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Efficiency of Handover Prediction Based on Handover History

Zdenek Becvar
Department of Telecommunication Engineering, Czech Technical University in Prague, Prague 16627, Czech Republic
becvaz1@fel.cvut.cz
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Abstract

The prediction of the handover in mobile wireless networks is an easy way of optimal disposing with radio resources and efficient increase of quality of services. The prediction can be based on the several approaches. This paper is focused on the monitoring of the history of serving and target base stations while the handover is executed. The information about previous handovers of all users are stored in base stations. Then the prediction is performed based on the frequency of previous handovers between pairs of base stations. The paper investigates an efficiency of target base station prediction for several scenarios. Further, an impact of a number of neighbor stations on the ratio of successfully predicted target base stations is analyzed.

Keywords

Handover, Handover history, Prediction, Efficiency.

1. Introduction

The mobile wireless networks have to enable full mobility for users with non degraded Quality of Service (QoS). The QoS is closely related to a mobility of users. As the users moving, the station to which are connected has to be updated. This process is known as handover. Within the user movement, the Mobile Station (MS) scans the neighborhood and monitors communication parameters such us signal strength or packet delay of all available Base Stations (BSs). When some of signal parameters of the BS to which the MS is connected (noted as serving BS) drops below the predefined level or below the level of a neighbor BS, the MS performs handover. It means that MS close all connections to the serving BS and subsequently it starts to negotiate connection with a new BS noted as target BS. The MS is disconnected from the network in the time interval between closing connections with the serving BS and setting up new connections with the target BS. This short time break can decrease QoS therefore it should be minimal. Above described principle corresponds to the so called hard handover when the MS communicates with just one BS in each time instant. However, the MS can be connected simultaneously to more then one BS while it performs handover. This type of handover is called soft handover. Within the soft handover, the MS communicates with more BS simultaneously [1], [2].

The minimization of break in hard handover or minimization of an overhead generated within the handover procedure can be easily achieved by a prediction of the handover. Another purpose of the handover prediction is to optimize an admission control as presented e.g. in [3], [4]. The utilization of handover prediction for reservation of resources for admission control is also presented in [5]. The paper proposes two schemes of the admission control to optimize a utilization of dedicated bandwidth. The effectiveness of prediction is considered in [6] for the minimization of the power consumption in adhoc networks. The reduction of the power consumption is accomplished by the postponement of the handover until a MS become closer to the target station. The prediction is done based on the MS's movement history. The prediction of users position is further exploited for example in [7]. The paper presents advanced algorithms for the prediction of user's location. However, this kind of prediction needs to know exact position of users. Therefore it implies to use some localization equipment such as GPS (Global Positioning System) [8].

Filtering methods for prediction of the handover are evaluated in [9]. The authors compare an efficiency of handover prediction for Gray, Kalman, Fourier and Particle filtering of RSSI (Receives Signal Strength Indication) values. The results show the best performance (about 80% of successful handover prediction hit ratio) for no filtering and Grey filtering techniques. The Grey filtering technique is analyzed in [10]. The paper evaluates and proofs positive impact of Grey prediction on the reduction of a number of performed handovers.

Two approaches of the handover prediction, cell and user are investigated in [11]. Cell approach predicts a number of users in the cell and user approach utilizes a mobility prediction for handover estimation. Further, the paper summarizes the advantages of both approaches and their suitability for utilization in different situations. An extension of previous paper is presented in [12]. The authors propose new mechanism for resource allocation that shows better performance with users approach in the area of reduction of the handover failures. On the other hand, the cell approach improve cell blocking probability.

In comparison to above mentioned works, this paper is focused on the evaluation of the efficiency (ratio of successfully predicted handovers) of technique that uses history of handovers to predict next target BS. Further, an impact of number of neighboring BSs on the prediction efficiency is evaluated.

The rest of paper is organized as follows. Next section explains the principle of prediction using the handover history. The third section describes the simulation scenario and setting of network parameters. Subsequent section consist the results of simulation. Last section presents our conclusions.

2. Prediction of Handover

The prediction of handover is a process when the next target BS (access BS) is predicted. Knowing in advance the target BS can enable the fast handover with minimal interruption. Besides, it can reduce the MAC management overhead due to an optimization of the list of neighborhood station for scanning.

The prediction can be based on the several approaches as was mentioned in the previous section. This paper is focused on the monitoring of pairs of the serving and corresponding target BSs of the handover procedure in the past. This method requires monitoring and registering updates of serving and targeting BSs within the handover of all MSs in the network. It means that if the handover of a MS is executed, the identification of the serving and target BSs are stored into memory.

Handover history based prediction has to be managed by network as the MS has no access to the information about the handover of other MSs. The amounts of the handovers among BSs are represented by the matrix (see example in Table 1). The matrix has the same number of rows (x) and columns (y). The number of rows and columns corresponds to the number of neighboring BSs. Each field of the matrix represents a number of handovers between BSx (serving BS) and BSy (target BS) within observed time interval. For example, the field in the third row and fifth column represents the number of handovers from the BS3 to BS6 (handover count is equal to 79). An amount of handovers performed in the opposite direction (from BS6 to BS3) is presented by field in the sixth row and third column (21).

Table 1. The matrix representing the number of the handovers among BSs (scenario with 7 neighboring BS)

HO coun	**BS1**	**BS2**	**BS3**	**BS4**	**BS5**	**BS6**	**BS7**
BS1	x	31	0	35	34	0	0
BS2	16	x	51	33	0	0	0
BS3	0	18	x	3	0	79	0
BS4	28	41	13	x	8	6	4
BS5	11	77	0	0	x	0	12
BS6	0	0	21	13	0	x	66
BS7	0	0	0	20	23	57	x

The situation that corresponds to the Table 1 is depicted in Figure 1.

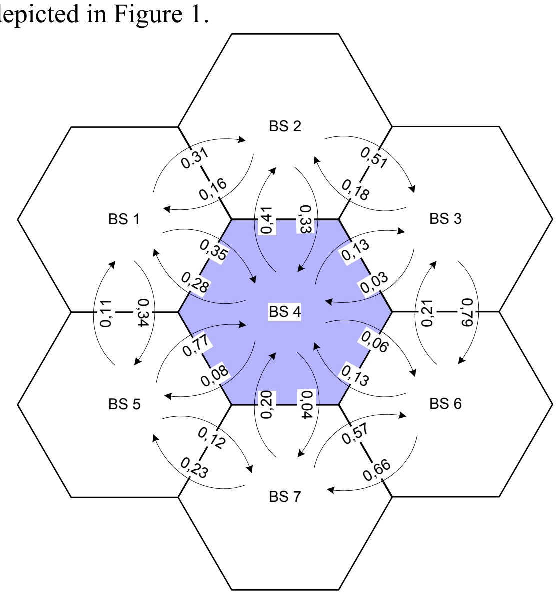


Figure 1. The probabilities of the handover among neighboring BSs

The matrix of the number of handovers is recalculated to the probability of the handover from serving BSx to target BSy ($P_{x,y}$) according to the following formula:

$$P_{x,y} = \frac{HO_{x,y}}{\sum_{y=1}^{y=NNS} HO_{x,y}} \tag{1}$$

where $HO_{x,y}$ represents the number of handover form BSx to BSy and *NNS* corresponds to the amount of neighboring BSs. All neighboring BSs of BSx are included in so called Neighbor Set of BSx – denoted in this paper as *NSx*. Based on the NS, the probability of handover from BSx to BSy can be rewrite as:

$$P_{x,y} = \begin{cases} \alpha, & y \in NS_x \\ 0, & y \notin NS_x \end{cases} \qquad (2)$$

where $0 \le \alpha \le 1$. The α depends not only on the number of BSs in the NS but also on the layout of the area where the situation is analyzed and monitored.

An example of the matrix of the probabilities calculated according to Table 1 and Eq. (1) is shown in Table 2.

Table 1. Matrix of handover probabilities among BSs (scenario with 7 neighboring BS)

HO prob	**BS1**	**BS2**	**BS3**	**BS4**	**BS5**	**BS6**	**BS7**
BS1	x	0.31	0	0.35	0.34	0	0
BS2	0.16	x	0.51	0.33	0	0	0
BS3	0	0.18	x	0.03	0	0.79	0
BS4	0.28	0.41	0.13	x	0.08	0.06	0.04
BS5	0.11	0.77	0	0	x	0	0.12
BS6	0	0	0.21	0.13	0	x	0.66
BS7	0	0	0	0.20	0.23	0.57	x

Figure 1 assumes the close area with no possibility of accomplishing the handover to another BS except BS1 – BS7. Thus, the sum of all probabilities in rows in Table 1 is always equal to 1 as expresses the next equation:

$$P_{x,y|x=const} = \sum_{y=1}^{y=NNS} P_{x,y} = 1 \qquad (3)$$

If we consider the real system when each BS has defined NS the sum of the probability of the handover from BSx to one of all neighboring BSs tends to 1 since we assume the handover in the infinite future (t→∞) as illustrates following formula:

$$P_{x,y|x=const,t\to\infty} = \sum_{y \in NSx} P_{x,y} = 1 \qquad (4)$$

The prediction of time when the handover occurs can not be predicted by this method since only information about serving and target BSs are collected. Therefore, the handover probability between BSx and all neighboring BSs over finite time interval is:

$$0 \le \sum_{y \in NSx} P_{x,y} \le 1, \qquad t < \infty \qquad (5)$$

where $P_{x,y}$ is a function of the time t.

3. Simulation

An evaluation of the prediction effectiveness is performed through simulations in Matlab.

A street scenario corresponding to the Manhattan Mobility Model (MMM) [13] is used for the simulation of the efficiency of the handover prediction based on the handover history. The parameters of the scenario are presented in Table 3.

Table 2. Simulation parameters and scenario definition

Parameter	**Value**
Number of BS [-]	15
Number of MS [-]	48
BS transmitting power [dB]	46
BS height [m]	32
MS height [m]	2
MS speed [m/s]	15
Frequency [GHz]	2.5
Frame duration [ms]	10
Scanning reporting period [s]	1
Simulation duration [s]	10800
Hysteresis margin [dB]	1
LOS/NLOS path loss model	Urban Microcell
Mobility model	Manhattan
Turn Probability [-]	0.5 / 0.75 / 0.9 / 1
Number of vertical streets [-]	10
Number of horizontal streets [-]	11
Street width [m]	30
Size of block of building [m]	200 x 200
Size of simulated area [m]	2330 x 2100

The BSs are deployed regularly as presented in Figure 2. All BSs are placed in the streets, not on the roof of the buildings. The 48 MSs is randomly dropped at the streets at the beginning of the simulation. The signal strength among all MSs and BSs is calculated using Urban Microcell path loss model defined in [14]. The signal parameters are calculated at each scanning reporting period – it corresponds to calculation of parameters each second in used scenario.

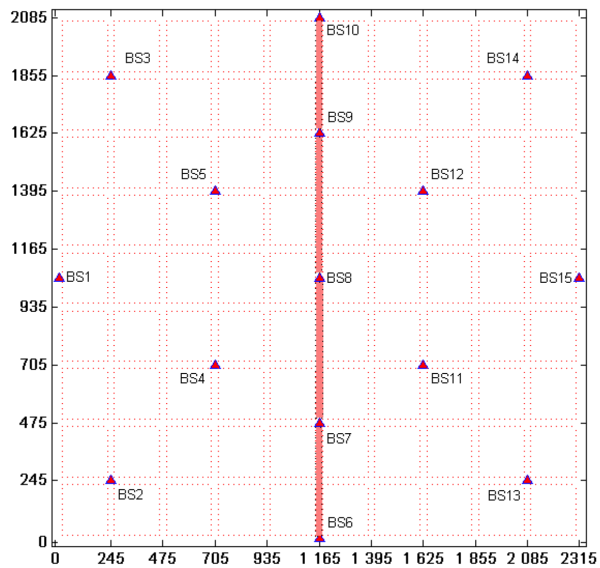
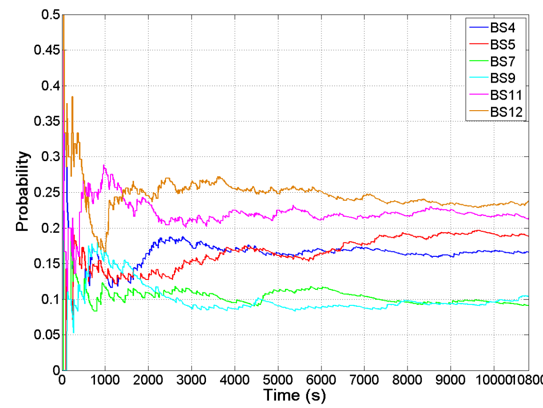


Figure 2. Scenario form simulation of the simulation of handover prediction

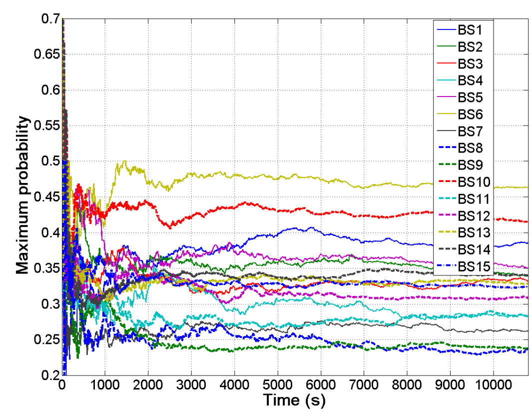
Four different varieties of mobility model are defined to compare results of the prediction. The first one represents conventional MMM with turn probability of 0.5. It means that the MS selects its next direction at each cross with 0.5 probability of the direct movement and 0.25 probability of the turn to the right and same probability of the turn to the left. Next three scenarios define so called "Main Street" (red vertical street no. 6 with x coordinate equal to 1165m in Figure 2). The turn probability of MS is 0.5 at all streets excluding Main Street. While a MS comes to the cross with the Main Street, the turn probability of belonging MS temporarily increases to the 0.75, 0.9 or 1 for three scenarios respectively. If the MS is moving on the Main Street, the probability of the direct movement is increased to 0.75, 0.9 or 1 respectively. The turn probability is set back to 0.5 while MS reach the end of the Main Street or if the MS leaves the Main Street. This situation corresponds much more to the real movement in the city centre with one busy street or with a main square.

4. Results

The simulation results are presented in Figure 3 - Figure 6. The probability of the handover of a MS from the BS8 to neighboring BSs (BS4, 5, 7, 9, 11 and 12) is presented in Figure 3a - Figure 6a. The scenario with no Main Street (Figure 3a) shows that time required to collect enough information about handovers is approximately between 2000 and 3000 seconds. Then the probability is getting stable and do not vary rapidly. Totally, about 2000 handovers occur per 1000 seconds of the simulation. The maximum sufficiency of prediction corresponds to the probability of handover since there is no other criterion considered for prediction. Based on the Figure 3a can be observed that BS12 is the most probable target BS for handover from BS8. However the handover probability from BS8 to BS12 is only about 25%. The lowest probability of the handover from BS8 is to BS7 and BS9. It is about 10%. That low probability results to the very low sufficiency of prediction. The sufficiency is related to the target BS probability and it could be assumed equal after the probability curves get stable.



(a)



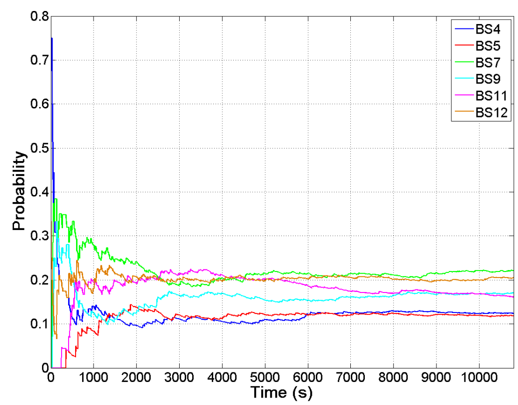
(b)

Figure 3. Results of handover prediction for no Main Street, Turn Probability = 0.5
(a) Handover probability over the duration of handover history collection for BS8
(b) Maximum probability of handover from all serving BS over the observation time

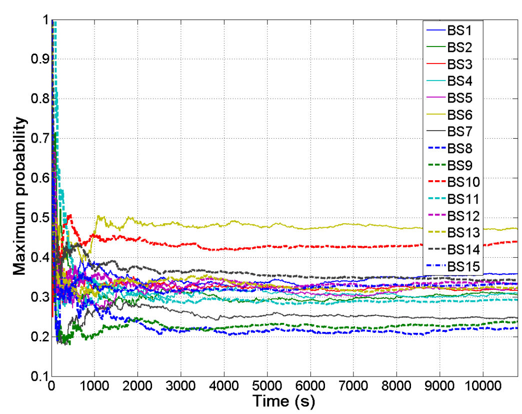
The maximum sufficiency of the target BSs prediction for all serving BSs are presented in Figure

3b. It expresses the ratio between sufficient and failed target BS prediction. Each curve corresponds to the one serving BS. Hence every curve copies the maximum value of the prediction probability for appropriate BS (e.g. the maximum of all curves in Figure 3a corresponds to the blue dash line in Figure 3b).

The presence of Main Street results into the increase of the ratio of the correct target BS prediction from the serving BS8 (see Figure 3b, Figure 4b, Figure 5b, Figure 6b) from 25% with no Main Street to 40% with mostly visited Main Street (Turn Probability=1 for the users coming to the Main Street and 0 for the users moving on the Main Street). The example of the probability of handover from BS8 shows the increase of the probability of the handover to the BS7 or BS9 since both are the neighbor BSs of BS8 deployed on the Main Street. The probabilities of handover from BS8 to BS7 and BS9 rise from 10% for no Main Street to 40% for the mostly visited Main Street.



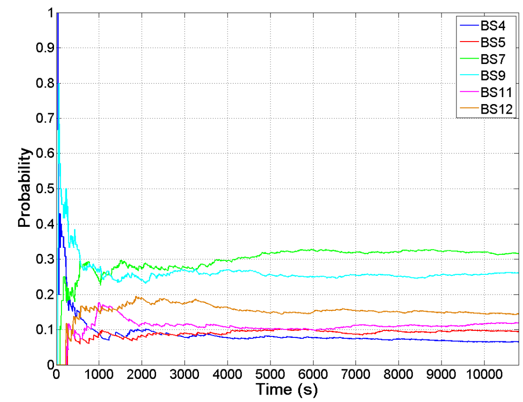
(a)



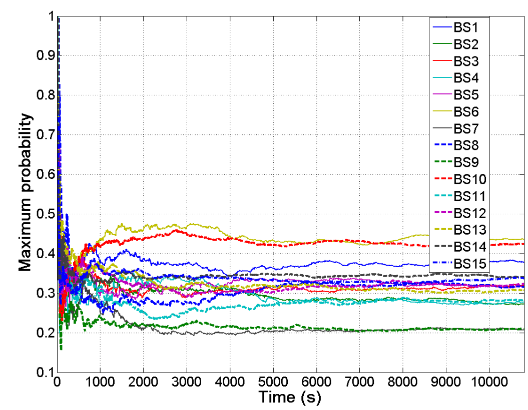
(b)

Figure 4. Results of handover prediction for Main Street Turn Probability = 0.75

(a) Handover probability over the duration of handover history collection for BS8
(b) Maximum probability of handover from all serving BS over the observation time

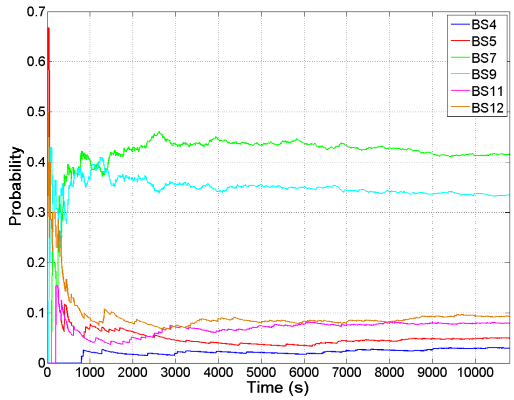


(a)

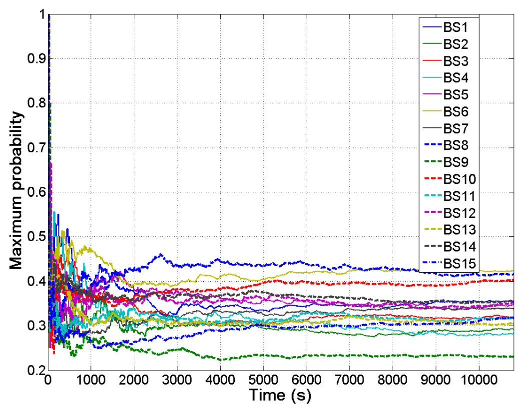


(b)

Figure 5. Results of handover prediction for Main Street Turn Probability = 0.9
(a) Handover probability over the duration of handover history collection for BS8
(b) Maximum probability of handover from all serving BS over the observation time



(a)



(b)

Figure 6. Results of handover prediction for Main Street Turn Probability = 1

(a) Handover probability over the duration of handover history collection for BS8

(b) Maximum probability of handover from all serving BS over the observation time

From Figure 3b - Figure 6b can be further observed that the maximum ratio of successful target BS prediction is achieved for the prediction of the handover from BS6 (about 47%) and BS10 (about 42%). The lowest ratio is attained while the MS is connected to the serving BS8 and BS9 (both about 25%). It leads to the conclusion that the sufficiency of target BS prediction depends on the number of neighboring BS since BS6 and BS10 has only 3 neighboring BSs however the BS8 has 6 neighboring BSs. The impact of number of neighboring BSs on the sufficiency of the target BS prediction is depicted in Figure 7. The efficiency of the prediction is significantly decreasing if the number of neighboring BSs is increasing for scenario without Main Street (Turn Probability 0.5) and with Main Street with Turn Probability 0.75 and 0.9. In these scenarios, the ratio of successfully predicted target BS decreases from about 45% to 24% while the number of neighboring BSs rises from 3 to 6. In case of Main Street with Turn Probability equal to 1, the handover probability decreases only up to 4 neighboring BSs and then the increasing number of neighbor BSs does not influent an efficiency of the prediction.

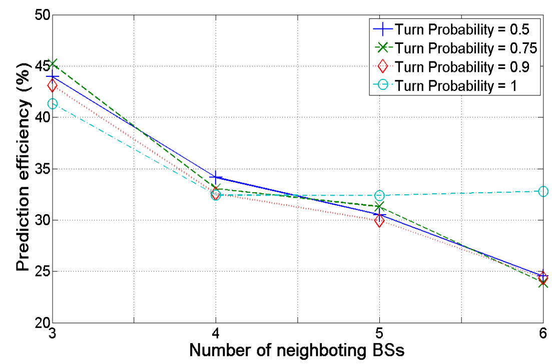


Figure 6. Average efficiency of the target BS prediction over number of neighboring BSs

5. Conclusion

This paper investigates an efficiency of the utilization of the target BS prediction based on the handover history. The advantage of the prediction using handover history is very simple implementation. Only a simple modification of a control mechanism of the BSs is required. On the other hand this method needs some time to adapt to the modification in environment (e.g. installation of new BS, close a road,...) or changes of channel characteristics (e.g. transmitting power) since the enough number of information must be collected (in our simulation it is between 2000 and 3000 seconds that corresponds roughly to 4000 - 6000 handovers).

The prediction efficiency is strongly influent by the number of neighboring BSs. The twice increase of neighboring BSs (from 3 to 6) leads to the drop of the prediction efficiency from about 45% to 24%.

In all cases, the prediction hit rates vary between 20% and 47%. Hence this way of prediction can be generally utilized as a supporting method for other techniques; however utilization as a stand alone technique is very inefficient due to low prediction sufficiency.

The future work will be focused on the analysis and optimization of the prediction techniques utilizing the signal parameters.

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