IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 18, Issue 3, Ver. II (May-Jun. 2016), PP 96-105
www.iosrjournals.org

Techniques for Reduction of HandoverInterruption in Mobile Networks

Shivi Saxena[1],S.Qamar[2]
[1]*PhD Scholar,Department of ECE, IFTM University,Moradabad,India*
[2] *Department of ECE,NIET,GreaterNoida,India*

Abstract: *Handoff is the procedure providing the connection to the backbone network while a mobileterminal is moving across the boundaries of coverage of two wireless points of connection.The handover management procedure is defined by a sequence of management messages exchanged between the mobile stations and serving base station. An individual set of messages is utilized for each of the handover stages. As the messages are exchanged consequently, a short interval during which the mobile station cannot receive and/or transmit data occurs inthe case of the hard handover. This interval is called handover interruption or handoverdelay. This paper discusses about the evaluation of the handover interruptionduration.As no data transmission is enabled during the handover, a quality of serviceprovided to users is temporarily impaired. It leads to a dissatisfaction of users withconnection. The impact of handover interruption duration on the quality of service isalso investigated in this paper in the form of voice over IP communication qualityassessment.Moreover, in this paper a novel procedure is analyzed not only from the handover interruption point of view, however its impact on a management overhead and user's throughput are also discussed.*
Keywords: *Cellular Networks, Hard Handoff, Handover Interruption and Mobile Station.*

I. Introduction

In hard handover, the mobile node has to disconnect first from the current network beforeconnecting to the new network.The paper is separated into five different sections. Each of them focuses on a mainparticular objective of this paper. The rest of paper is organized as follows.

The **second section**describes and analyzes the problem of handover interruptionoccurrence. Moreover, it also defines parameters for evaluation of thehandover interruption duration. This model is later utilized for analysis of the impact ofhandover interruption on speech quality in VoIP communication and on the throughputof single MS. The impact of techniques utilized for a reduction a number of handoversis also investigated in this subsection.

The **third section** focuses on Methodology, in which different techniques for reduction of redundant handover discussed..The**fourth section**deals with the result and discussion in which different Simulation parameters for evaluation of throughput are discussed. All evaluations of the proposed techniques are done via simulations in MATLABsince it is common and the universal simulation tool used for mobile networks. The **fifth** and**six sections**present general conclusions of the whole paper. Furthermore, itoutlines possible ways of future investigation and future objectives of research work inthe field of handover optimization.

1.1 WiMAX

Based on standards developed by IEEE 802.16 working groupWiMAX (Worldwide Interoperability for Microwave Access) is a broadband wireless technology. IEEE 802.16-2004 standard has described the first completed version of WiMAX.[4]Thisversion was published in October 2004. Standard IEEE 802.16-2004 does not supportfull mobility of users. To enable full mobility of users, a handover procedure isintroduced in consequent version of WiMAX defined by standard IEEE 802.16e issued in 2006. Following version of standard, IEEE 802.16j, introduces RSs intonetwork topology. [5]The next version, IEEE 802.16m, the main objective of this version is to provide higher quality of serviceand higher throughput. Both versions, IEEE 802.16j and IEEE 802.16m, assume fullmobility of users. Thus, IEEE 802.16m defines, among others strict requirements on thehandover procedure.

1.2 HANDOVER ACCORDING TO IEEE 802.16M

The IEEE 802.16m standard is in the middle stage of the standardization process.Generally, a goal of this version is to provide an advanced air interface foroperation in licensed bands. The standard should design a system with performanceimprovements necessary to support future services and applications specified by IMTAdvancedIn target IEEE 802.16m system, the handover procedure shall be compatible withall previous IEEE 802.16 standards.[8] The handover procedure has to beEnhanced (in comparison to IEEE 802.16e) especially on the meaning of minimizationof a handover interruption time, sometimes called handover latency or handover delay.

II. Analysis Of Handover Interruption

2.1 Duration Of Handover Interruption

A handover interruption in mobile wireless systems is caused by switching of aMS from a serving BS to a target BS. Justification of the interruption caused by the hardhandover is presented in Figure 1. Before handover, the MS converse with theserving BS (Phase 1 in Figure 1).[11]All connections with the serving BS are terminated ifthe MS crosses a border of cells between the serving and target BSs (Phase 2 in Figure1) and the MS has no connection to the network. Subsequently, new connections withthe target BS are established (Phase 3 in Figure 1). The short disruption in connectionbegins when the MS gets cut off from the serving BS and it lasts until the MS setsup new connections with the target BS. During interruption all packets must beforwarded from the serving BS to the target BS via backbone. When the connectionsbetween the MS and object BS are established, the packets are transmitted to the MS.

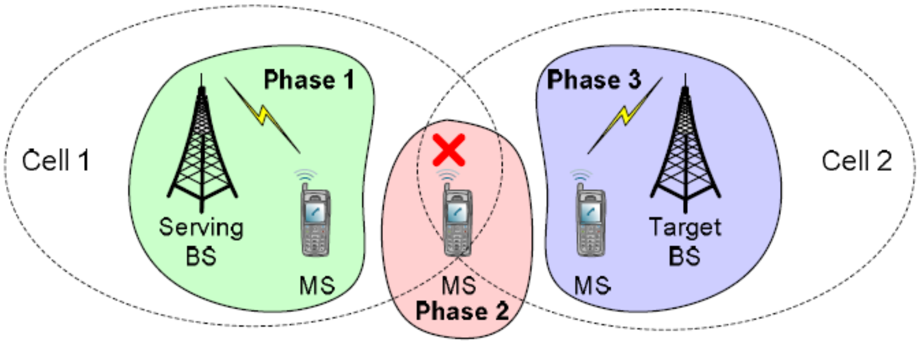

Figure 1. Interruption within Hard Handover

The minimization of this interruption is the main goalof this paper.

2.2 SUPPRESSION OF NEGATIVE IMPACT OF HANDOVER

The handover interruption and its negative impact on the VoIP speech quality canbe minimized by decrease a number of redundant handover technique.To improve the VoIP speech quality, PLC techniques, can be considered.However, these techniques are focused on a signal processing of speech and not on theprogress of the handover procedure.

III. Methodology

3.1 Reduction Of Number Of Redundant Handovers

Redundant handovers (or unnecessary handovers) represent a case when thehandover is executed, however it is not finished before the time when a next handoverdecision is made. Also a handover that is repeated several times between two adjacentcells can be considered as the redundant handover. Several techniques can be utilizedfor minimization of the number of redundant handovers caused by short time channelvariation (e.g. Fast fading or shadowing) or by movement of MSs along the border of thetwo neighboring cells. Standard IEEE 802.16e defines Hysteresis Margin (HM)and Time-To-Trigger (TTT) for removal of the redundant handovers. Anothercommonly used technique is windowing (known also as signal averaging) .[22] Lastmethod that will be considered is based on the similar principle as TTT. It is calledHandover Delay Timer (HDT). All methods are based on delaying of thehandover for some time interval. During this interval, the MS is not connected to thestation providing the best quality of communication channels. Therefore, it has a negative impact on Quality of Service (QoS) provided to the MS due to the utilization of worse quality of the channelthan a quality available from other BS. On the other hand, each stand alone methodreduces the amount of redundant handover initiations.

3.1.1 Techniques For Reduction Of Redundant Handovers

The principle of all four techniques for reduction of amount of redundancyhandovers is briefly introduced in following subsections.

(A) **HYSTERESIS MARGIN:** The handover decision and initiation are based on a comparison of one or severalsignal parameters (CINR, RSSI, Round Trip Delay (RTD) or relative delay) of a serving and target BS. The handover is initiated if the signal parameter of target BS exceeds the signal parameter of serving BS plus *HM*.

$$S_i^{Tar} > S_i^{Ser} + HM$$

Where $\mathbf{S_i^{Tar}}$ and S_i^{Ser}represents a signal quality parameter of the serving and the targetBS, respectively.The disadvantage of this principle is that it cannot eliminate rapid variation inobserved parameter (e.g. Fast fading). Moreover, it cannot cope with short timeShadowing with the decrease of signal higher than HMas it compares only current values ofobserved parameter.

(B) TIME TO TRIGGER

The handover initiation is accomplished after a short period within the signalParameters from a target BS or higher than parameters of a serving BS. It can bedescribed by the following equation:

$$S_t^{Tar} > S_t^{Ser} \Big| t \in (t_{HO}, t_{HO} + TTT)$$

Wheret_{HO}corresponds to a time when the handover decision would be done if noother technique for handover elimination is considered, and TTTis a duration of Time-To-Trigger timer. Standard [2], enables to use TTT duration with the following values:TTT (0, 255 ms).In comparison to the HM, this technique monitors signal parameters for a shorttime interval. Therefore, it enables to deal with, fast fading. On the other hand, a MS hasto monitor signal parameters for a whole duration of TTT. It leads to the reduction ofthroughput during TTT. Furthermore, very low level of maximum duration of TTTlimits the effect of this technique (e.g. It cannot fully eliminate the ping-pong effect orshadowing with duration over 255 ms).

(B) WINDOWING

The handover decision is done if an average value of observed signal parameterfrom target BS drops below an average level of the same parameter at serving BS. The average value is calculated over a number of samples, denoted asWindow Size (*WS*).

$$\frac{\sum_{i=1}^{WS} S_i^{Tar}}{WS} > \frac{\sum_{i=1}^{WS} S_i^{Ser}}{WS}$$

The efficiency of elimination of redundant handovers that are the result of ping-pongeffect, shadowing or fast fading depends heavily on the value of WS.

(D) HANDOVER DELAY TIMER

Technique HDT is developed with the purpose to manage, especially with the temporarydrop of a signal level due to fast fading or when a user is located in shadowed placesfor a short time period (longer than Reporting Period (RP)). Additionally, itenables a reduction of ping-pong effect.According to the IEEE 802.16e version of WiMAX [2], the handover startsimmediately after the channel conditions (e.g. Signal levels) reach a threshold level.[57]

However the handover must be canceled (if it has not finished yet) or must beperformed again (if it has finished) when a MS moves from the shadowed place.Implementation of the HDT results into insertion of a short delay between thetime when handover conditions are met and the time when the handover initiation iscarried out (see Figure 2). This delay is noted as HDT (HDT=2* RP InFigure 2).

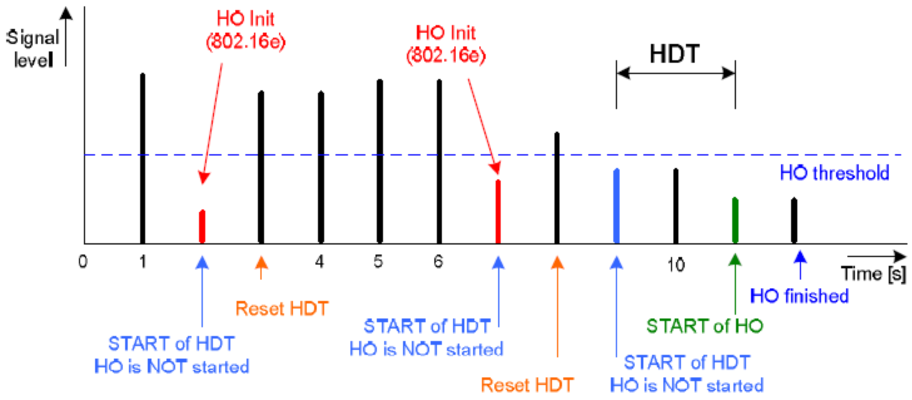

Figure 2Handover initiation with HDT

These conditions for the handover have to be fulfilled over the whole duration ofHDT to execute handover initiation. Generally, the handover is performed only if:[47]

$$S_t^{Ser} < S_t^{Tar} \Big| t \in (t_{HO}, t_{HO} + HDT)$$

WhereHDTrepresents a duration of the handover delay timer.As the signal level is measured and reported to the serving BS in discrete timeInterval (not continuously), the handover decision is executed if the accurate number of resultssamples $n_{samples}$ fulfills handover conditions as expresses the next equation:

$$S_i^{Ser} < S_i^{Tar} \Big| i \in (1, n_{samples})$$

The samplesare equal to an amount of a channel quality report sent during HDTfrom the MS to the BSn_{rep}as it is defined by the following formula:

$$n_{samples} = \frac{HDT}{n_{rep}}$$

If the periodic reporting is considered, the reports are transmitted in regular timeintervals (equal to the reporting period *RP*). Then the $n_{samples}$can be derived as:

$$n_{samples} = \frac{HDT}{RP}$$

As the HDT is based on the TTT, only HDT is considered for further evaluations

3.2. Impact OfHm, Hdt And Windowing On Ms's Throughput

All above mentioned techniques enable to reduce a number of handovers [16], howeverit is at the cost of a decrease of throughput since all of them results in a postponement ofHandover execution. The delay of handover execution leads to the utilization of lowerModulation and Coding Scheme (MCS) [2] for communication between a MS (Mobile station) and itsserving BS (Base station). The impact of the HM, HDT and windowing on the user's throughput is investigated for scenario with single MS (see Figure 3).

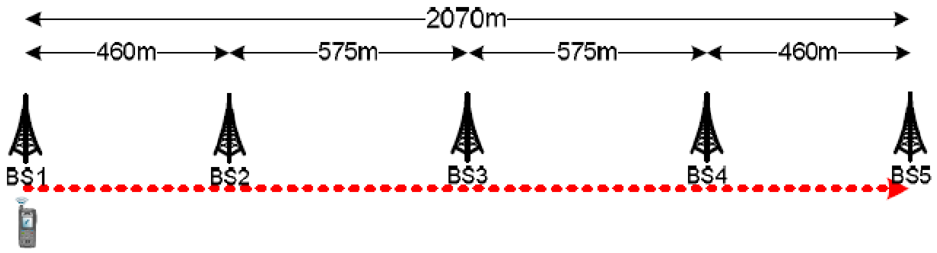

Figure 3 Scenario for evaluation of impact of all techniques on throughput

The MS moves along the straight line crossing 5 BSs. Speed of the MS is 10 m/s.The scanning reporting period is setup to 0.5 s since this value is close to an optimumscanning interval for maximization of throughput [31]. All parameters for evaluation aresummarized in Table .

Table Simulation parameters for evaluation of throughput of single MS

Parameter	Value
Number of BS [-]	5
Number of MS [-]	1
BS transmitting power [dB]	36
BS height [m]	32
MS height [m]	2
MS speed [m/s]	10
Frequency band [GHz]	2.5
Frame duration [ms]	20
Data subcarriers per sub-channel	48
OFDMA symbols per frame	198
Bandwidth [MHz]	20
Hysteresis Margin [dB]	0-20
Window Size [samples]	1-20
Duration of HDT [s]	0-5
Scanning reporting period [s]	0.5
Path loss model	802.16m Urban Macrocell

The throughput of single MS is calculated based on the received signal quality.
The full buffer traffic model is assumed. It means that the MS has always a full queue of data for transmission. This model is often used in simulation as it enables to evaluatethe maximum efficiency of a system [22]. The strength of receiving signal is used for aCalculation of the number of data carried per one downlink sub-channel (Data PerSubchannel− DPS).

$$DPS = NoDSC \times N_{ob} \times CR$$

WhereNoDSCexpress a number of data subcarriers per a sub-channel in PUSC(Partial Usage of Sub-Channels) OFDMA (Orthogonal Frequency Division MultipleAccess), CRrepresents Code Rate and Nob is a number of bits carried per one subcarrier(depending on used modulation scheme). The $N_{ob}$is derived from the next equation:

$$N_{ob} = log_2(N_{States})$$

WhereStatesis a number of modulation states.Every frame can be divided into sub-channels and a number of frames transmittedper second depends on the frame duration (*FD*). Therefore, the final bit rate at each step(BR_{step}) can be evaluated by the following way:

$$BR_{step} = \frac{DPS \times SPF}{FD}$$

WhereSPFrepresents a number of sub-channels per frame.The average throughput over the simulation duration (*AvgBR*) is calculated as athe weighted average of the all throughput obtained during simulation (see followingformula).

$$AvgBR = \frac{\sum_{Step=1}^{N_{steps}} \left(BR_{Step} \times StD \right)}{SimD}$$

Where*StD*is a duration of a simulation step, *SimD*is a duration of wholeSimulation and N Stepsrepresent the overall number of steps during simulation. It can becalculated according to the following equation

$$N_{steps} = SimD / StD$$

IV. Result And Disussion

All evaluations of the proposed techniques are done via simulations in MATLAB. Since it is common and the universal simulation tool used in mobile networksFigure 4 and Figure 5 showsthe results of the impact of HDT and windowing on thethroughput of single MS. The evaluation considers several levels of HM. Significant decrease of the MS's throughput is noticeable from both figures, especially withincreasing HM. In both cases, the reduction of throughput for low HM is not so rapid ifShorter duration of HDT or lower amount of average samples are considered. [59]On theother hand, the fall of throughput over the duration of HDT or WS is getting more linearfor higher levels of HM.The impact of only HM is depicted in Figure 6. The HM leads to the minor dropof throughput at lower levels of HM. Then the reduction of MS’s throughput is moresignificant.Note that the impact of all techniques on throughput depends heavily on adeployment of BSs described by function □□sand on a time interval between twohandovers (HO_{per}). The (HO_{per})is influenced by a speed of user □ □$_{MS}$ and a movement ofuser (□$_{MS}$). Therefore, the average bit rate can be expressed as the following function:

$$AvgBR = f(\Theta_{BS}, HO_{per}) = f\left(\Theta_{BS}, v_{MS}, \chi_{MS}\right)$$

Higher□$_{MS}$, higher density of BSs and more direct movement of MSs among BSsleads to the decrease of the negative impact of all these techniques on the throughput ofsingle MS.Combined effect of HDT and WS over HM on the throughput is depicted in Figure7. [35]The figure shows that the increasing of one of the parameters while the others are constantleads to a nearly linear reduction of the throughput (compare the spacing between lineswith same color or with same marker at the constant HM).

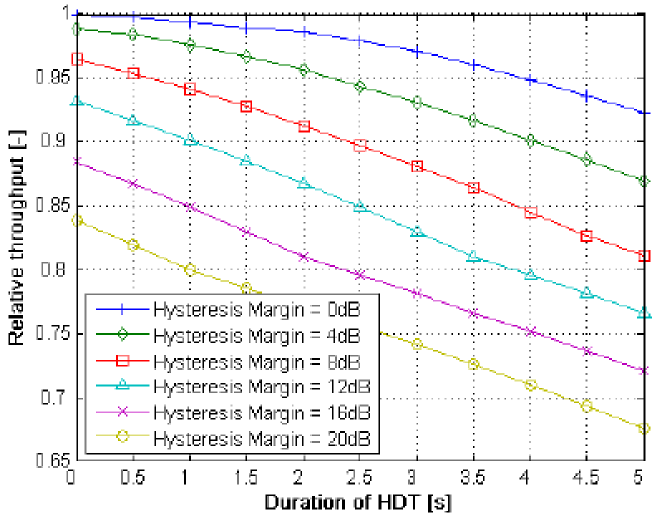

Figure 4 Impact of HDT duration onthroughput of single MS

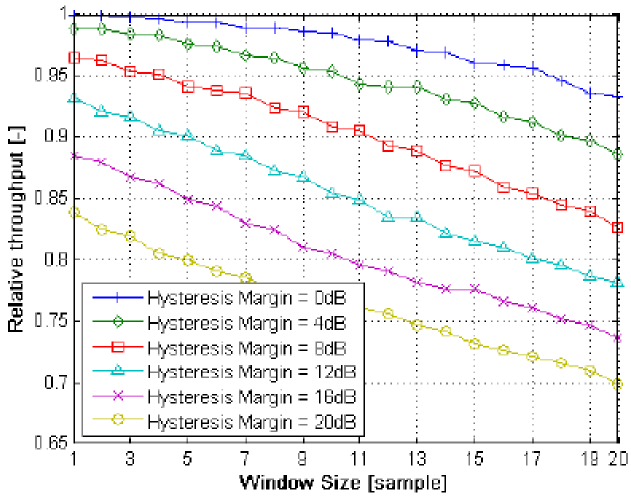

Figure 5 Impact of Window Size onthroughput of single MS

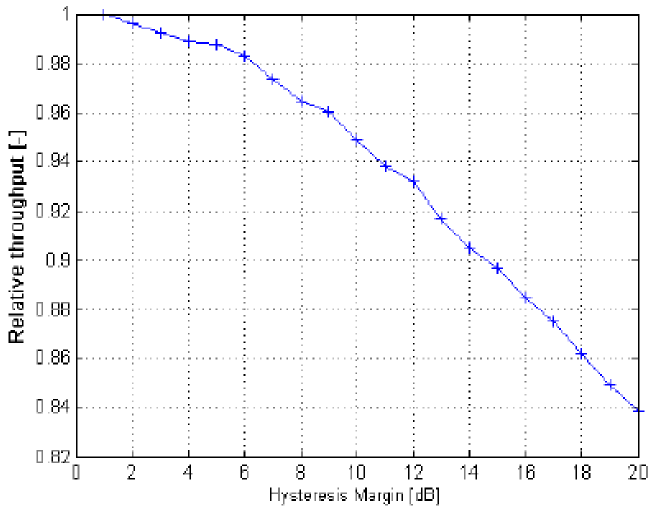

Figure 6Impact of HM duration onthroughput of single MS

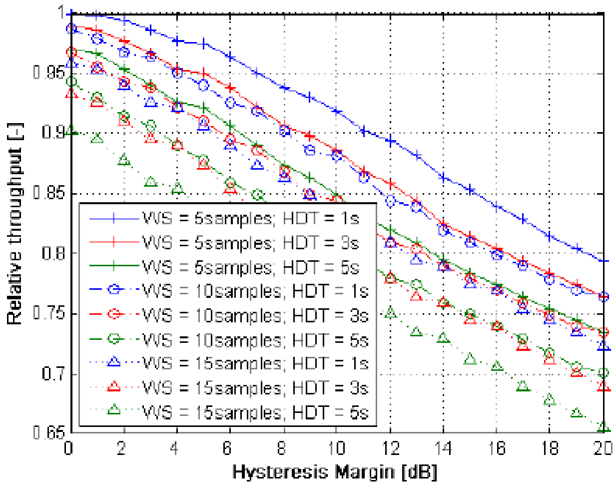

Figure 7Joint impacts of HDT andWS on throughput of single MS

V. Conclusion

This paper addresses the problem of user mobility in relation to the quality ofservice known as the handover interruption.The duration of interruption caused by hard handover depends on the duration ofthe following stages: synchronization of a MS to a target BS andnetwork re-entry. The above mentioned results lead to the assumable conclusion that the negative impact of handover can be minimized by reduction of anumber of handovers thisapproach developed exactly for this purpose. Hence, it results in thedecrease of MS's throughput.[33]The impact of handover interruption on VoIP speech quality dependson the frame duration as well as on the intervals between handovers. Therefore, theutilization of shorter frames and the reduction of the number of handovers lead to theimprovement of speech quality.

Hence this paper discusses the analysis and evaluation of the impact of techniques originally proposed withthe purpose of the reduction of the handover amount on the throughput of a singleMS.
The proposed solution is designed with respect to possible adoption to thecurrently developed IEEE 802.16m standard. Therefore, it is designed with norequirementsfor modification of hardware of currently used WiMAX devices and equipments manufactured according to IEEE802.16e standard. Only softwareModifications of handover control procedure must be implemented.

VI. Future Work

Future investigations in the area of handovers or common support of user's mobilitycan be divided into three groups. The first one is to further improve the predictionefficiency by all three techniques: handover history, channel characteristics and MS'smovement. Especially, the third one provides a lot of areas for further research (e. g. Utilization of advanced algorithms for prediction of the user's movement together withPrediction of a user's profile evolution[62]). Also the combination of those three methods canlead to the improvement of prediction efficiency.

Nextway of future investigation has been related to the implementation of RSs into network since itrequires a new approach to the handover procedure. In this scenario, the handover ismore related to the selection of the best routing path.[50] Therefore, the investigation ofinnovative techniques to enable the handover initiation based on conditions onindividual hops between a MS and its serving BS need more improvement.

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