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Performance of Mobile Communication Networks "A Dependent of Handover Techniques"

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Abstract: *Handoff is the procedure providing the connection to the backbone network while a mobile terminal is moving across the boundaries of coverage of two wireless points of connection. 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 in the case of the hard handover. This interval is called handover interruption or handover delay.The handover management procedure is defined by a sequence of management messages exchanged between the mobile stations and serving base station. Handover is very essential in mobile communication networks which mainly resides in the Base Station Subsystem (BSS).So the BSS design is heavily affected by handover process and vice versa.Mainly of this paper handover related performance evaluation issues are outlined. Different types of handover are taken into account. As no data transmission is enabled during the handover, a quality of service provided to users is temporarily impaired. It leads to a dissatisfaction of users with connection. The impact of handover interruption duration on the quality of service is also investigated in this paper in the form of voice over IP communication quality assessment. Moreover in this paper a novel procedure is analyzed from the handover interruption point of view. However,its impacton on a management overhead and user's throughput have also been discussed.*
Keywords*: Handoff, Handover Interruption,MS and Base Station.*

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I. Introduction

A **Mobile Station** (MS) is a device used by a mobile user to access the mobile network. The MS typically consists of the mobile telephone equipment and a Subscriber.To ensure uninterrupted calls while a MS is using between two different cells,two different service providers or two different environment,Handover feture which is of paramount importance.In hard handover, the mobile node has to disconnect first from the current network before connecting to the new network.This paper is organized as follows.The Handover performance is presented in **Section II,** Moreover it also describes and analyzes the problem of handover interruption occurrence. The **Section III** focuses on Methodology in which different techniques for reduction of redundant handover discussed. The **Section IV**deals with the result and discussion in which different Simulation parameters for evaluation of throughput are discussed. All evaluations of proposed techniques are done via simulations in MATLAB since it is common and universal simulation tool used for mobile networks. The **V** and **VI sections** present general conclusions of the whole paper. Additionally, it summaries possible ways of future exploration of research work inthe field of handover optimization.

1.1ANALYSIS OF HANDOVER INTERRUPTION

A Base Station (BS) is a fixed point of communication for customer cellular phones on a carrier network.The Base Station is connected to an antenna (or multiple antenna) that receives and transmits the signals in the cellular network to customer phones and cellular devices. A handover interruption in mobile wireless systems is caused by switching of a MS from a serving Base Station to a target BS. Justification of the interruption caused by the hard handover is presented in Figure 1. Before handover, the MS converse with the serving BS (Phase 1 in Figure 1). All connections with the serving BS are terminated if the 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.[1] Subsequently, new connections with the target BS are established (Phase 3 in Figure 1). The short disruption in connection begins when the MS gets cut off from the serving BS and it lasts until the MS sets up new connections with the target BS. During interruption all packets must be forwarded from the serving BS to the target BS via backbone. When the connections between the MS and object BS are established, the packets are transmitted to the MS.

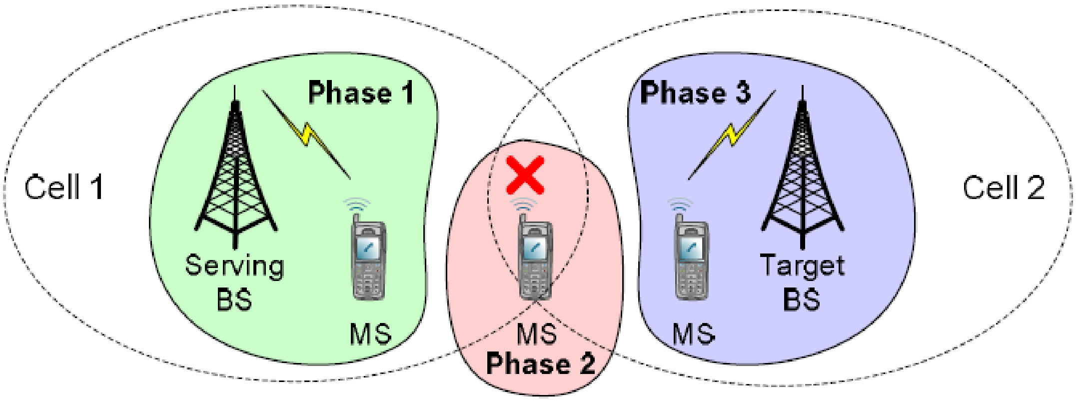

Figure 1 Interruption within Hard Handover

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

II. Handover Performance

Handoff plays a vital role in the Cellular Network and its beaviour has a direct impact on the performance of a Cellular Network in terms of Network's QoS.

2.1.HANDOVER PERFORMANCE FACTORS

There are certain factors that shows significant rolein network performance .These factors are as mentioned below :

- Handover rate
- Handover blocking probability
- Call blocking probability
- Duration of interruption of user traffic-in band signalling

2.2. TYPES OF HANDOVER

Handover is fundamentally a group of events under a common name. Their connecting glue is that they result in atleast one change in the sequence of channels that connect two users. However, they are activated by different events and they are controlled by different mechanisms **[3].**This diversity has its impact on the performance evaluation of handover. In this section, the main types of handover are available and corresponding performance evaluation issues are highlighted.

A . Radio Link

This handover type is mainly due to movement of the mobile terminal. It is based on the monitoring of radio link parameters (signal strength, interference, bit error rate) and the comparison of their values with preset thresholds. At a first glance, it should be easy to give an estimation for radio link induced handover by measuring the number of mobile terminals crossing cell borders.A more detailed analysis includes the following parameters for a given time interval:[7,8]

- Number of mobile subscribers that have entered the cell.
- Number of mobile subscribers that have left the cell.
- Number of calls transferred to the cell from neighbour number of calls generated in the cell under study.
- Number of calls transferred from the cell to neighbouring cells by the handover mechanism.
- Number of terminated calls in the cell.
- Number of calls transferred to the cell from neighbouring cells by the handover mechanism or generated in the cell.
- Number of calls that ended in the cell or were handed over to neighbouring cells.
- Number of active calls.
- Cell population.
- Duration of a call terminated within the cell.
- Time spent in the cell by a subscriber involved in a call.
- Total time spent in the cell by a call.

- Arrival time of a call in the cell.

B.Network Management

1) Congestion of a single cell:

An issue of premium importance for any mobile communication network is the optimum exploitation of the limited spectral resources. Within the day period the traffic demand varies, which may result in unbalanced traffic distribution over adjacent cells. The network could initiate handovers so that the traffic be uniformly distributed among cells. To achieve this, the network should adopt a centralised resource control scheme,responsible for collecting measurements concerning adjacent cells (needed for the handover initiation decision), as well as for adjusting the handover decision parameters accordingly.

2) Macroscopic diversity:

For the set-up of the macroscopic diversity call, the same channel must be obtained in a number of base stations. This may cause network directed handover of calls in progress to free the appropriate channels.

3) Dynamic Channel Allocation (DCA):

In order to deal with the traffic variations,it is anticipated that in a real 3G cellular systems channels will be dynamically assigned to the base stations. Due to high complexity of propagation phenomena this will be essential in microcellular environments. The DCA schemes must be compliant to traffic fluctuations and to changing interference patterns resulting at the same time in an increase of capacity.[5] DCA can be implemented by centralised or decentralized schemes, according to whether the fixed network controls the overall interference distribution or not; hybrid schemes are also possible. The efficiency of decentralised schemes is rather poor, while centralised ones significantly increase the signalling traffic load imposed on the system.

4) Distribution of trafic over a mixed cell architecture:

The use of microcell architecture results in the escalation of handover rate and signalling load. The main reasons for this may be the congestion of certain microcells, the lack of microcells serving some certain area, or the high speed of a category of users. To tackle the problem, a mixed cell architecture macrocells and microcells can be adopted. In this case, the macro cells will cater for mobile terminals being in an area not covered by microcells, or for mobile terminals that are moving with high speed, or for mobile terminals that cannot be served by microcells due to lackof channels, thus reducing the handover rate. A crucial point in a mixed cellular layout is to determine the optimum distribution of channels to the macro and micro cellular subsystems. It is well known that the highest system is obtained when calls are connected to microcellular base stations. This will imply that macrocells will be mostly used when a mobile terminal is in an area not served by a microcell or when all microcellular channels are engaged or when the macrocell is temporarily used as an umbrella cell to cope with the optimum load balancing between microcells and macrocells. In fact, when microcells are present, the macrocell can be more or less loaded by the same traffic density. In this problem has been addressed by finding that the optimum load balancing condition is reached when the macrocell is always loaded by the same traffic density no matter whether microcells are present or not.[14]

5) Information rerouting:

A handover may arise, where the network identifies that the path used for information transfer is not the shortest one.This results in releasing of the redundant system resources. If the point of attachment is changed by a handover, then a second handover may follow in order to optimise the utilisation of fixed network resources. Also, handover may occur when rerouting is needed due to identification of a malfunction at some part of the system. The related performance parameters can of course be evaluated by simulation. In that case the simulation model must take into account the routing algorithm of the fixed network. The most important parameter is the handover failure probability, because of lack of sufficient bandwidth in the fixed network. In order to invent a tractable analytical model for handovers due to information rerouting the problem should be separated from the problem of the performance evaluation of generic handovers. In such an approximate model a number of dependent call sources, one for each node point of attachment, must be constructed. The dependence should be such that after the end of a call a new call in a neighbouring node begins with some probability.This probability must be carefully evaluated by using the generic handover model. It depends on the call duration distribution, on the mobility of users and on the network .The signalling load on the fixed network due to rerouting may well be important, since it is of the same order of magnitude with the number of generic handovers.

C. Service Issues

The phenomena described in this section should normally be occasional and considering their performance is an exaggeration.

1) QoS continuity : To improve the QoS,the network may have to initiate the handover when a degradation of service quality is identified/ reported. The degradation of the service quality may have its origin in fault handling or maintenance reasons.

2) Service provision: During an active call, the mobile terminal may ask for an additional service component which is not provided at the current cell. In order to satisfy this request, the network will initiate a handover to another cell, where the required service can be offered.

3) Charging issues: It is possible that a certain service is provided in a certain location by different service providers with different tariffs. In this case, the user may initiate a handover to the service provider with the lower tariff.

III. Methodology

3.1 REDUCTION OF NUMBER OF REDUNDANT HANDOVERS

Redundant handovers (or unnecessary handovers) signify a case when the hand over is performed, however,it is not complete before the time when a next handover choice is made. Also a handover that is repeated several times between two adjacent cells can be considered as the redundant handover.[11]Several techniques can be utilized for minimization of the number of redundant handovers caused by short time channel variation (e.g. Fast fading or shadowing) or by movement of MSs along the border of the two neighbouring cells. Standard IEEE 802.16e defines Hysteresis Margin (HM) and Time-To-Trigger (TTT) for removal of the redundant handovers. Another commonly used technique is windowing (known also as signal averaging) .[29] Last method that will be considered is based on the similar principle as TTT. It is called Handover Delay Timer (HDT). All methods are based on delaying of the handover for some time interval. During this interval, the MS is not connected to the station 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 channel than a quality available from other BS. On the other hand, each stand alone method reduces 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 redundancy handovers is briefly introduced in following subsections.

(A) HYSTERESIS MARGIN

The handover decision and initiationare based on a comparison of one or several signal parameters (SINR, 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 S_i^{Tar} and S_i^{Ser} represents a signal quality parameter of the serving and the target BS respectively.

The drawback of this principle is that it cannot abolish rapid variation in observed parameter (e.g. Fast fading [26]). Moreover, it cannot cope with short time Shadowing with the decrease of signal higher than HM as it compares only current values of observed parameter.

(B) TIME TO TRIGGER

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

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

Where t_{HO} corresponds to a time when the handover decision would be done if noother technique for handover elimination is considered, and TTT is a duration of Time-To-Trigger timer. Standard [31] enables to use TTT duration with the following values:TTT$\in$(0, 255 ms). In comparison to the HM, this technique monitors signal parameters for a short time interval. Therefore, it enables to deal with, fast fading. On the other hand, a MS has to monitor signal factors for a whole duration of TTT. It leads to the drop of throughput during TTT.

Furthermore, very low level of maximum duration of TTT limits the effect of this technique (e.g. It cannot fully eliminate the ping-pong effect or shadowing with duration over 255 ms).

(C) WINDOWING

The handover decision is done if an average value of observed signal parameter from 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 as Window Size (WS).[36]

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

The proficiency of elimination of redundant handovers that are the result of ping-pong effect 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 temporary drop of a signal level due to fast fading or when a user is located in shadowed places for a short time period (longer than Reporting Period (RP)). Additionally, it enables a reduction of ping-pong effect. According to the IEEE 802.16e version of WiMAX [39], the handover starts immediately after the channel conditions (e.g. Signal levels) reach a threshold level.However the handover must be canceled (if it has not finished yet) or must be performed again (if it has completed) when a MS moves from the shadowed place. Implementation of the HDT results into insertion of a short delay between the time when handover conditions are met and the time when the handover initiation is carried out (in Figure 2). This delay is noted as HDT (HDT=2* RP in Figure 2).

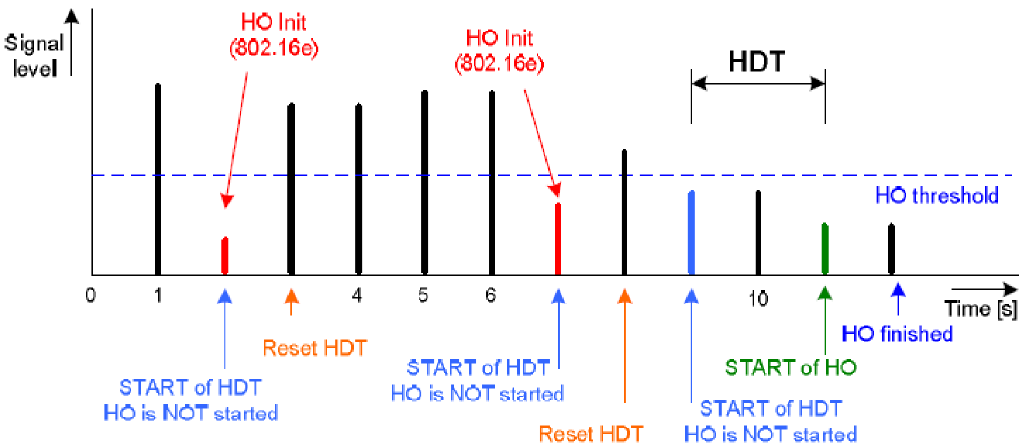

Figure 2 Handover initiation with HDT

These conditions for the handover have to be fulfilled over the whole duration of HDT to execute handover initiation. Generally, the handover is performed only if:

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

Where HDT represents a duration of the handover delay timer.

As the signal level is measured and reported to the serving BS in discrete time interval (not continuously), the handover decision is executed if the accurate number of results samples $n_{samples}$ fulfills handover conditions as expresses the next equation:

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

The samples are equivalent to an amount of a channel quality report sent during HDT from the MS to the BS, n_{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 time intervals (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 OF HM, HDT AND WINDOWING ON MS'S THROUGHPUT

All above mentioned techniques enable to reduce a amount of handovers [17], however,it is at the cost of a reduction of throughput since all of them results in a postponement of Handover execution. The delay of handover execution leads to the utilization of lower Modulation and Coding Scheme (MCS) [7] for communication between a MS (Mobile station) and its serving BS (Base station). The impact of the HM, HDT and windowing on the user's throughput is investigated for scenario with single MS (in Figure 3).

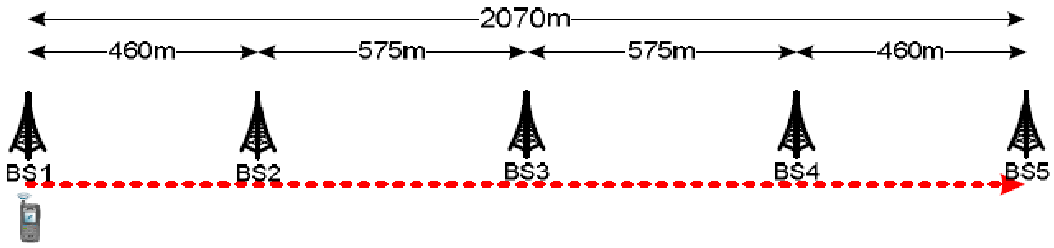

Figure 3 : Scenario for evaluation of impact of all techniques on throughput

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 optimum scanning interval for maximization of throughput [18]. All parameters for evaluation are summarized in Table .[39]

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 evaluate the maximum efficiency of a system [24]. The strength of receiving signal is used for a Calculation of the number of data carried per one downlink sub-channel (Data Per Subchannel− DPS).

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

Where No DSC express a number of data subcarriers per a sub-channel in PUSC (Partial Usage of Sub-Channels) OFDMA (Orthogonal Frequency Division Multiple Access), CR represents Code Rate and N_{ob} is a number of bits carried per one subcarrier (depending on used modulation scheme). The N_{ob} is derived from the next equation:

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

Where N_{States} is a number of modulation states.

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

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

Where SPF represents a number of sub-channels per frame.

The average throughput over the simulation duration (AvgBR) is calculated as at the weighted average of the all throughput obtained during simulation (in following formula).

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

Where S_{tD} is a duration of a simulation step, SimD is a duration of whole Simulation and N_{Steps} represent the overall number of steps during simulation. It can be calculated 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 for mobile networks. Figure 4 and Figure 5 shows the results of the impact of HDT and windowing on the throughput of single MS. The evaluation considers several levels of HM.

Significant decrease of the MS's throughput is noticeable from both figures especially with increasing HM. In both cases, the reduction of throughput for low HM is not so rapid if Shorter duration of HDT or lower amount of average samples are considered. On the other hand, the fall of throughput over the duration of HDT or WS is getting more linear for higher level of HM. The impact of only HM is depicted in Figure 6. The HM leads to the minor drop of throughput at lower levels of HM. Then the reduction of MS's throughput is more significant. Study shows that the impact of all techniques on throughput depends heavily on a deployment of BSs described by function Θ_{BS} and on a time interval between two hand overs (HO_{per}). The (HO_{per})is influenced by a speed of user v_{MS} and a movement of user (χ_{MS}). Therefore, the average bit rate can be expressed as the following function:[35]

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

Higher v_{MS},higher density of BSs and more direct movement of MSs among BSs leads to the decrease of the negative impact of all these techniques on the throughput of single MS.[28]
Combined effect of HDT and WS over HM on the throughput is illustrated in Figure7.
The figure shows that the increasing of one of the parameters while the others are constant leads to a nearly linear reduction of the throughput (compare the spacing between lines with same color or with same marker at the constant HM).[40]

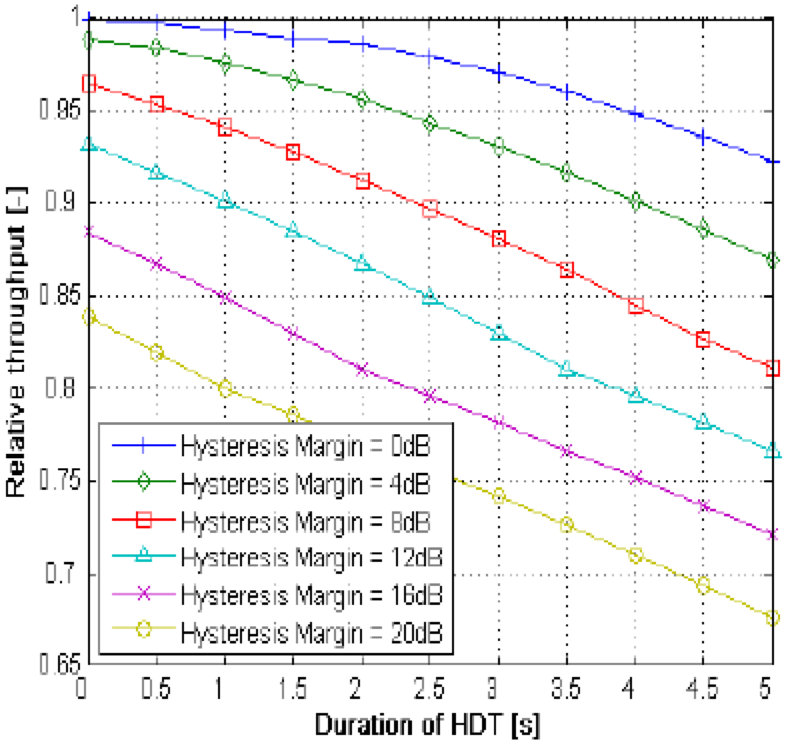

Figure 4 Impact of HDT duration on throughput of single MS

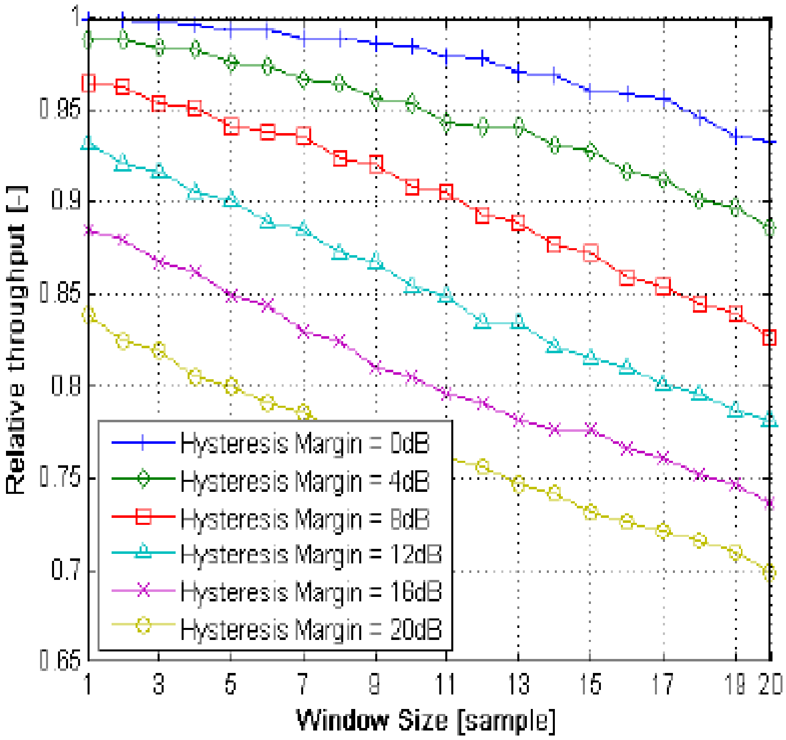

Figure 5 Impact of Window Size on throughput of single MS

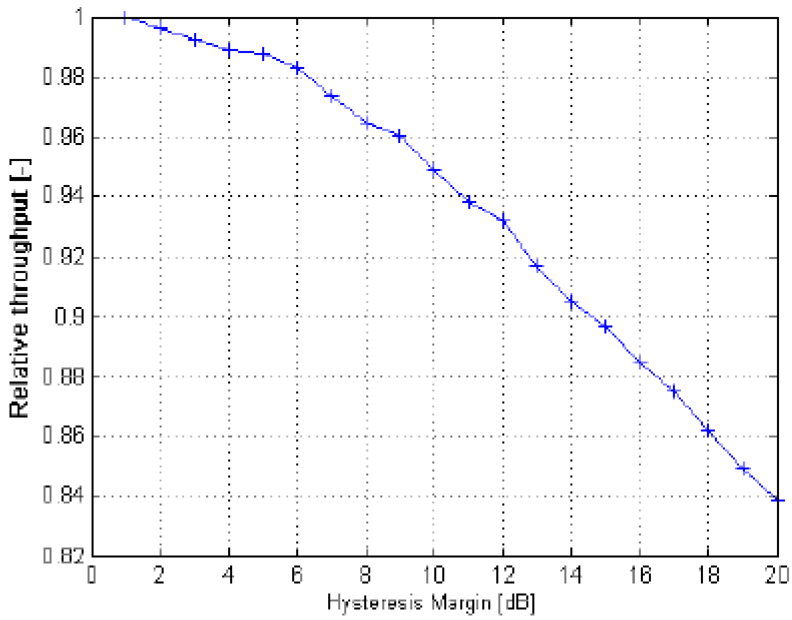

Figure 6 Impact of HM duration on throughput of single MS

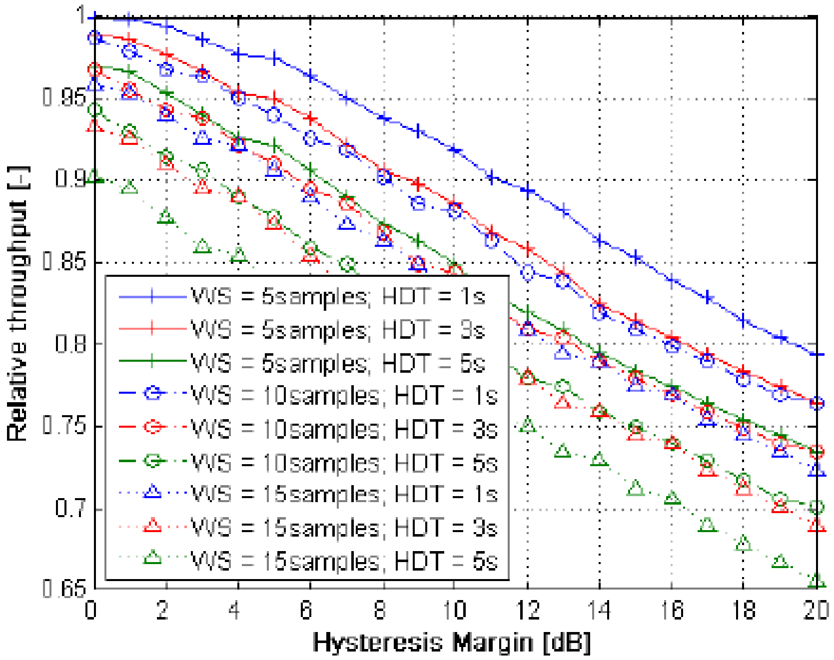

Figure 7 Joint impacts of HDT and WS on throughput of single MS

V. Conclusion

This paper discusses the analysis and evaluation of the impact of techniques originally proposed with the purpose of the reduction of the handover amount on the throughput of a single MS. It should have been clear from the beginning that the design methodology presented above is wrong, yet it may be the best available. It is wrong because there is strong interrelationship between almost all its stages.[12,34] Let us give an example: The formulation of a functional model cannot ignore the division of the system into network entities. If no physical separation existed the design would be completely different. To say the least, a communication system is necessary only because of the physical separation of its end users. This paper addresses the problem of user mobility in relation to the quality of service known as the handover interruption.The duration of interruption caused by hard handover depends on the duration of two phases: (A) Synchronization of a MS to a target BS and (B) Network re-entry.The above mentioned results lead to the assumable conclusion that the negative impact of handover can be minimized by reduction of a number of handovers this approach developed exactly for this purpose.[27]

Hence, it results in the decrease of MS's throughput.The impact of handover interruption on VoIP(voice over internet protocol)speech quality depends on the frame duration as well as on the intervals between handovers. Therefore, the utilization of shorter frames and the reduction of the number of handovers lead to the improvement of speech quality.

VI. Future Work

Future investigations in the area of handovers or common support of user's mobility can be divided into two groups. The first one is to further improve the prediction efficiency by all three techniques as mentioned below:

A. Handover history
B. Channel characteristics and
C. MS's movement

Especially, the third one provides a lot of areas for further research [42] (e.g.Mutilization of advanced algorithms for prediction of the user's movement together with Prediction of a user's profile evolution). Also the combination of those three methods can lead to the improvement of prediction efficiency. Nextway of future investigation has been related to the implementation of RSs into network since it requires a new approach to the handover procedure. In this scenario, the handover is more related to the selection of the best routing path.Therefore, the investigation of innovative techniques to enable the handover initiation based on conditions on individual hops between a MS and its serving BS need more improvement. Therefore later stages in the design process often influence preceding ones. It may be said that this problem can be cured by having more iterations, but this clearly constitutes another approximation.

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