\mathbf{P_n} = [\mathbf{P_{n-1}}] \text{ x } [\mathbf{P}] \tag{2}$$

where $\mathbf{P_{n-1}}$ is denoted as current transition probability matrix, n is denoted as number of state transition. Since we consider multi cells, the minimum number of n should be 2. Therefore, it can be addressed that $\mathbf{P_1} = \mathbf{P}$ and $\mathbf{n = 2, 3,}$ ….

3.2 Initial Distribution Matrix

The mobility prediction can be more precisely calculated if we can determine the initial number of object (MS) in particular state, or the initial probability of the object in the particular state, or any other parameter e.g. the velocity of MS, distance target, etc. These parameters can be represented by an *initial distribution matrix* (***p***).

If we consider the dimension 3x3 of the **P** (as in equation (1)), then the initial distribution matrix, ***p***, can be determined as:

$$p = \begin{bmatrix} j & k & l \end{bmatrix} \tag{3}$$

Where *j, k* and *l* represent the parameters mentioned above. Since the row of *p* represents the coordinate position of the object, thus the prediction of the object position in both 2D (flat area) or 3D (inside the building) can be determined.

$$\begin{array}{c} x \\ y \end{array} \begin{bmatrix} \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots \end{bmatrix} = p \quad , \qquad \begin{array}{c} x \\ y \\ z \end{array} \begin{bmatrix} \cdots & \cdots & .. \\ \cdots & \cdots & .. \\ \cdots & \cdots & .. \end{bmatrix} = p$$

The position of the MS after one movement or one state transition ($\boldsymbol{p_1}$) can be determined as $\boldsymbol{p} \text{ x } \mathbf{P}$. Therefore, the position of the MS after n movement can be predicted as:

$$p_n = [p] \text{ x } [P_{n-1}] = [p_{n-1}] \text{ x } [P] \tag{4}$$

3.3 Movement Prediction Simulation Rules

In the movement prediction simulation we manage some assumptions regarding the MS's mobility. When equation 4 is executed, the ***d*** is denoted in initial distribution matrix as the distance from current position to the next position. We assume the distance is uniform ($\boldsymbol{d_{min} = d_{max}}$). The MS, serving BS and all target BSs are in the flat movement area of 6,25 Km^2 (2500m x 2500). Target BS B and C (see Fig. 7) within the movement area is assumed to have the highest probability value. In contrast, the target BSs outside the movement area is assumed have the lowest probability value. In case of the both target BSs have a same probability value, we predefined the state priority, in which the target BS B has highest priority than target BS C.

Table 1. Simulation parameters and predefined scenario

Parameter	**Value**
Number of BS [-]	3
Number of MS [-]	10
Number of state transition [n]	15
BS transmitting power [dB]	46
BS height [m]	32
MS height [m]	2
MS speed [m/s]	15
Distance between position [m]	10
Frequency [GHz]	2.5
Frame duration [ms]	10
Hysteresis margin [dB]	1
LOS/NLOS path loss model	802.16m Urban Microcell
Mobility model	Random waypoint
MS velocity [km/h]	$V_{min} = 5$, $V_{max} = 20$
Size of simulated area [m]	2500 x 2500 (6.25km^2)

In addition, though the random waypoint mobility model is used in this prediction, it can be assumed that nobody walks randomly, but usually several paths could be followed, so we presume the distances of next position are known in advance.

The detail simulation parameters and predefined scenario can be seen in Table 1. The number of transition probability matrix that is used in the simulation is eleven matrixes and can be found in Table 2.

Table 2. Transition probability matrixes

Matrix	Value	Matrix	Value
$tpm_{.1}$	$\begin{bmatrix} 1/3 & 1/3 & 1/3 \\ 1/3 & 1/3 & 1/3 \\ 1/3 & 1/3 & 1/3 \end{bmatrix}$	$tpm_{.2}$	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$
$tpm_{.3}$	$\begin{bmatrix} 0 & 1/3 & 2/3 \\ 2/3 & 0 & 1/3 \\ 1/3 & 2/3 & 0 \end{bmatrix}$	$tpm_{.4}$	$\begin{bmatrix} 0 & 1/3 & 2/3 \\ 1/3 & 2/3 & 0 \\ 2/3 & 0 & 1/3 \end{bmatrix}$
$tpm_{.5}$	$\begin{bmatrix} 2/5 & 2/5 & 1/5 \\ 2/5 & 2/5 & 1/5 \\ 2/5 & 2/5 & 1/5 \end{bmatrix}$	$tpm_{.6}$	$\begin{bmatrix} 1/6 & 2/6 & 3/6 \\ 1/6 & 2/6 & 3/6 \\ 1/6 & 2/6 & 3/6 \end{bmatrix}$
$tpm_{.7}$	$\begin{bmatrix} 1/6 & 2/6 & 3/6 \\ 3/6 & 1/6 & 2/6 \\ 2/6 & 3/6 & 1/6 \end{bmatrix}$	$tpm_{.8}$	$\begin{bmatrix} 1/4 & 1/4 & 2/4 \\ 2/4 & 1/4 & 1/4 \\ 1/4 & 2/4 & 1/4 \end{bmatrix}$
$tpm_{.9}$	$\begin{bmatrix} 2/5 & 2/5 & 1/5 \\ 1/5 & 2/5 & 2/5 \\ 2/5 & 1/5 & 2/5 \end{bmatrix}$	$tpm_{.10}$	$\begin{bmatrix} 1/3 & 1/3 & 1/3 \\ 2/3 & 1/3 & 0 \\ 1/6 & 2/6 & 3/6 \end{bmatrix}$
$tpm_{.11}$	$\begin{bmatrix} 1/6 & 3/6 & 2/6 \\ 1/4 & 2/4 & 1/4 \\ 1/3 & 0 & 2/3 \end{bmatrix}$		

4. Results and Discussion

The eleven transition probability matrixes provide many figures of MS movements. They are plotted into a cartesian coordinate system as shown in Figure 8. In fact, there are some forms of movement which are then simplified into five category direction based on the MS's final position: *toward target BS-B*, *toward target BS-C*, *motionless or reside*, *outside the movement area* and *in the cell's boundary*. Some transition probability matrixes in some MSs also delivered some errors during the simulation. Table 3 shows the prediction result of MS's direction after several movements.

Table 3. Prediction results of MS's direction after several movements

	MS 1	MS 2	MS 3	MS 4	MS 5	MS 6	MS 7	MS 8	MS 9	MS 10
$tpm_{.1}$	C	C	C	C	C	C	C	C	C	C
$tpm_{\_2}$	C	out	-	B	C	C	C	C	C	B
$tpm_{\_3}$	C	border	out	border	border	border	C	border	border	border
$tpm_{\_4}$	C	C	C	B	C	C	C	C	B	B
$tpm_{\_5}$	B	B	B	B	B	B	B	B	B	B
$tpm_{\_6}$	C	C	C	C	C	C	C	C	C	C
$tpm_{\_7}$	C	C	out	border	border	border	C	border	border	border
$tpm_{\_8}$	C	reside	out	reside	reside	out	C	border	C	out
$tpm_{\_9}$	C	reside	out	reside	reside	reside	C	reside	reside	C
$tpm_{\_10}$	-	C	C	border	C	B	-	C	-	-
$tpm_{\_11}$	C	C	C	C	C	C	C	C	C	C

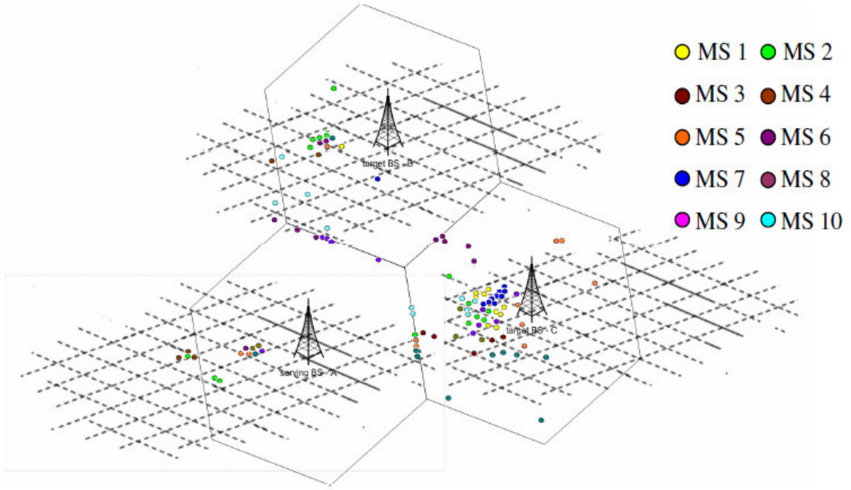


Fig. 8. Result of mobility prediction

As can be seen on Fig. 8, most MSs are predicted to hit the target BS C (52%), even though the state priority is set to target BS B. It can be explained that the value in the third column (state 2) has the larger values than in the first and second column. 14.5% MSs hit the target BS B when predicted by using the given transition probability matrixes. 13.6% of the MS arrived at the cell boundary, 8.2% is predicted reside on the current position. About 5.5% of the MSs is predicted moving outside the movement area. The rest of the prediction is found as error.

The simulation results also provide various form of MSs movement that is listed in Table 4.

Table 4. The forms of MSs movement.

	MS 1	**MS 2**	**MS 3**	**MS 4**	**MS 5**	**MS 6**	**MS 7**	**MS 8**	**MS 9**	**MS 10**
$tpm._{1}$	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear
$tpm\_{}_{2}$	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear
$tpm\_{}_{3}$	liniear	random	reside	random	random	random	random	random	random	random
$tpm\_{}_{4}$	liniear	linier	linier	linier	linier	linier	linier	linier	linier	linier
$tpm\_{}_{5}$	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear
$tpm\_{}_{6}$	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear	liniear
$tpm\_{}_{7}$	liniear	random	reside	random	random	random	random	random	random	Random
$tpm\_{}_{8}$	liniear	patterned	reside	patterned	patterned	patterned	patterned	random	patterned	reside
$tpm\_{}_{9}$	liniear	patterned	linier	patterned	patterned	patterned	random	patterned	patterned	patterned
$tpm\_{}_{10}$	reside	reside	reside	reside	reside	reside	Reside	reside	reside	reside
$tpm\_{}_{11}$	liniear	liniear	liniear	liniear	liniear	liniear	Liniear	liniear	liniear	liniear

According to the results, all MSs with transition probability matrix $\boldsymbol{tpm\_{}_{1}}$ moved linearly toward target BS C, because the elements in $\boldsymbol{tpm\_{}_{1}}$ have the same value. The prediction of MS's position (p_n) will has the same to all MSs. In this case, the mobility of MSs are depend on defined state priority.

The movement forms as the result of mobility prediction can be seen in Figure 9. The simulation and calculation finally provide two kinds of prediction:

1). Prediction of movements form (see Fig. 9).

The statistical prediction shows there are several forms of movement:

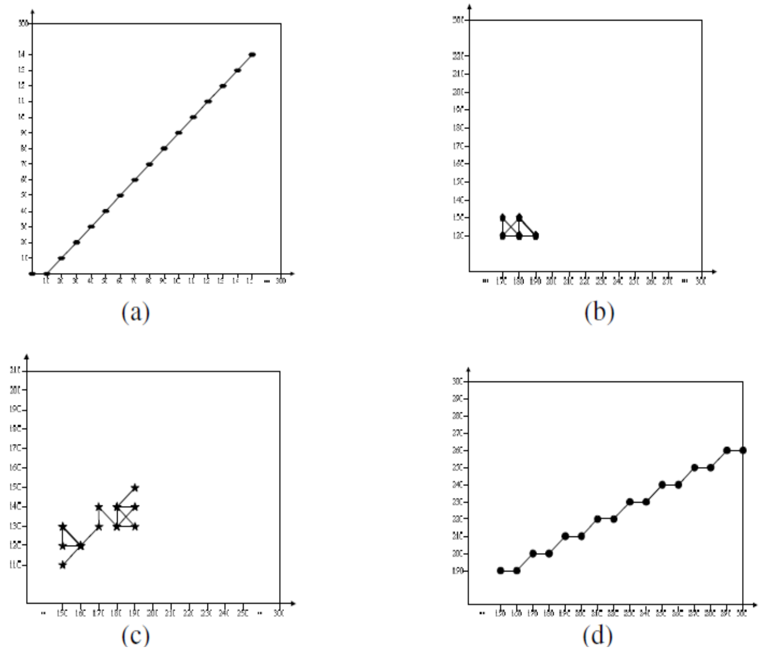


Fig. 9. Various forms of MS's movement: (a) Linear, (b) Reside, (c) Random and (d) Patterned

a. Linear; the MS is moving linearly toward next positions until reach the final position. The movement form is generated when the MS moving in a relatively low speed. The proactive handover seems suitable in this condition since the MS can postpone the handover until it definitely receives a good signal condition from the target BS. In addition, during the time before handover upon knowing the next target BS, serving BS (or other network elements) can manage everything that could be useful when performing the handover. The loss of data transfer during handover process can be avoided. The handover interruption time can also be reduced.

b. Reside; after several movements the MS is back at its initial position. The movement form is generated when the MS moving in a relatively low speed. When this form of movement is predicted, both MS and serving BS do not need managing the handover procedure.

c. Random; the MS is moving randomly toward next positions until reach its final position. The movement form is generated when the MS moving in a relatively low speed. However, the result also shown that the random movement form is also generated by high speed mobility. In this form of movement, the uncertain direction may occur until the MS reaches its final position. In case of low speed mobility, proactive handover tends to be implemented. Moreover, the reactive handover strategy can be implemented when the MS moves in higher mobility.
d. Patterned; the MS is moving in a specific pattern toward next positions until reach the final position. The movement form is generated when the MS moving in a relatively high speed. In this case the reactive handover strategy may be the best option since it is effective in minimizing the number of handovers, e.g., by avoiding triggering a handover process when a MS approaches a new wireless cell, without losing the origin signal, and immediately returns back to the origin serving BS. However, reactive handovers tend to be long because they include looking for new APs, choosing one of them, and asking for re-association. Moreover before e reactive handover available bandwidth is limited, since signal quality is low (in first analysis signal quality depends on AP-wireless client distance)

2). Prediction of movement direction. The direction, in fact, is based on the coordinates obtained.

5. Conclusions

In this paper we perform the mobility prediction on wireless network based on IEEE802.16m system profiles. The prediction results obtained are used to perform the handover. Based on the prediction results, we proposed two handover strategies. As the conclusion, the mobility prediction can be used to predict the movement direction of the MS, the form of MS' movement and the next and final position of the MS. At the end it can predict the next target BS. Prior those information obtained, the MS or the serving BS (or other network elements) can prepare the suitable handover (proactive or reactive handover). In the mean time, the serving BS can inform the MS to which target BS it supposes to connect and performing the scan. The serving BS can also send all information, needed by the MS to perform the pre-registration process, to the potential target BS. So, the overhead and handover interruption time can be reduced. Finally, based on our results, the prediction of MS's mobility can enhance the handover strategy to be more efficient and effective.

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Biography

Ardian Ulvan received the B.Eng degree in electrical engineering in 1997 from The University of North Sumatra, Indonesia, and MSc in Networks Engineering from Sheffield Hallam University, UK in 2001. In 2006 he received the accredited Engineering (Ing.) acknowledgement from Czech Technical University in Prague, Czech Republic. His PhD degree in Telecommunication Engineering is planned to be awarded in 2009 from CTU in Prague. In 1999-2005 periods he worked as a Senior Lecturer in Department of Electrical Engineering, The University of Lampung, Indonesia. He is currently working as researcher at wireless networks research group Department of telecommunication engineering, CTU in Prague. His research interests include MAC functionalities on broadband and gigabit wireless based on standards IEEE802.16d/e/j/m and 3GPP LTE/LTE-A, multihops-multicells wireless networks and the IP Media Subsystem (IMS). He involves in European research projects FIREWORKS (IST-FP6) and ROCKET (IST-FP7) and several projects at CTU R&D Centre.

Melvi Ulvan received the B.Eng degree in electrical engineering in 1997 from The University of North Sumatra, Indonesia, and M.Eng in Telecommunication Information System from Bandung Institute of Technology, Indonesia in 2002. In 2008 she received the accredited Engineering (Ing.) acknowledgement from Czech Technical University in Prague, Czech Republic. She is currently studying PhD degree in Telecommunication Engineering at CTU . In 2000-2006 periods she worked as a Senior Lecturer in Department of Electrical Engineering, The University of Lampung, Indonesia. She is currently working as researcher at wireless networks research group Department of telecommunication engineering, CTU in Prague. Her research interests include Mobile IP, IP Multimedia Subsystem (IMS), and femtocell networks. She involves in several projects at CTU R&D Centre.

Robert Bestak received his engineering degree from the Czech Technical University in Prague, Faculty of Electrical Engineering, in 1999. Within 1999/2000, he did one-year engineering program in telecommunications and computer networks at the Institute EERIE de l'Ecole des Mines d'Alès, Nimes, France. In 2003, he received his Ph.D. degree in computer science from ENST Paris, France. Since 2004, he works as a researcher at the Department of telecommunication engineering, CTU in Prague. Since 2006, he heads wireless research group at the department. His research interests include RRM techniques in HSPA/LTE systems and multi-hop networks. He participated in EU FP projects ALLIPRO, FIREWORKS and he currently participates in EU FP7 project ROCKET. He has been involved in several R&D Centre projects.