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Time Domain Efficient Handoff Scheme for Mobile WiMAX

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Abstract: Mobility is one of the distinctive values that wireless mobile technology offers for the end user. To maintain an ongoing session without interruption, while on the move, even at vehicular speeds is one of the main mobility challenges. Such type of challenge is referred to as handoff (HO), commonly known as Handover. HO in smallest possible interval of time is one of the basic design requirements of all mobile networks including Global System for Mobile Communications (GSM) Network, Universal Mobile Telecommunications System (UMTS), and Mobile WiMAX. Performing excellent HO is one of the key objectives of Quality of Services (QoS). This paper presents a time domain efficient handoff scheme for mobile WiMAX. It is a new method to upgrade performance of HO with reference to HO time delay. For HO decision, cell reselection via scanning, initiation and network entry including synchronization and ranging with a target Base Station (BS), the proposed HO scheme follows the recommendations given in the IEEE 802.16e. This paper demonstrates HO performance metrics via simulation and the steps involved in it from one BS to other BS for efficient and successful HO. As time has direct impact on application performance perceived by a user, the proposed HO scheme takes latency as a key metric to evaluate. Simulation experiments have revealed that the proposed approach has decreased HO latency for Network Entry Time, Connection Setup Time and Service Disruption Time while minimizing HO Process.

Key words: Wireless Networks, Mobile WiMAX, IEEE 802.16e, Mobility, Handoff, Latency.

INTRODUCTION

Worldwide Interoperability for Microwave Access, commonly known as WiMAX is based on the IEEE 802.1 standard for Metropolitan Area Networks (MAN). For fixed and mobile users WiMAX facilitates delivery of wireless broadband services everywhere. For WiMAX, IEEE 802.16 standard is used as an air interface while Mobile WiMAX technology is mainly based on the IEEE 802.16e amendment, which was approved by the IEEE in December 2005. IEEE 802.16e uses Orthogonal Frequency Division Multiple Access (OFDMA) air interface and it also supports mobility (Macros, 2009). In order to achieve similar seamless mobility as that of cellular users, 802.16e includes a new MAC level request/grant mechanism (Syed Ahson and Mohammad Ilyas). Although WiMAX technology has been progressed through following four stages, i.e. narrowband wireless local-loop systems, first-generation line-of-sight (LOS) broadband systems, second-generation non-line-of-sight (NLOS) broadband systems, and standards-based broadband wireless systems (Jeffrey, 2004). It only considers fixed and nomadic links that can be used for "last mile" connectivity making an alternate to T1 and DSL wired lines or in case of Wi-Fi and cellular networks it can be used as a backhaul(Kai).

HO is one of the main mobility management issues faced during the mobile communication. This paper presents HO scheme in time domain for Mobile WiMAX. Different three handoff methods are supported in IEEE 802.16e. One of them is known as hard handover (HHO), which is a mandatory as it is the only type required to be implemented by mobile WiMAX initially. The other two types are optional. Transfer of connection from one BS to another follows an instantaneous transfer. Such a decision to HO is performed by the BS, Mobile Station (MS), or another entity, on the basis of measurement results of scanning reported by the MS. The signal quality of neighboring BSs is being measured occasionally by MS and it also performs a Radio Frequency (RF) scan.

The rest of this paper is organized as follows: Section II gives an overview of the recent related work. Section III briefly explains Mobile WiMAX HO mechanism. Section IV explains proposed time domain efficient handoff scheme. Section V presents performance analysis and Section VI gives a brief conclusion.

Related Work:

No doubt, WiMAX generated a high degree of joy within the commercial wireless industry; while being a baby plant emerged few years back, there is an immense research margin in this promising field.

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As per literature review few researchers have come up with promising HO techniques for mobile WiMAX. In (Hossam and Hussem, 2008), Fattah et al. have presented a HO scheme for the deployment of 802.16e capable stations. This scheme puts only reflection on the aspects of IEEE 802.16e operations such as ranging, authorization, and registration. It neglects steps like scanning, synchronization required in HO procedure. Without which major latency factors that are important in analyzing HO performance cannot be achieved. The scheme had tried to minimize the time spent in the HO based on the service flows, running at the MS, and lacks important delay factor that is faced while scanning process.

In (Wenhua, 2007), Jiao *et al.* have presented an enhanced link-layer QoS aware HO scheme, *Passport Handover* to assignment strategy to avoid confliction of CIDs of handing over services with that of ongoing services in the target accelerate the HO process. It reveals a connection CID BS. It has got limitation as it applies only to the delay and packet loss sensitive applications. For the non-real-time applications, the MSS (Mobile Subscriber Station) does not start the uplink transmission until new connection CIDs are assigned by the target BS, which can be crucial at times and which increases latency rate if additional time is taken in getting the new connection CIDs. In (paul), Boone et al. have demonstrated strategies, that can be used by an MS to reduce the time required for scanning operations while attempting to establish network connectivity or perform the HO between neighboring BSs. Proposed solution needs to present different HO performance metrics related to the scanning as accordingly define by WiMAX forum (www.wimaxforum.org).

In (Salhani *et al.,* 2008) have considered a model of mobility for WiMAX network users introducing horizontal HO mechanism with channel reservation. In order to carry out the reservation it takes into account different approaches which can evaluate the performance of the proposed model. It mostly considers Received Signal Strength (RSS) level and lacks reasons like Quality of Services (QoS) for HO to evaluate HO performance in more efficient manner.

In (Taaghol *et al.,* 2008) have presented specific case of seamless integration of mobile WiMAX with evolved 3GPP networks. It investigates the architecture and the key procedures that enable this integration, and also has introduced a novel HO mechanism that enables seamless mobility between mobile WiMAX and the legacy 3GPP access, such as UTRAN or GERAN. It does not define overall steps of HO involved in such seamless integration.

In (Chen *et al.*, 2007)have presented a pre-coordination mechanism (PCM) for supporting fast handover in WiMAX networks and enhancing disruption time (DT). It measures the distance between BS and MSS and predicts time at which the handover occurs. It performs pre-allocation of available resources for handover usages, which is not optimized solution to minimize the disruption time, in spite of the fact that paper mentions achieving DT approximately 11 milliseconds.

In (Majanen *et al.*, 2009) have presented a novel simulation model for ns-2 network simulator called WISMU. It discusses HO technologies with reference to throughput and network re-entry time by using association and HO optimization via BS-BS signaling. It limits its work to BS-BS signaling and association level and has ignored HO process, takes Mobile IP tunnel as key contributor to the work.

Related work in this section defines a generalized solution for HO. While as this proposed paper gives a comprehensive solution in the light of IEEE 802.16e. To the best of our literature research, there has been as such no work on minimizing *HO process.*

The proposed scheme is aimed at to minimize the HO process for the mobile WiMAX, within minimal use of resources; which eventually reduces different latency parameters that are important in the HO process. Main focus is to minimize latency parameters, including Network Entry Time (NET), Connection Setup Time (CST) and Service Disruption Time (SDT). Mobility models have been shown in the section of HO scheme and their results have been analyzed. Results have shown reduced latency time for NET, CST and SDT while minimizing the HO process.

Mobile WiMAX Handoff Mechanism:

HO function presented by IEEE 802.16e system is used to support mobility of MS. Due to fading because of mobility, the signal quality of the serving BS deteriorates; the MS hands over to another BS that can present a better quality signal level and QoS.

HO procedure is divided into two processes for the IEEE 802.16e: network topology acquisition and HO process(Syed Ahson and Mohammad Ilyas).

Network Topology Acquisition:

The network topology acquisition is aimed to collect information before an actual HO occurs. During this process the information about channel’s description and its physical quality from an MS’s neighboring BSs are determined. By performing a network topology advertisement process and a scanning process, information about the network topology is acquired (Syed Ahson and Mohammad Ilyas).

An MOB_NBR-ADV message is used by BS to advertise information about the network topology; however, it is broadcasted periodically by the BS. At least one MOB_NBR-ADV message should be broadcast every 30s by BS (IEEE Standard for Local and Metropolitian Area Networks, Part 16, 2006).

With the reception of the MOB_NBR-ADV message, an MS is made aware of the existence of neighboring BSs. An MS analyzes their suitability to locate a target BS for HO i.e. MS scans neighboring BSs.

Once an MS is made aware of the existence of neighboring BSs by reception of the MOB_NBR-ADV message, it monitors their suitability to find a target BS for HO; that is, the MS scans neighboring BSs. The following messages are classified for this scanning process (Syed Ahson and Mohammad Ilyas): to request scanning and to negotiate scanning parameters MOB_SCN-REQ message is issued by the MS. MOB_SCN-RSP is sent by the BS, to inform the MS its approval or rejecting the scanning request in reply as a response to the MOB_SCN-REQ message.

HO Process:

The handoff process is described as the set of procedures and decisions for mobile WiMAX, which facilitates an MS to migrate from the air interface of one BS to the air interface of another. It consists of the following stages:

Cell reselection: Neighbor BS information obtained from MOB_NBR-ADV message, can be used by MS. Such information is also used during the cell reselection stage in order to determine BSs suitability as HO target, the MS performs scanning and association with one or more neighboring BSs. After performing cell reselection, normal operation is resumed with the serving BS by MS.

HO decision and initiation: HO process initiates with a decision for an MS to HO from a serving BS to a target BS. However this decision may be originated either at the MS or the serving BS. Using the messages MOB_MSHO-REQ or MOB_BSHO-REQ, the HO decision is acknowledged containing a notification of MS intent to HO.

HO cancellation: As ongoing call can be cancelled at any time. In case of HO cancellation for the mobile WiMAX networks, it is mostly done after transmission of MOB_HO-IND message, that an MS may cancel HO at any time though prior to expiration of Resource_Retain_Time interval.

Synchronization to target BS downlink: In order to obtain Downlink (DL) and Uplink (UL) transmission parameters, MS has to synchronize to the downlink transmissions of target BS. The process may be shortened in case MS has previously received a MOB_NBR-ADV message that contains target BSID, Physical Frequency, DCD and UCD.

Use of scanning and association results: The target neighboring BSs are scanned by MS. It also provides an option to try association. During association MS can associate itself to one or more neighboring BSs with the help of initial ranging and different three levels of association (Jeffrey *et al.*).

Ranging: After synchronization phase, an initial or simply know as HO ranging is performed with the target BS downlink. Common time interval is informed using an MOB_BSHO-REQ or MOB_BSHO-RSP message while as target BS provides dedicated initial ranging transmission opportunity for the MS.

Termination with the serving BS: As a result services with serving BS are terminated by the MS, after receiving an MOB_BSHO-RSP or MOB_BSHO-REQ message in case the MS decides to carry out an HO. Whereas such type of operation is accomplished by sending an MOB_HO-IND message with the message of serving BS release.

Drops during HO: During the HO when an MS ceases to communicate with its serving BS before the normal HO procedure has to been completed. After showing its failure to demodulate the DL or by the failure of the periodic ranging mechanism, a drop can be detected by the MS.

Network entry/reentry: After a successful ranging process MS starts to perform network entry procedures with a new BS.

Following are the messages that are associated with the HO process:

In order to initiate HO, MOB_MSHO-REQ is issued by an MS. It also includes the recommended neighboring BS information.

As a response, an MOB_BSHO-RSP is sent by a BS to reception of the MOB_MSHO-REQ message. For the HO function it delivers information about the recommended neighboring BSs.

For initiation of HO, MOB_BSHO-REQ is issued by a BS that wants to initiate it. The MS that receives this message scans the recommended neighboring BSs that are specified in this message.

The Proposed Handoff Scheme:

Problem Statement:

As mentioned in section II, mobile WiMAX is newly developed technology introduced few years back. It needs to have enhancements in HO related issues. It is crucial for HO process to take much time during any of IEEE802.16e defined steps. Keeping in view delay problem, the proposed time domain scheme has been designed for mobile WiMAX HO.

In order to ensure real-time applications, mobile WiMAX supports optimized HO schemes with latencies less than 50 milliseconds such as VOIP performs without service degradation (Mobile wiMAX Part 1, 2006).

Though HO is one of the central issues of mobility management, and performing it efficiently in time domain perspective is critical in providing a good user experience. In order to prevent loss or interruption of services, an operation of transferring ongoing connection from one BS to another BS is performed (Naima Rehmani and Abid Ali minhas, 2010).

It is necessary that HO should be performed successfully, but it needs to occur as infrequently and imperceptibly as possible (Jeffery *et al.*).

To put together these challenges of HO mobility, time domain efficient HO scheme has been proposed. As the user moves across BSs, it supports seamless handing over an ongoing session from one BS to another. Since HO process requires many steps to complete the procedure, it becomes risky due to increase in delay parameters.

Therefore, an advance approach has been demonstrated which shows how to minimize the HO process for the mobile WiMAX, within minimal use of resources and how it reduces time delay. It also shows different latency parameters that are important in the HO process.

Although previously mentioned work in mobile WiMAX tried to focus on minimizing different latency rate parameters, but it needs to be further polished and improved. In order to improve latency time, this scheme is defined which focuses on improving NET, SDT and CST.

The proposed solution includes exploring the performance of HO with its different latency parameters. The system is to be modeled using 3-tier cell topology. And for this time domain approach, the proposed solution is simulated and excellent results are produced. Main design goal of the proposed approach is to minimize the main three delay parameters i.e. NET, CST and SDT while minimizing HO Process (Naima Rehmani and Abil Ali Minhas, 2010).

This Proposed time domain efficient HO scheme consists of two main steps, network topology advertisement (acquisition) and main HO process, as explained below:

Network Topology Advertisement:

During this step of proposed solution which is before the start of actual HO process, serving BS advertises information about the network topology. It is done by broadcasting MOB_NBR-ADV message every 30s [15]. With this advertising message, MS is in continuous process of looking for or scanning for the neighboring BS which could be its target BS. Fig. 1 showed the pseudo code used during the advertising process for the neighboring BSs reception, whereas Fig. 2 shows pseudo code for the cell reselection or process of MS scanning.

```
If BS = bsType.Serving Then
    If req = Request.MOB_NBR_ADV Then
Return NeighborAdvertisement()
swTimer.Reset()
swTimer.Start()
BS.ProcessRequest(Request.MOB_NBR_ADV,
bsType.Serving)
swTimer.Stop()
AddStatus(Request.MOB_NBR_ADV.ToString(),
swTimer.Elapsed.TotalMilliseconds)
```

Fig. 1: Algorithm neighboring BSs reception

```
sw.Reset()
sw.Start()
BS.ProcessRequest(Request.MOB_SCN_REQ,
bsType.Serving)
sw.[Stop]()
AddStatus("T1- " & Request.MOB_SCN_REQ.ToString(),
sw.Elapsed.TotalMilliseconds)
System.Threading.Thread.Sleep(50)
T1 = sw.Elapsed.TotalMilliseconds
```

Fig. 2: Process of MS Scanning

In the proposed scheme BS broadcasts information about the network topology using the MOB_NBR-ADV message. This message usually provides channel information for neighboring BSs which is normally provided by each BS's own Downlink/Uplink Channel Descriptor (DCD/UCD) message transmissions [1]. During the network topology advertisement and scanning as shown in Fig. 3, MS receives the parameters for its target BSs through serving BS. Then scanning request is sent to target BSs which contains its scan duration, number of iterations and measures physical channel quality during synchronization with target BSs. With this response from the target BSs network topology advertisement and scanning process is completed (Syed Ahson and Mohammd Ilyas).

HO Process:

As soon as the scanning process completes as discussed above, actual HO begins. For time domain efficient handoff, it is considered as a first step of the scheme. For a network topology, as shown in Fig. 4, a 3-tier cell topology is defined with five MS nodes each with a considers different line patterns for its cell clusters. Each cell cluster in this tier is comprised of 7 cell structure.

In case of this HO scheme MS initiated HO is designed, so HO decision is achieved with a notification of MS intent to HO through MOB_MSHO-REQ as shown in Fig. 4. An initial ranging or commonly known as HO ranging is conducted between an MS and a target BS after the synchronization process with the target BS's downlink.

Latency parameters that are defined for each MS as per standard to analyze NET, CST and SDT are as follows (Naima Rehmani and Abil Ali Minhas, 2010):

T1 = Time required to perform neighbor BS scanning by using variable MOB_SCN-REQ

T2 = Time required to perform neighbor BS synchronization by using variable MOB_SYNC_REQ

T3 = Time required to perform MS initiated HO request by using variable MOB_MSHO_REQ.

T4 = Time required to perform contention-based ranging by using variable RNG_REQ_CB.

T5 = Time required to perform contention-free ranging by using variable RNG_REQ_CF.

T6= Time required to perform basic capability negotiation by using variable CAP_NEGO_CF.

T7 = Time required to perform authentication and key exchange by using variable AUTH_KEY_EXG.

T8 = Time required to perform registration by using variable MOB_REG_REQ.

For each of the above parameters time values are defined in milliseconds.

Network Entry Time is defined as a value that represents the delay between an MS's radio layer synchronization at T2, and its completion of a Layer 2 network entry procedure at T3, due to HO occurrence. This consists of ranging, UL resource request processes (contention or non-contention based), negotiation of capabilities, and registration.

Success/failure rates of all HO MAC messages must be consistent with the packet error rate used for data (WiMAX System Evaluation Methodology, 2007).

The NET is calculated by using following for WiMAX standard [12].

$$\text{NET} = \frac{\sum_{i=1}^{N_{HO\_success}} (T_{3,i} - T_{2,i})}{N_{HO\_success}} \quad (1)$$

Radio Layer Latency (RLL) is the value that measures the delay between the time instance T1, that an MS transmits a serving BS its commitment to HO (for a HHO, this is the time that the MS disconnects from the serving BS) and the time instance T2, that the MS achieves the success of the PHY layer synchronization (i.e., frequency and DL timing synchronization) due to HO (WiMAX System Evaluation Methodology, 2007).

$$RLL = \frac{\sum_{i=1}^{N_{HO\_success}} (T_{2,i} - T_{1,i})}{N_{HO\_success}} \quad (2)$$

Connection Setup Time is the value that represents the delay between the completion of Layer 2 network entry procedure at T3, and the transmission of first data packet from new BS (target BS) at T4, due to handoff occurrence (WiMAX System Evaluation Methodology, 2007).

$$CST = \frac{\sum_{i=1}^{N_{HO\_success}} (T_{4,i} - T_{3,i})}{N_{HO\_success}} \quad (3)$$

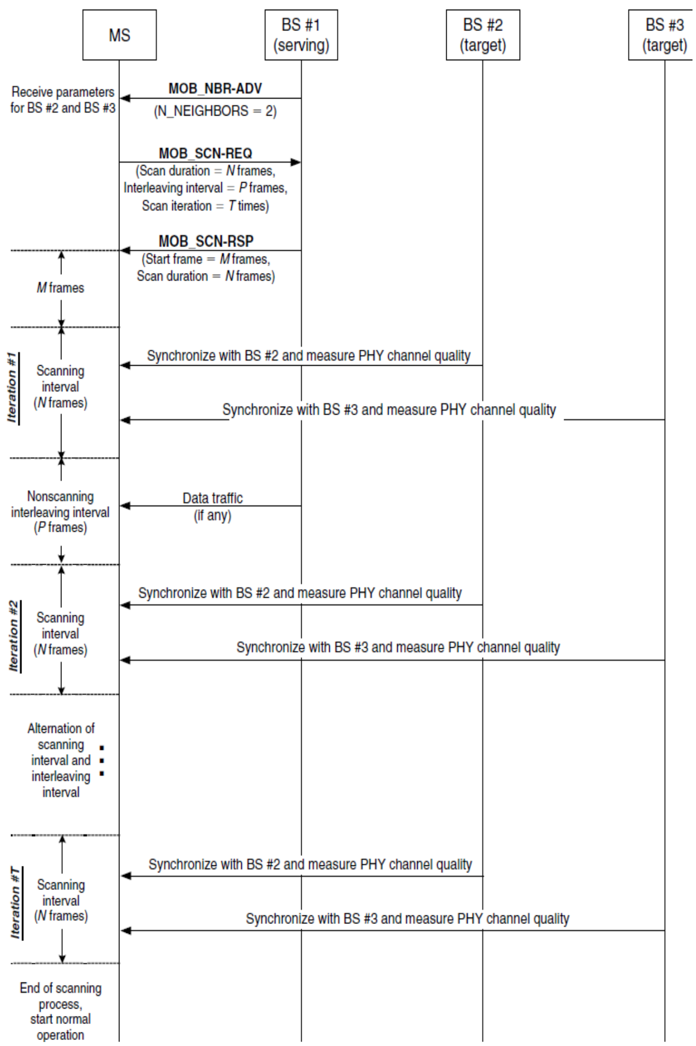

Fig. 3: Network topology advertisement process and scanning (Syed Ahson and Mohammad Ilyas)

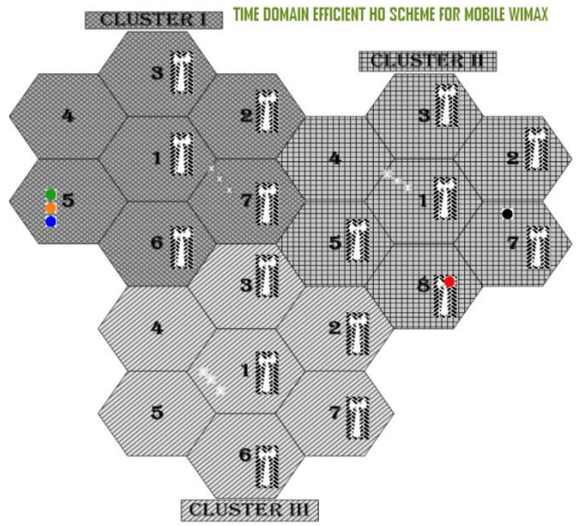

Fig. 4: Cell topology for simulation

During HO process, results of different latency parameters are defined. Due to these results T1 to T8 delay results are produced. Putting the values of T1, T2, and T3 in equations (1), (2) and (3), NET, CST, SDT and RLL can be derived for the standard.

Depending on the amount of the information Target BS may decide to skip one or several of the following Network Entry steps i.e. negotiate basic capabilities, PKM Authentication phase, TEK establishment phase, Send REG-REQ and BS may send unsolicited REG-RSP message with updated capabilities information or skip (IEEE Standard for Local and Metropolitan Area Networks). Using Ref. (IEEE Standard for Local and Metropolitan Area Networks), above parameters and equation; we prove in this scheme that as NET is the value that represents the delay between an MS's radio layer synchronization at T2, and its completion of a Layer 2 network entry procedure at T3, due to HO occurrence. The NET of the proposed scheme is:

Where,

$T2 = MOB\_SYNC\_REQ$

$T3 = MOB\_MSHO\_REQ$

Service Disruption Time is the value that represents time duration that a user can not receive any service from any BS. It is defined as the sum of RLL, NET and CST due to handover occurrence.

As in [6], indicates that the service interruption time of conventional scheme is:

$$D = Tsync + Tcont\_resol + Trng + Tauth + Treg \quad (4)$$

While as the service interruption time of proposed scheme in (Wenhua *et al. 2007*) is:

$$D = Tsync + Tcont\_resol + Tr \quad (5)$$

As SDT represents time duration during which user can not receive any services from BS. On the basis of Proposed HO process and in view of (Wenhua *et al. 2007*), SDT of the proposed scheme is:

$$SDT_{Proposed} = T2 + T4 + \quad (6)$$

Where,

$T2 = SYNC$

$T4 = RNG\_REQ\_CB$

$T5 = RNG\_REQ\_CF$

As CST is the delay between completion of network entry procedure and transmission of first data pack from new BS. So according to the proposed handoff process flow chart the CST for proposed scheme is:

$$CST_{Proposed} = T3 + T8 \quad (7)$$

Where,

$T3 = MOB\_MSHO\_REQ$

$T4 = REG\_REQ$

Fig. 5 has shown MS initiated HO, so HO decision is achieved with a notification of MS intent to HO through MOB_MSHO-REQ. For the proposed time domain efficient handoff scheme the simplified proposed HO scheme flowchart is depicted in Fig. 6. It shows the process of cell reselection, Ho decision and initiation, etc till the selection of alternative target BS. Fig. 7 shows the MS HO initiated flow chart of messages exchanged during proposed handoff scheme.

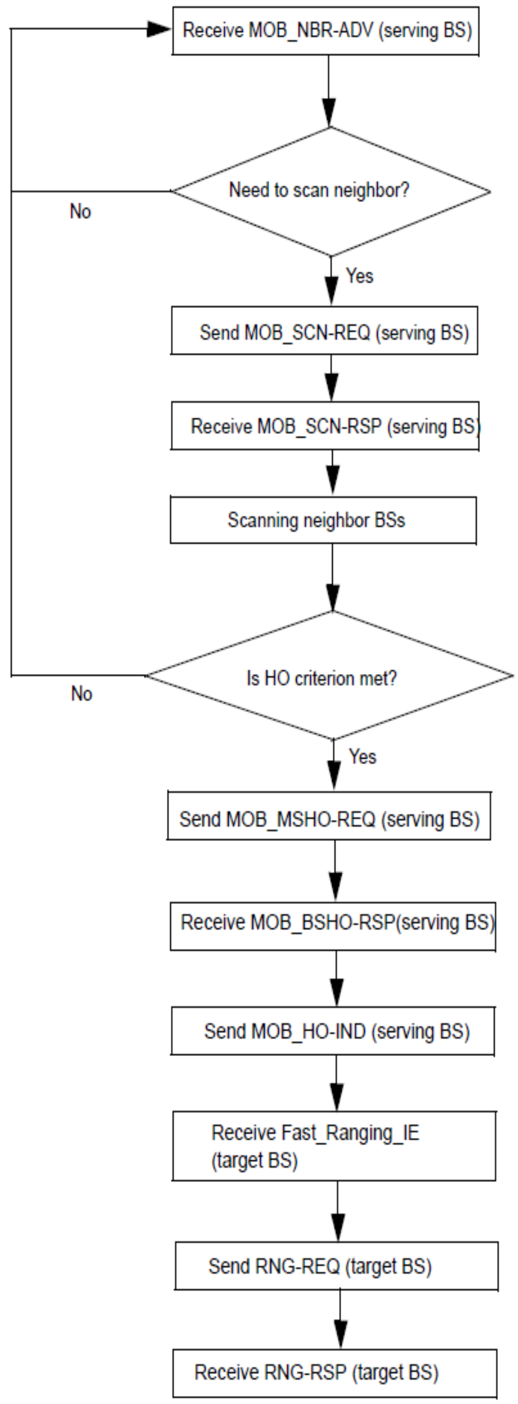

Fig. 5: Initiation of HO Process by MS (IEEE Standard for Local and Metropolitan Area Networks).

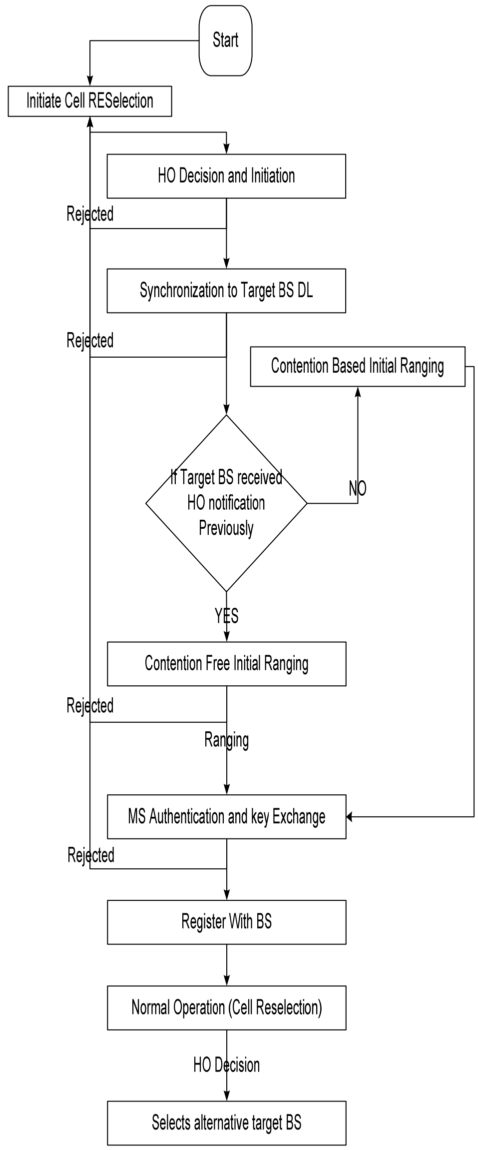

FIG. 6: SIMPLIFIED PROPOSED HO PROCESS

Performance Analysis:

In this section, simulation results and analysis of time domain efficient HO scheme for point to multi-point WiMAX structure, from one BS to another using various types of mobility models is presented.

At the beginning of the simulation, input parameters are taken for the time domain scheme. These parameters are also applied to calculate the path loss for the HO and used to calculate signal strength. Fig. 8 depicts input parameters for the simulation. Normal HO triggers after end of scanning process or step one of the scheme i.e. on clicking the start button as shown in Fig. 9 main simulation interface. It is the interface which is shown after input parameters are entered. As the simulation starts serving BS advertises information about the network topology as shown in Fig. 10. In this figure three advertising messages are displayed during advertisement and scanning process. These MOB_NBR-ADV messages are transmitted by BS after every 30s.

This handoff scheme considers different line patterns for its cell clusters. Crossed line pattern of cells are considered as cluster I, square line pattern as cluster II and diagonal line pattern as cluster III. Three MS nodes can be seen in Cell 5 of cluster I. While as 2 MS nodes are connected with the BSs of Cell 7 and 6 of cluster II respectively.

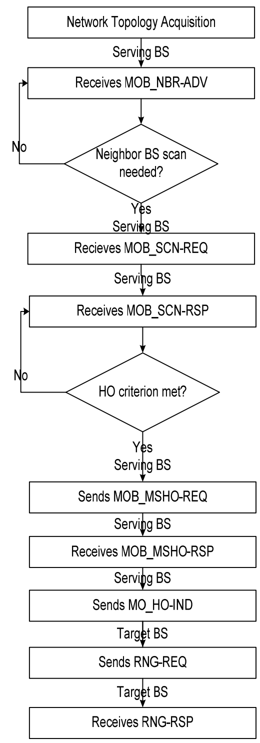

Fig. 7: Proposed HO Process message exchange

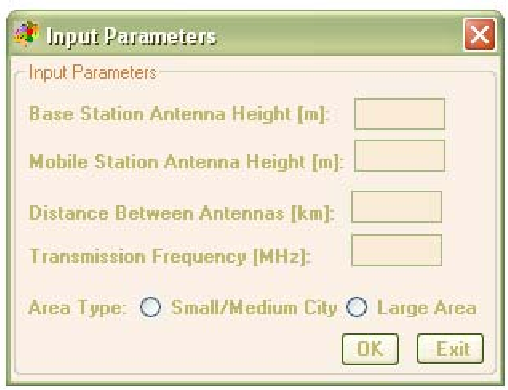

Fig. 8: Input parameters for simulation

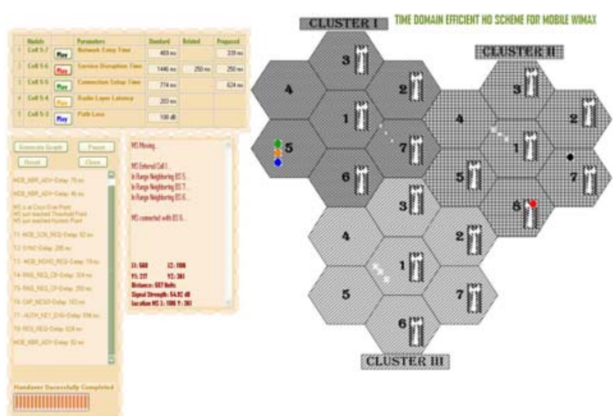

Fig. 9: Main Interface for Simulation

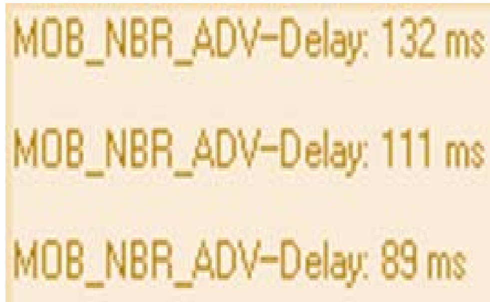

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Fig. 10: Broadcasting information using MOB_NBR-ADV message

For each of the latency parameters snapshot of the simulation for the variables is shown in Fig. 11 for the time taken by MS in each of the parameters for mobility model from cell 5 of cluster I to cell 7 of cluster II.

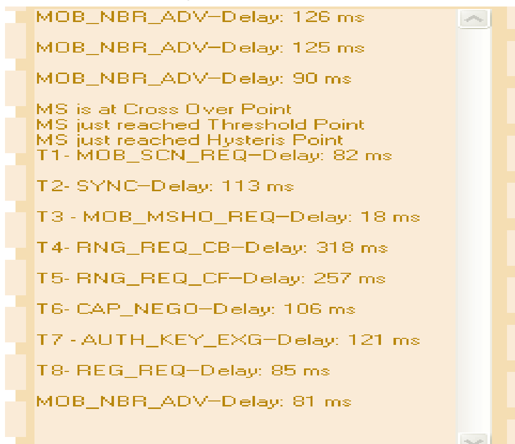


Fig. 11: MS HO results from Cell 5 to Cell 7 mobility model

Channel Modelling:

It is too complex to model accurately actual environments. Most of the simulation models use empirical models that are developed based on the measurements taken in various environments (WiMAX Sysem Evaluation Methodology, 2007). The nearly suited empirical path loss model that can be used for this HO scheme is COST 231, an Extension to Hata Model. As IEEE 802.16e operates in 2 GHz frequency bands with a cell radius of 1-3 miles having mobility up to 120 km/h, so the proposed scheme assumed that the simulation runs on 2 GHz frequency. This path loss model is mainly designed for large and small macro-cells, with base station antenna heights above rooftop levels adjacent to BS.

The European Cooperative for Scientific and Technical (COST) research extended the Hata model to 2 GHz as follows (8):

$$P_{L,Urban}(d)dB = 46.3 + 33.9\log_{10}(f_c) - 13.82\log_{10}(h_t) - a(h_r) + (44.9 - 6.55\log_{10}(h_t))\log_{10}(\qquad (9)$$

Where, C_M is 0 dB for medium sized cities and suburbs and is 3 for metropolitan areas. is the frequency, is the height and d defines distance between BSs. These remaining parameters are taken as input parameters for the algorithm as shown in figure 8.

The input parameters that were taken for the proposed scheme are Base Station Antenna height, Mobile Station Height, Distance between antennas and the transmission frequency. The area has been divided on the bases of transmission frequency in terms of small/medium type and large type of area with respect to mobile speed.

In most cases the model is applied to the following range of parameters given in Table I.

Table I: Parameters for Analyses and Simulations

Parameters	Value
Carrier Frequency	2 GHz
Base Antenna Height	30m
Mobile Antenna Height	0.01m
Distance *d*	1 km to 20 km
Topology	3-Tier cluster 7 cell topology
Simulation Length	In Milliseconds
Signal Strength	In Decibel (dB)
No. of Mobile Stations	5
Radius of each cell	3miles
Channel model	COST 231 Extension to Hata Model
Cell Range	30-miles radius from BS
No. of mobility models	5

Mobility Models:

As the MS starts moving, its X and Y coordinates are generated from the HO starting point to the end point where the HO process is completed. The proposed scheme displays the location of MS randomly as it moves on. Distance formula is applied to find out its distance as shown in Fig. 10. Given the two points (x_1, y_1) and (x_2, y_2), the distance between these two points is given by the formula (10):

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{10}$$

As defined, distance is inversely proportional to the signal strength; so the scheme generates its signal strength during HO [26]. With the increase in distance between BS and MS the signal strength degrades.

Statistical Analysis:

Simulation framework supports mobility of mobile equipment from any cluster to any other cluster. But, in fig. 13 only cluster I to II is shown. For example when one clicks *play* button for cell 5-7 mobile, following route is followed; first the MS enters cell 1, where from it gets in range with neighboring BSs 2, 6, 7 of cluster II and eventually it gets connected with BS 7 of cluster II on the basis of its signal strength and distance calculated.

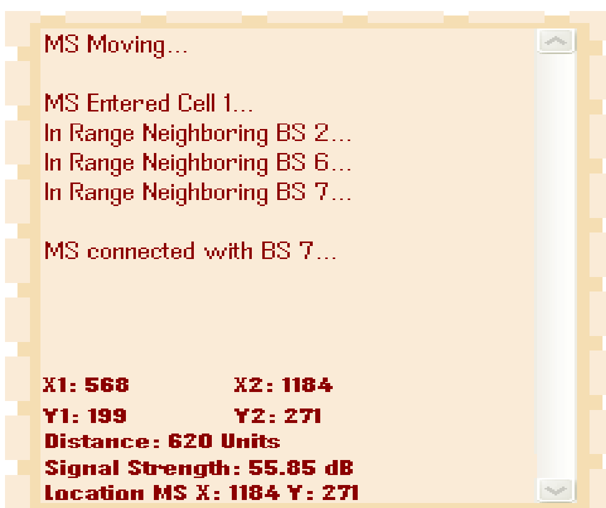
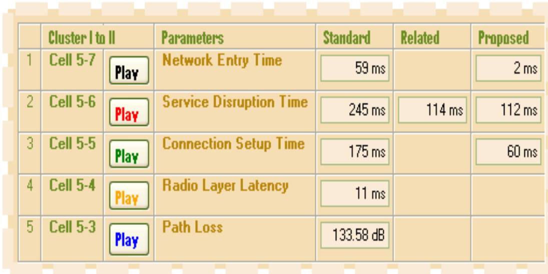


Fig. 12: Calculated Distance for MS from one BS to other

Mobility models that are defined for the simulation and the time taken by MS in each of the proposed parameters are shown in Fig. 13. Results shown in this figure are shown for the cluster I-cell 5 to cluster II-cell 7 and the calculated distance and signal strength for it is already shown above in Fig. 12.



	Cluster I to II		Parameters	Standard	Related	Proposed
1	Cell 5-7	Play	Network Entry Time	59 ms		2 ms
2	Cell 5-6	Play	Service Disruption Time	245 ms	114 ms	112 ms
3	Cell 5-5	Play	Connection Setup Time	175 ms		60 ms
4	Cell 5-4	Play	Radio Layer Latency	11 ms		
5	Cell 5-3	Play	Path Loss	133.58 dB		

Fig. 13: Latency for conventional and proposed parameters for cluster I-cell 5 to cluster II-cell 7

Results Analysis:

This part of section evaluates the performance of the time domain efficient handoff scheme for mobile WiMAX in metrics of number of neighboring BSs and time. Time taken for each of parameter results is divided in 1000ms. The number of neighboring BSs used is 7 for that of proposed as well as conventional scheme parameters. Blue bar represents proposed results while as red bar display conventional results.

Fig. 14 is shown for the mobility model of cluster I-cell 5 to cluster II - cell 7 by bar graph for conventional network entry time with the network entry time of proposed scheme. It has shown network entry time in milliseconds for both conventional as well as proposed network time against number of neighboring BSs. When the number of neighboring BSs is just one, the NET for the proposed scheme is 9ms where as conventional NET is 129ms. This trend is maintained when number of neighboring BSs is three, so conventional and proposed NET remains same.

Fig.15 is shown for the mobility model of cluster I - cell 5 to cluster II - cell 7 using bar graph for conventional connection setup time with the proposed Connection Setup Time. It has also shown Connection Setup Time in milliseconds for both conventional as well as proposed Connection Setup Time against number of neighboring BSs. When the number of neighboring BSs is single, the CST for the proposed scheme is 121ms where as conventional CST is 467ms. While as when number of neighboring BSs is seven, time taken in conventional CST is 269ms and proposed CST is 77ms.

In Fig. 16 mobility model for the cluster I - cell 5 to cluster II - cell 7 is shown using bar graph for conventional Service disruption time and that of proposed Service Disruption Time. It takes Service Disruption Time in milliseconds for both conventional as well as proposed Service Disruption Time parameters against neighboring BSs. For each of the graphs shown, during simulation and experiments number of neighboring BSs taken is seven.

As visible form figure proposed SDT nearly maintained same level of time taken in it.

When the number of neighboring BSs is single, the SDT for the proposed scheme is 238ms where as conventional SDT is 631ms. While as when number of neighboring BSs is two, time taken in conventional SDT is 639ms and proposed SDT is 258ms.

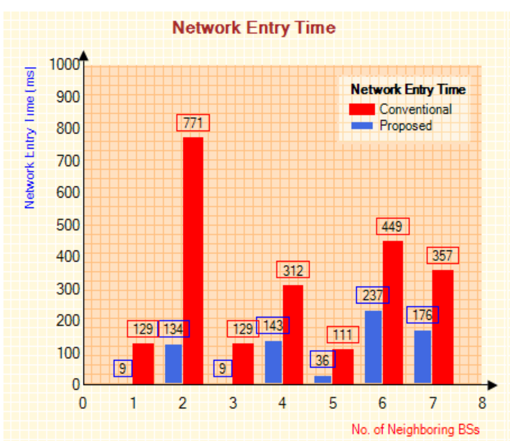


Fig. 14: Conventional vs. Proposed Network Entry Time

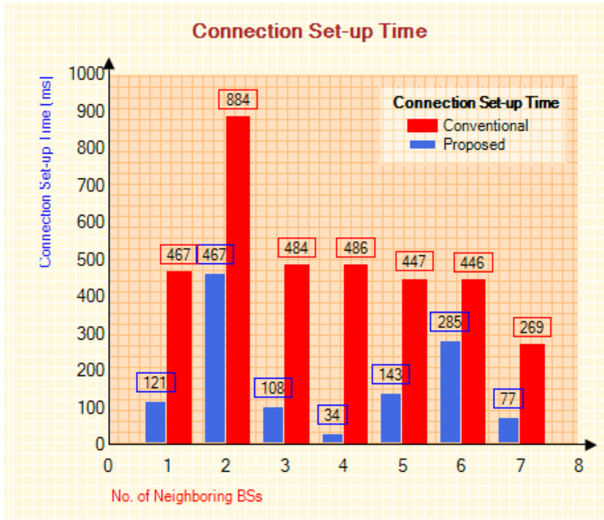


Fig. 15: Conventional vs. Proposed Connection Set-up Time

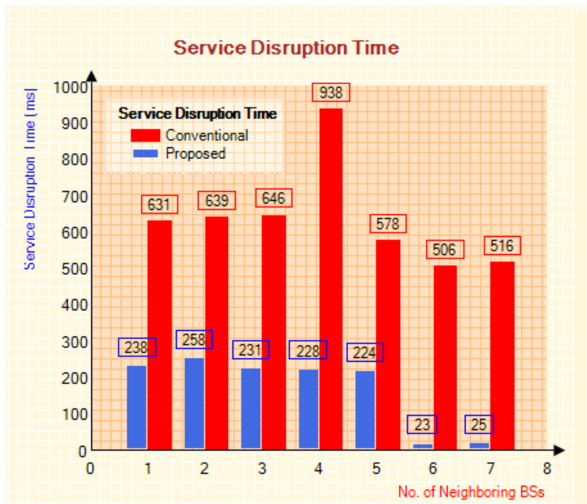


Fig. 16: Conventional vs. Proposed Service Disruption Time

Conclusion:

In this paper, a time domain efficient handoff scheme has been proposed in order to minimize NET, CST and SDT latencies. Mobility models have been simulated and their results were analyzed in the above section. Paper has evaluated HO performance and improved the latency parameters within the minimal use of resources. Time taken in NET is achieved up to 29% less in respect to conventional NET. While as proposed CST is achieved to get improved results up to 40% as compared to conventional CST. And the DST for the proposed scheme is achieved by 27%. Simulation has also proved that the propose HO scheme is more efficient as compared to the conventional or usual scheme. It is observed that the proposed HO scheme gains merits in the aspects of improving latency parameters for the mobile WiMAX network. Overall, proposed HO scheme is an effective, scalable, and simple.

Future Work:

There is always a space to improve any system development or enhance any application. Real world deployments are ultimately the ideal evaluation environment. To determine the flexibility that HO scheme is able to cope with, implementation of proposed HO scheme can be carried out in Mobile WiMAX.

Further work can also be carried out for improving Radio Layer Latency time, HO failure or implementing any other performance metrics like HO drop, HO cancellation. This algorithm can be extended for HO between mobile WiMAX network and 4G network, which could possibly fulfill all security needs related to message authentication, integrity and confidentiality. There are many related issues that can be further investigated.

For practical implementation, the accurate estimation of all the latency parameters investigated, T_i i.e. T1 to T8 deserve further research. One can investigate how the delay constraint can be absolutely guaranteed by manipulating the value of T_i.

Fairness is another important metric to evaluate the performance of a proposed HO scheme.

A general mobility model is assumed in this thesis. However, the mobility model variation affects the performance of schemes. This impact can be investigated in future work.

Finally, a validation of the results against other simulators should be done when appropriate.

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