Implementation of Handover Delay Timer into WiMAX

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***Abstract* — The WiMAX networks are generally based on the 802.16 standards. There exist several versions of this standard which differs mainly in the mobility support. It can be realized by several different handover procedures. There can occur occasional problems with accurate determination of proper signal level values within network operating. These values are used for performing handover. It is possible to suppress these problems by implementing Handover Delay Timer. This paper deals with the impact of this timer duration on the number of unnecessary handover initializations, which are caused by inaccurate signal level assessment.**

I. INTRODUCTION

Mobile WiMAX (Worldwide Interoperability Microwave Access) is a wireless networking system based on the IEEE 802.16e [1] standard. This standard, published in September 2005, innovates previous version IEEE 802.16-2004 [2], which was published in October 2004.

The physical layer uses OFDM (Orthogonal Frequency Division Multiplexing) and SOFDMA (Scalable Orthogonal Frequency Division Multiple Access) in 802.16-2004 and 802.16e respectively [3]. The communication is specified in two frequency ranges: 2-11 GHz for NLOS (Non-Line Of Sight) and 10-66 GHz for LOS (Line Of Sight). On the physical layer WiMAX allows communication on a distance about 8 km with bitrate up to 70 Mbps for NLOS transmission [4]. In case of LOS conditions, a coverage distance is about 50 km [5].

Only fixed and nomadic access is allowed in 802.16-2004 [3]. The support of handovers between cells is not implemented there. It means that moving user must establish a new network connection after each cell boarder overrun.

The handover mechanism is implemented in the newest version 802.16e. The support of soft and hard handovers is introduced in this recommendation. The handover allows to users high speed mobility (up to 160 km/h [6]) and it can provide continuous data flow for all applications.

The rest of paper is organized as follows. Next section describes existing types of handovers implemented in mobile WiMAX and the procedure for decision about the handover initialization. The third section generally describes signal level measurement procedure and proposal of a Handover Delay Timer. The simulation scenario is described in the fourth section. The fifth section focuses on the results acquired by evaluating the simulation. The last section provides a summarization and conclusions.

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II. HANDOVER TYPES AND HANDOVER DECISION

The main target of handover in cellular mobile networks is to provide the continuity of services during a Mobile Station (MS) traveling across the cell boundaries of Base Stations (BS). IEEE 802.16e defines three basic types of handover [7]: Hard Handover (HHO), Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS). HHO is mandatory in WiMAX systems. Other two types of handover are optional. MDHO and FBSS can be called as the soft handovers.

A. Hard Handover

Within hard handover, the MS communicates with just one BS in each time. All connections with the old BS (called Serving BS) are broken before the connection to a new BS (Target BS) is established. It means that there is a very short time when MS is not connected to any BS. Handover is executed after the signal strength from neighbor's cell exceeds the signal strength from the current cell. This situation is shown in Figure 1. Red thick line at the boarder of the cells represents the place where the hard handover is realized. The threshold level hysteresis is usually used, in practice, to avoid the repeated switching of neighbor's BS during a movement lengthwise to the cell boundaries.

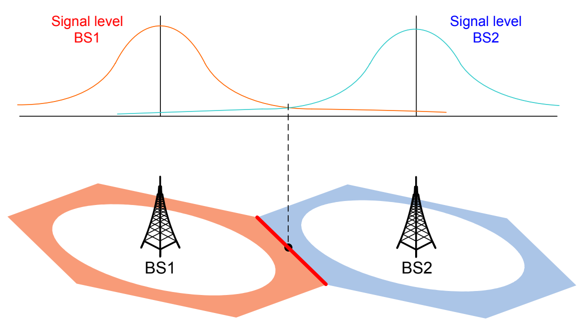

Fig. 1. Hard handover.

This type of handover is less complex, fairly simple but it has high latency. Higher latency causes the unsuitability for services requiring low latency (such as VoIP). Hard handover is typically used for data.

B. Macro Diversity Handover

When the MDHO is supported by MS and by BS, the “Diversity Set” (in some publications noted as “Active Set”) is maintained by MS and BS. The Diversity Set is a list of the BSs, which are involved in the handover procedure.

The Diversity Set is maintained by the MS and BS and it is updated via MAC (Medium Access Control) management messages [1]. A sending of these messages is usually based on the long-term CINR (Carrier to Noise plus Interface Ratio) of BSs and depends on two thresholds: Add Threshold and Delete Threshold. Threshold values are broadcasted in the DCD (Downlink Channel Descriptor) message [1]. The Diversity Set is defined for each MS in the network.

The MS continuously monitors the BSs in the Diversity Set and defines an “Anchor BS”. The Anchor BS is one of the BSs from Diversity Set in MDHO. The MS is synchronized and registered to the Anchor BS, further performs ranging and monitors the downlink channel for control information. The MS communicates (including user traffic) with Anchor BS and Active BSs in the Diversity Set (see Figure 2).

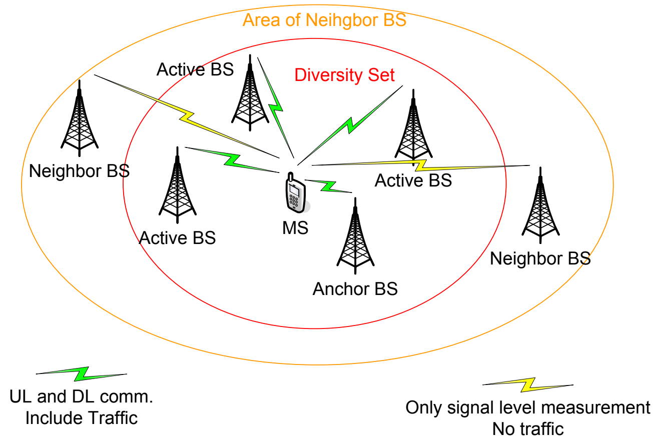

Fig. 2. Macro Diversity Handover.

For downlink, two or more BSs transmit data to the MS such that diversity combining can be performed at the MS. For uplink, the MS transmission is received by multiple BSs and selection diversity of received information is performed. The BS, noted as “Neighbor BS”, can receive communication which is among MS and other BSs, but the signal level is not sufficient to be added to the Diversity Set.

C. Fast Base Station Switching

In FBSS, the Diversity Set is maintained by the MS and the BS similar as in MDHO. Opposite to MDHO, the MS communicates only with Anchor BS for all types of uplink and downlink traffic including management messages (see Figure 3). When MS is connected to just one BS, thus the Diversity Set contains only this one BS that shall be termed the Anchor BS. The Anchor BS can be changed from frame to frame depending on BS selection scheme. This means that every frame can be sent via different BS in the Diversity Set.

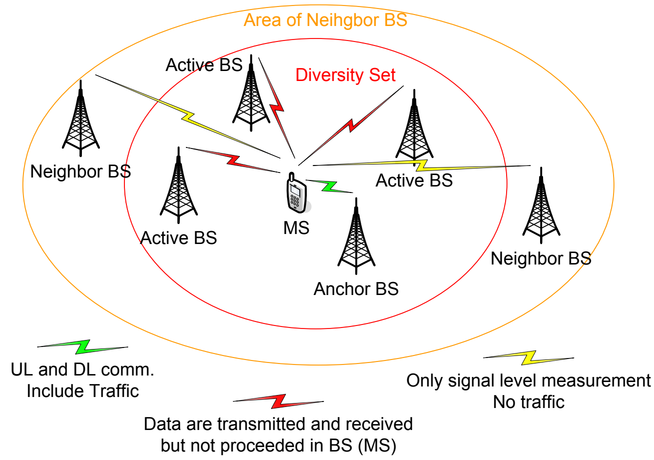

Fig. 3. Fast Base Station Switching.

Anchor BS updating procedure is based on the same principle as the Diversity Set update.

III. HANDOVER DELAY TIMER IMPLEMENTATION

The MS seeks for Neighbor BSs that are suitable to be added to the Diversity Set. It occurs within normal operations in special intervals noted as “Scanning Interval” [1]. Scanning intervals are allocated via MAC management messages. The MS determines BS suitability to be a Target BS in these intervals. After the MS finishes scanning of Neighbor BSs, it sends results to the BS.

There exist two types of results reporting. In the first, “Event trigger report”, MS sends reports based on a defined trigger (CINR, Receive Signal Strength Indicator (RSSI), Relative delay, Round Trip Delay (RTD)). The report of measurement is sent to the Serving BS after each measurement in this case. In the second type, “Periodic report”, MS sends reports at periodic intervals. The spacing of reporting intervals is indicated in a number of frames. The length of each frame can be up to 20 ms, and the number of frames between reports can be 256 (2^8) [1]. This means that the maximal value can be set to 5.12 s. The handover procedure starts based on the reports (Anchor BS update, Diversity Set update, etc.).

Sometimes the user can be on shadowed places (e.g. behind wide pillars, walls, etc.) for a very short time interval (shorter then reporting period) during the user’s movement. This causes that the measured CINR value temporary drops. Besides this, some other errors in measurements can occur and the measured value of CINR can be hardly inaccurate. These damaged data are called “affected values”.

According to the current version of WiMAX, the handover should start immediately after the BS resolution. However, when the user moves from the shadowed place or the next CINR value is unaffected, the handover must be stopped (if it has not finished yet) or must be proceeded again (if it has finished). The values can vary very considerably, hence it cannot be suppressed by setting of Add and Delete thresholds. This effect can be suppressed by implementation of a Handover Delay Timer (HDT). It means that there is inserted a short delay between the time when handover conditions are met and the time when the handover initialization is started. The conditions should not change during HDT duration. Analogical principles are used e.g. in UMTS system [8].

IV. Simulation Scenario

The simulation allows an evaluation of a number of handovers between the BS and the MS in the defined area. The number of handover depends on duration of the HDT. For the handover quantity simulation was used the MATLAB simulation environment.

Table I shows the main parameters used in the simulation. We assume MDHO handover and the periodic reporting with reporting period set up to 1 s (20 ms frame length and reporting after each 50 frames) in our simulation.

Table I
Simulation scenario parameters

Handover type	MDHO
Propagation model	Okumura-Hata
Mobility Model	Probabilistic Random Walk
Area	10 x 10 km
Number of MSs	42
Number of BSs	4
Height of BSs	30 m
Height of MSs	2 m
Frequency	5 GHz
Speed of MSs	50 km/h
Simulated time	30 minutes
Step of simulation	1 s
Delete Threshold	3 dB
Add Threshold	4 dB
Frame length	20 ms
Reporting period	50 frames
HDT duration	0 – 5 s
CINR distortion perc.	0.5 %, 0.05 % and 0%

The first step in the simulation is a calculation of all distances among all BSs and MSs in area of 10km x 10km. There are placed 4 BSs with 30m antennas height and 42 MSs, which are 2 m above the land in our scenario. All systems operate in the 5 GHz frequency band.

After distance calculation, all signal strengths among MSs and BSs are evaluated based on path losses. The Okumura-Hata model for small or medium city [9] was used for evaluating path losses.

The BS with the best signal strength is selected for each of MSs (in equations (1), (2) is this BS noted as *Best BS*). Next, the Diversity Set is created for each MS and it is based on defined thresholds and signal strengths. All BSs with signal strength that meet condition (1) are added to the Diversity Set. In further step, the BS can be also deleted from the Diversity Set if a signal level meets the requirement defined in the equation (2). The signal strengths from all BSs (in equations *TestedBS*), excluded BestBS, are compared with signal strength from the Best BS. If one of conditions mentioned in equation (1) or (2) is met, the BS is added (deleted) to (from) the Diversity Set. Add and Delete thresholds are set up on 4 dB and 3 dB respectively.

$$\mathrm{BestBS} - \mathrm{TestedBS} < \mathrm{Add\_Threshold} \quad (1)$$

$$\mathrm{BestBS} - \mathrm{TestedBS} > \mathrm{Delete\_Threshold} \quad (2)$$

New positions of all MSs are evaluated before the whole cycle is repeated. The evaluation of a new position is based on a Probabilistic Random Walk Mobility Model [10].

Three different cases were simulated. In the first case (*variety I*), the probability of affected CINR value is 0.5% (it means that the 99.5% of values are unaffected). In the second case (*variety II*), the probability of affected value is 0.05% (99.95% of values are unaffected). In the third case (*variety III*), no values were affected (100% of values are unaffected).

There has been simulated 30 minutes time interval and the values were evaluated with 1 s step for all varieties.

V. Results

The results of three variations (*variety I*, *variety II*, and *variety III*) are shown in the Figure 4.

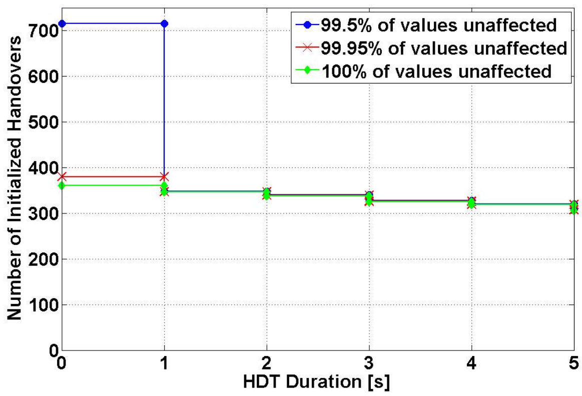

Fig. 4. The number of initialized handovers during simulation in function of HDT duration.

You can notice a difference between no-HDT case and the case with HDT, with values from 1 s to 5 s for *variety I*. The rapid slope in the figure is caused by often handover initializations, which is a result of affected measurements of the CINR value. In this case, after the CINR value received in the BS is affected, the handover is initialized immediately. After receiving a next value (unaffected), the handover procedure must be stopped.

In *variety I* (blue line in Figure 4) handover initializations can be reduced between 50% (for 1 s HDT duration) and 58% (for 5 s HDT duration) by implementing the HDT. However, the reduction of the handover initializations is not so expressively depending on the duration of the HDT.

In the *variety II* (red line in Figure 4), there is not so noticeable decrease between situation with and without HDT because the event of affected measured values is not so often. There can be saved between 10 % (for 1 s HDT duration) and 20 % (for 5 s HDT duration) handover initializations in *variety II*.

In the *variety III* (green line in the Figure 4), there is a uniform decrease on the average about 3.5 % per each second of HDT duration.

The uniform decreasing behavior in Figure 4 for timer duration greater than 1 s (this time corresponds to a reporting period) is evoked by the moving along cell boarders (e.g. the user is moving on the cell boarders and the conditions for handover are met in a time instant A. Further, when the user changes a moving direction, the conditions can be disturbed in a time instant B. If the HDT duration is longer than a difference of time instants (B – A) then a handover is not initialized). The affected values are eliminated in this part of Figure 4; consequently all variations have a similar behavior.

A total number of initialized handovers for six different HDT durations (axis y) at every moment (axis x) by this moment is presented in Figure 5 (*Variation I*) and in Figure 6 (*Variation II*). The figure for V*ariation III* is very close to *Variation II* so it is not presented.

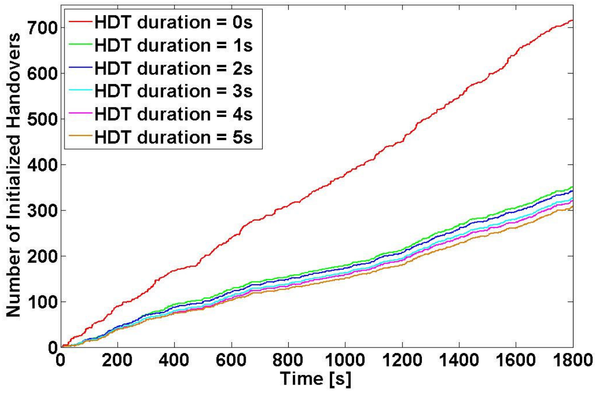

Fig. 5. The number of initialized handovers by each simulated step for different HDT durations in *variety I*.

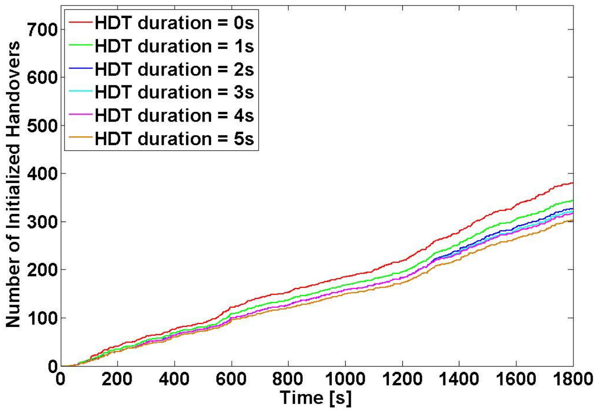

Fig. 6. The number of initialized handovers by each simulated step for different HDT durations in *variety II*.

VI. Conclusion

This paper deals with an implementation of Handover Delay Timer into WiMAX network.

We suppose that the users are moving in the city where they can get into a shadowed place for a very short time so there can be discovered affected measurements. As the simulation shows, the reduction of handover initializations by implementation of the HDT depends on the quantity of the short time variations that are significant. The importance of the HDT is rising with increasing percentage of quantity of affected measurements. When the 0.5 % of all sent measured values are affected, it is possible to save more then 50 % of handover initializations.

For a case when the probability of affected value is 0.05 %, the HDT allows reducing more then 10 % of handover initialization procedures by implementing HDT.

Affected values can be generally eliminated by implementation of the HDT with duration longer than the reporting period. Implementation of HDT with 1 s duration is required in our scenario for the elimination of affected values.

Without assuming affected values, the HDT reduces the number of handover initializations on the average about 3.5 % per each second of HDT duration.

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