Handoff in Mobile WiMAX: Forced Handoff Scheme with Load Balancing in Mobile WiMAX Networks

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Abstract— **Mobile WiMAX is a rapidly growing broadband access technology based on IEEE 802.16 suite of standards. Supporting fast and seamless handover is a key requirement for the implementation of an efficient mobility framework in WiMAX systems. The IEEE 802.16 standard defines only the handover management framework but does not specify any specific handover techniques. Thus, devising efficient handover techniques and mechanism are of utmost importance. This paper proposes and devises an efficient forced handover technique in mobile WiMAX to improve performance and capacity handling of base station.**

Keywords-component; Mobile WiMAX; 4G; 802.16, Handoff, Load Balance, Forced Handover

I. INTRODUCTION

Problem like unbalanced traffic load distribution [1,2] between different WiMAX adjacent cells can force the traffic load in a particular cell to exceed the ultimate capacity of that cell. With the overlapping nature of the cells, unevenly distributed resource utilizations among the different adjacent BSs incur additional cost and reduce the service quality. Therefore, evenly balancing the loads and evenly distributing the different available resources within a cluster of BSs is a critical research issue. Though the Mobile WiMAX Forum has supported a Radio Resource Management (RRM) framework for efficient load balancing and resource utilization with the help of BS-initiated directed handovers, the specification provides only a framework and lacks any detailed implementation concepts and algorithms. Thus, it is an open research issue. This paper starts with the introduction of WiMAX architecture and Handover (HO) process followed by Various methods of HO. At the end a fast handover scheme is presented and comparison with existing WiMAX HO techniques is evaluated.

A. *WiMAX Network Architecture*

When WiMAX network started to deploy, it targeted only stationary devices with roof mounted antennas or indoor WiMAX routers. That version of WiMAX is known as IEEE 802.16-2004 or 802.16d. Since these networks designed to handle stationary devices, so no handovers of connections between base stations are required.

Second version of WiMAX known as IEEE 802.16-2005 or 802.16e or mobile WiMAX is the advanced air interface which not only supports mobility of subscribers but also handovers between base stations. Since mobile subscribers and handovers require more administration so it became necessary to define the network beyond base stations. As IEEE is only responsible for the air interface so that task was carried over by WiMAX Forum. Moreover in order to ensure interoperability of devices and components among variety of vendors, WiMAX forum also conducts certification program for base stations, network equipments and end user devices. Figure 1 shows Mobile WiMAX network reference model [4,5].

As evident from the figure 1, R1 reference point is the air interface between mobile devices and base station. This is fully based on IP protocol. The protocol used over this interface is either IEEE 802.16d for only fixed clients or IEEE 802.16e for both mobile and fixed clients. Base stations can carry out smooth handovers among them using R8 interface. R6 interface is between base stations and Access Service Network Gateway (ASN-GW). ASN-GW is the gateway between radio network and core network. R3 interface is defined between ASN-GW and core network.

B. *The Handover Process in Mobile WiMAX*

The MS, using its current information on the neighbor BS or after a request to obtain such information, evaluates its interest in a potential handover with a target BS [3]. The handover process is made of five stages as described in figure 2;

- Cell Reselection
- Handover Decision and Initiation
- Synchronization to Target BS Downlink
- Ranging and Network Re-entry
- Termination of MS Context.

1) *Cell Reselection*

Cell reselection refers to the process of an MS scanning and/or association with one or more BS in order to determine their suitability, along with other performance considerations, as a handover. The MS may use neighbor BS information acquired from a decoded message or may make a request to schedule scanning intervals or sleep intervals to scan, and

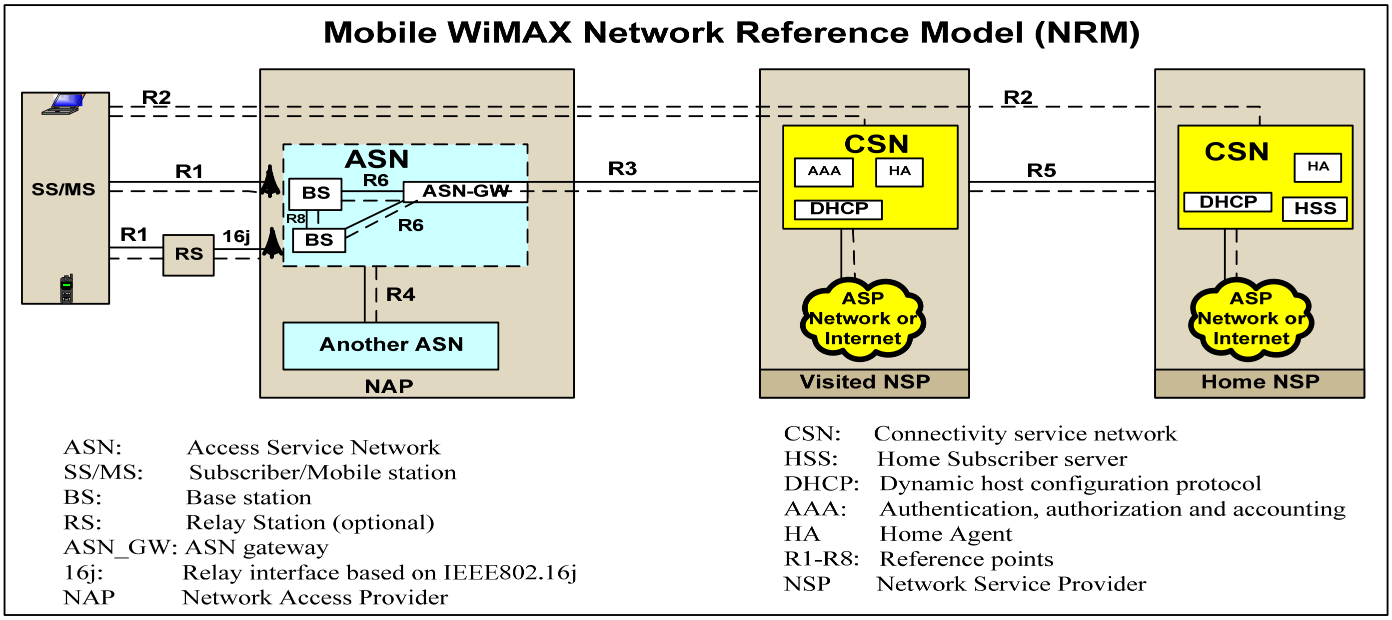

Figure 1. Mobile WiMAX Network Reference Model (NRM)

possibly range, the neighbor BS for the purpose of evaluating the MS interest in handover to a potential target BS.

2) Handover Decision and Initiation

A handover begins with a decision for an MS to make a handover from a serving BS to a target BS. The decision may originate either at the MS or the serving BS.

3) Synchronization to Target BS Downlink

Synchronization to a Target BS downlink must be done. If the MS had previously received a MAC management message including a target BSID, physical frequency, this process may be shortened. If the target BS had previously received handover notification from a serving BS over the backbone, then the target BS may allocate a non-contention-based initial ranging opportunity.

4) Ranging and Network Re-entry

The MS and the target BS must conduct handover ranging. Network re-entry proceeds from the initial ranging steps in the Network Entry process: negotiates basic capabilities, authentication phase, establishment phase, registration and optional network entry steps. Network re-entry may be shortened by target BS possession of MS information obtained from serving BS over the backbone network. Depending on the amount of that information, the target BS may decide to skip one or several of network entry steps. Following are network re-entry steps,

a) Negotiate basic capabilities
b) Authorization
c) Registration
d) Establish service flows

Regardless of having received MS information from a serving BS, the target BS may request MS information from the backbone network.

5) Termination of MS Context

Termination of the MS context is defined as the serving BS termination of the context of all connections belonging to the MS and the discarding of the context associated with them.

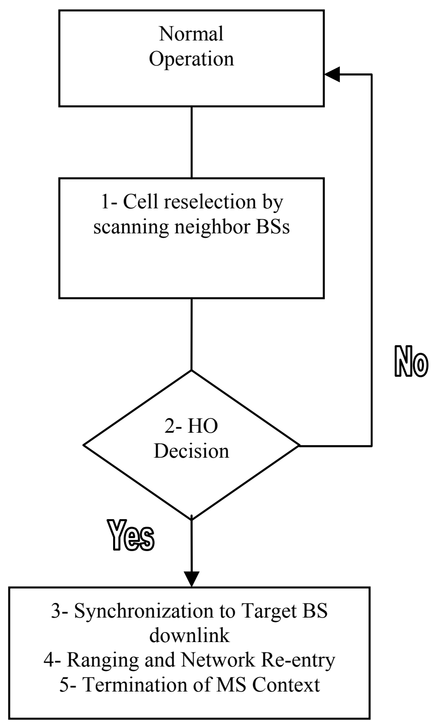

Figure 2. Handover Process

II. Types of Existing Handover

A. Fast BS Switching (FBSS)

An FBSS handover begins with a decision for an MS to receive and transmit data from/to the anchor BS that may change within the diversity set. When operating in FBSS, the MS only communicates with the anchor BS for uplink and downlink messages (management and traffic communication). The MS and BS maintain a list of BSs that are involved in FBSS with the MS. This is the FBSS diversity set. The MS scans the neighbor BSs and selects those that are suitable to be increased in the diversity set. Among the BSs in the diversity set, an anchor BS is defined. An FBSS handover is a decision by an MS to receive or transmit data from a new anchor BS within the diversity set.

The MS continuously monitors the signal strength of the BSs of the diversity set and selects one of these BSs to be the anchor BS. Transition from one anchor BS to another, i.e. BS switching, is performed without exchange of explicit handover signaling messages. An important requirement of FBSS is that the data are simultaneously transmitted to all members of a diversity set of BSs that are able to serve the MS.

B. Macro Diversity Handover (MDHO)

An MDHO begins with a decision for an MS to transmit to receive from multiple BSs at the same time. When operating in an MDHO, the MS communicates with all BSs in the diversity set for uplink and downlink unicast traffic messages. For downlink MDHO two or more BSs provide synchronized transmission of MS downlink data such that diversity combining can be performed by the MS. For an uplink MDHO, the transmission from an MS is received by multiple BSs such that selection diversity of the information received by multiple BSs can be performed. The BSs involved in an MDHO or equivalently a member of an MS MDHO diversity set must use the same CIDs for the connections that have been established with the MS. The same MAC/PHY PDUs should be sent by all BSs involved in the MDHO to the MS.

III. Part I: No Forced Handover Scenario in WiMAX

A. WiMAX Handover scenario Simulation Parameters

The simulation WiMAX network is composed of three WiMAX base stations forming three cells, one serving base station and two neighboring base stations named as Serving BS, Nbr_BS_1 and Nbr_BS_2 respectively. As shown in figure 3, Serving_BS cell has 7 mobile stations (MS), neighboring base stations both have 8 MS. All MS carrying 64 Kbps of voice traffic. Serving_BS cell MS's remain stationary while all Nbr_BS_1 and Nbr_BS_2 Cells MS's have trajectories that start movement around 110 seconds. All these MS's end their movement between 115 and 120 seconds when they reach in the vicinity of Serving_BS Cell. Serving BS has BS ID of 0, Nbr_BS_1 has BS ID of 1 while Nbr_BS_2 has BS ID of 2.

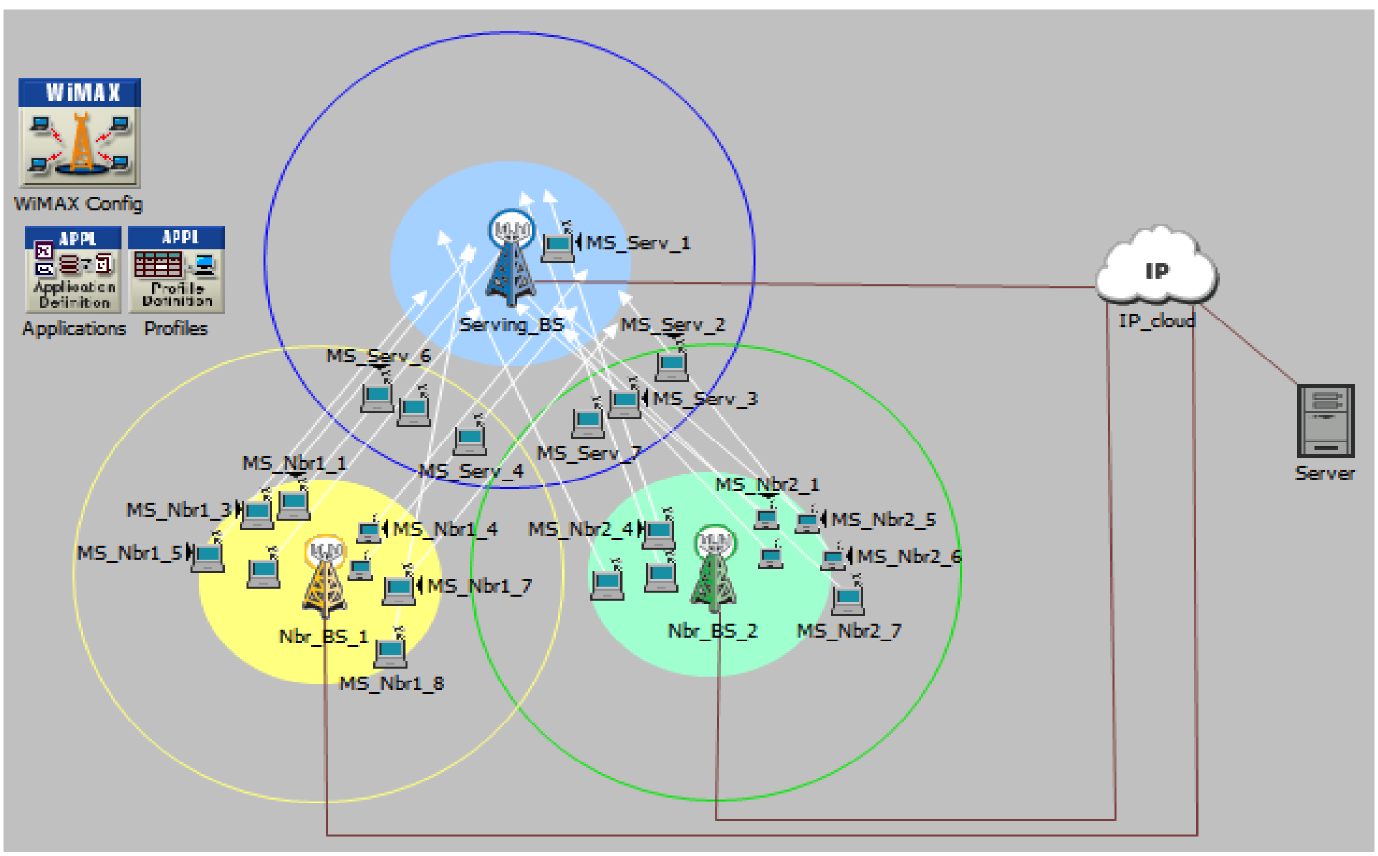

Figure 3. WiMAX Handover scenario Simulation

After simulating the conventional WiMAX network without forced handover, we get the following results.

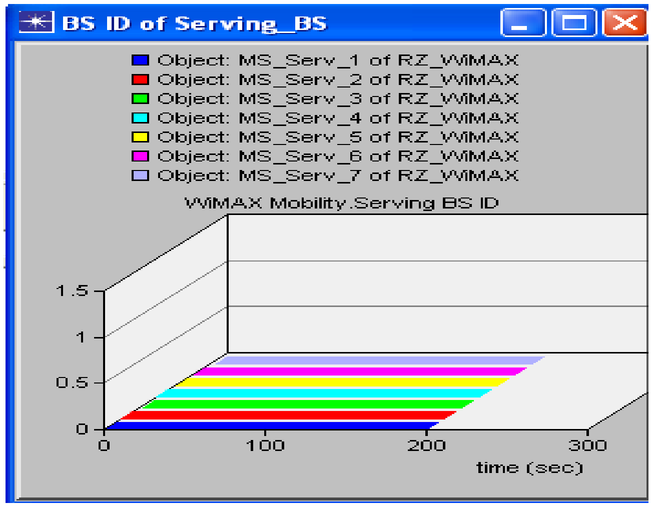

Figure 4. Conventional WiMAX network without forced handover

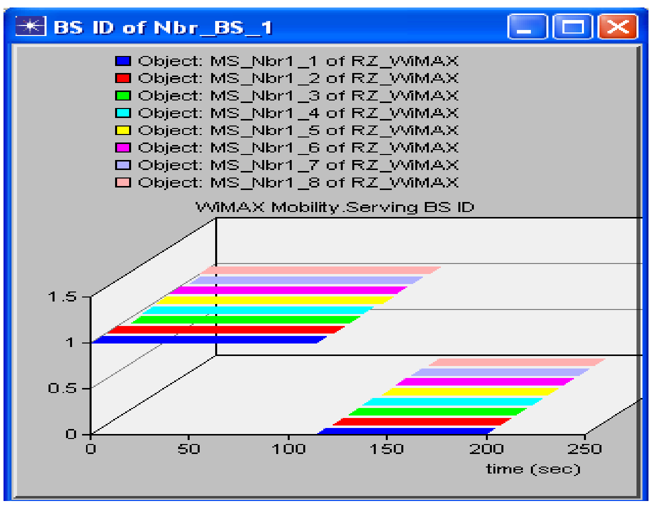

Figure 5. WiMAX network without forced handover (MS_NBR_1)

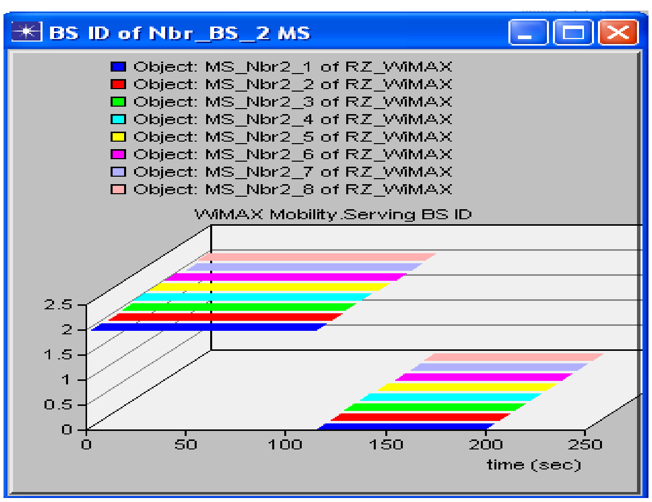

Figure 6. WiMAX network without forced handover (MS_NBR_1)

From figure 4 it is obvious that BS ID of MS's remain 0, which is the BS ID of Serving_BS, through the course of simulation. While Figure 5 & 6 show that after 110 seconds the BS ID of MS's belong to Nbr_BS_1 and Nbr_BS_2 change from 1 to 0 and 2 to 0 respectively

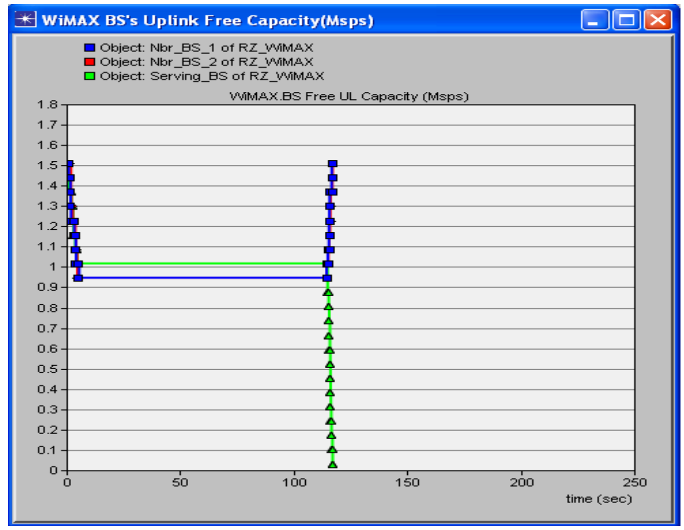

Figure 7. WiMAX network without forced handover

Figure 8 is obtained after zooming of the graph in Figure 7 for the period when Nbr_BS_1 and Nbr_BS_2 MS's converging to the Serving_BS.

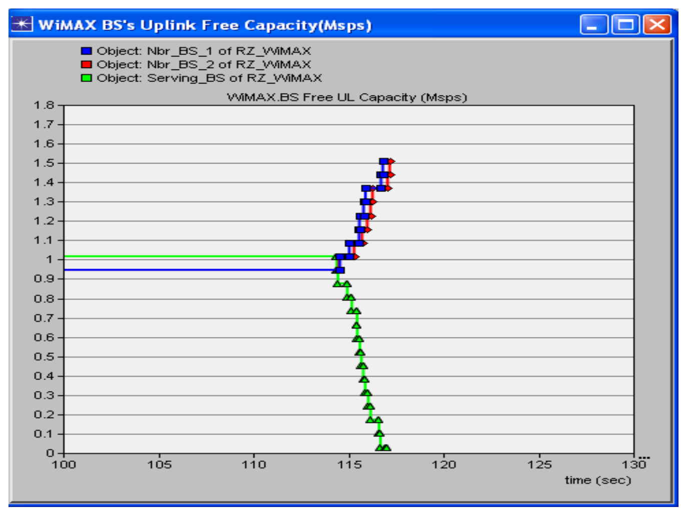

Figure 8. WiMAX network without forced handover

For the uplink voice connection of 64 Kbps, actual demand placed on the network would be 96 Kbps due to the overhead included by protocol layers. Since the WiMAX BS or MS capacity is given in symbols per seconds (sps). We are using QPSK ¾ modulation so each MS would require around 70 Ksps or 0.07 Msps for its uplink voice connection.

When a BS grants capacity to a MS in response to DSA-REQ, its capacity is reduced. The BS releases resources for a MS that left the cell after handover is complete and resource retain timer is expired and so its capacity is increased. This is quite clear from the Figure 7 and Figure 8 that when a MS joins a BS its capacity is decreased by 0.07 Msps and when a MS leaves a BS its capacity is increased by 0.07 Msps around 116 seconds, Serving _BS reached its capacity. The line in the graph is unchanged which shows that BS receives DSA-REQ message but rejects it because of lack of resources. This happens when capacity is exhausted in Serving_BS.

Figure 9 shows the throughput of MS's by their BS. Before 110 seconds all MS's have throughput of around 64 Kbps. Between 110 and 120 seconds the capacity of most MS's is interrupted temporarily because of handover.

For Serving BS, throughput of MS's is reduced temporarily after 110 seconds because MS's from Nbr_BS_1 and Nbr_BS_2 attach to Serving_BS. This reduction is because of the interference caused by MS's from neighboring BS's as they enter into Serving_BS. This interference is for the duration until handover is complete. However MS_serv_1 is unaffected of this interruption as it is very close to the BS.

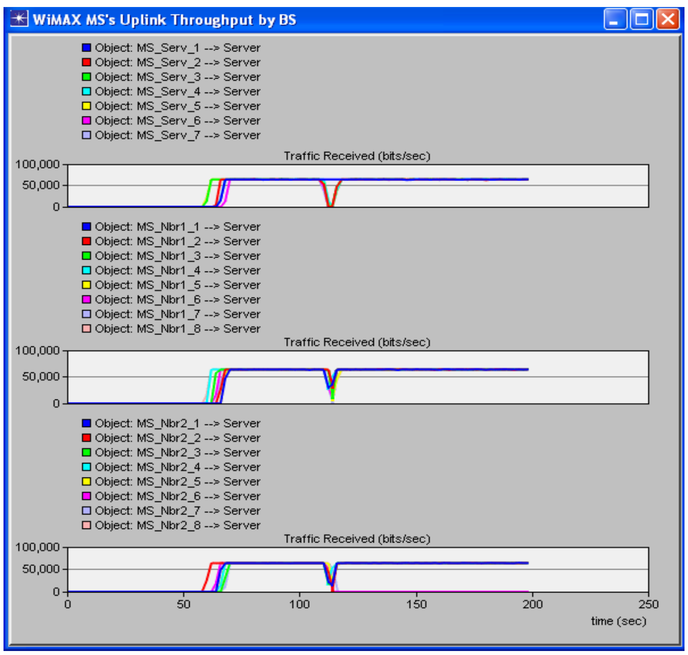

Figure 9. WiMAX network without forced handover

For Nbr_BS_1, their MS's start moving around 110 seconds so their throughput is reduced temporarily as they complete their handover to the Serving_BS.

For Nbr_BS_2, their MS's also start moving around 110 seconds and their throughput is also reduced temporarily but since Serving_BS was reaching its capacity, so connections of two MS's are rejected i.e., MS_Nbr_6 and MS_Nbr_7 as show in Figure 9.

IV. Part II : WiMAX Forced Handover

It is obvious in part I that in conventional WiMAX network if MS's attach to a serving BS then its capacity keeps on decreasing until its resources exhaust and then it rejects the incoming connections whereby resources are available in the neighboring BS's. In this part we present a new handover scheme which requires the co-ordination of BS and MS.

A. Proposed Algorithm

If the serving BS capacity crosses 80% threshold and the neighboring BS has more than 25% capacity available and its SNR as measured from the MS candidates is not less than 5 dB then it sends unsolicited MOB_BSHO_RSP message to the MS candidate. MS candidates then process unsolicited MOB_BSHO_RSP and after initial ranging attach themselves to the neighboring BS and send MOB_HO_IND (release) message to the serving BS. The process is shown in figure 10.

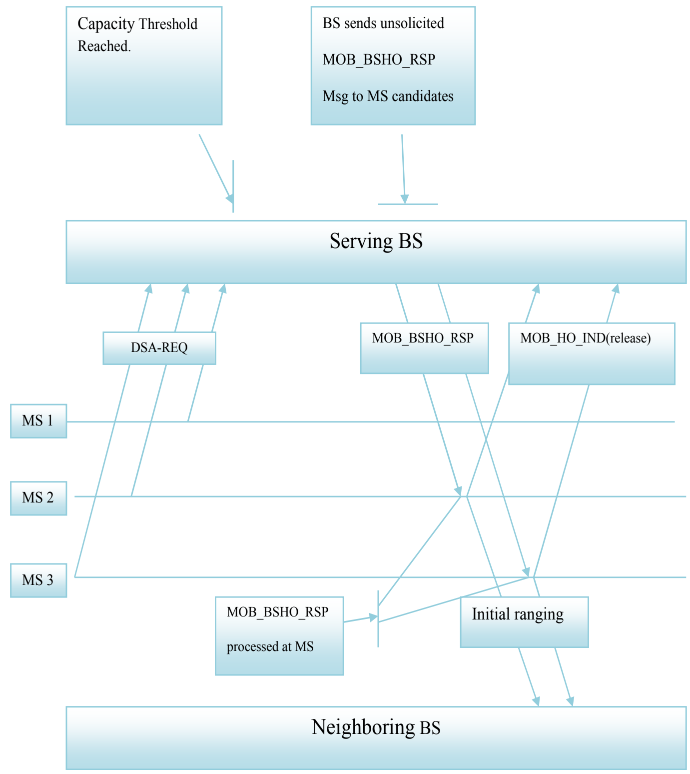

Figure 10. Handover Process Algorithm

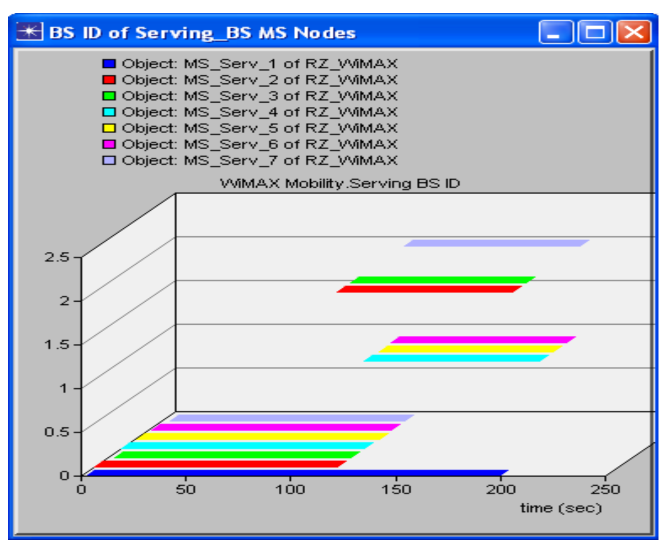

Figure 11. Forced Handover Scenario

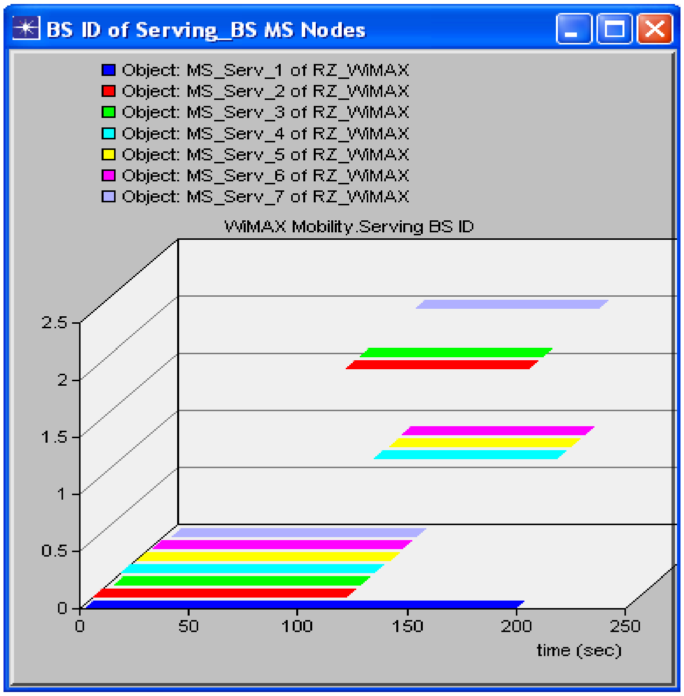

Figure 12. Forced Handover Scenario

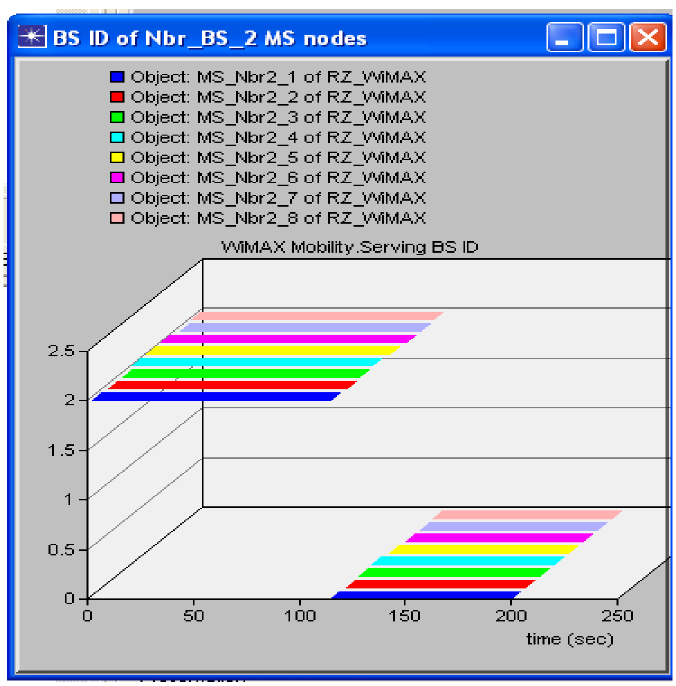

Figure 13. Forced Handover Scenario

It is obvious from Figure 13 that MS nodes of Serving BS changed their serving BS ID to Nbr_BS_1 and Nbr_BS_2 after 110 seconds as these base stations had available capacity and their own BS was exhausting resources because of handoff process.

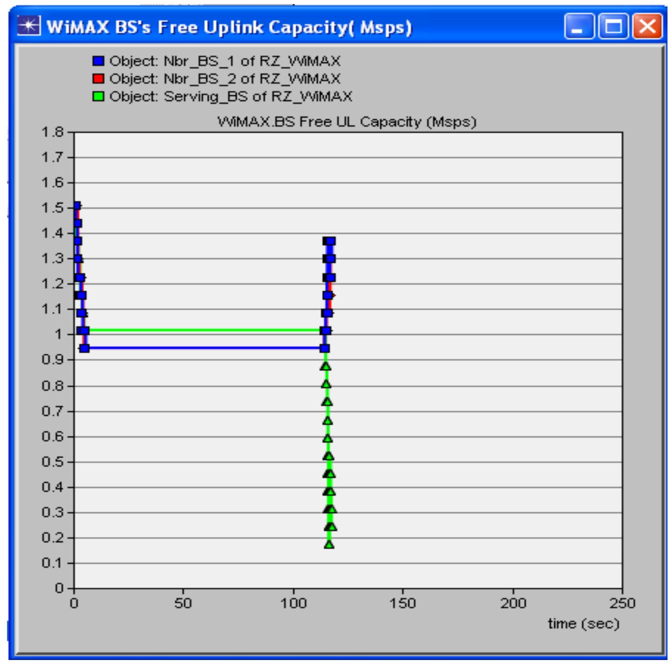

Figure 14. Forced Handover Scenario

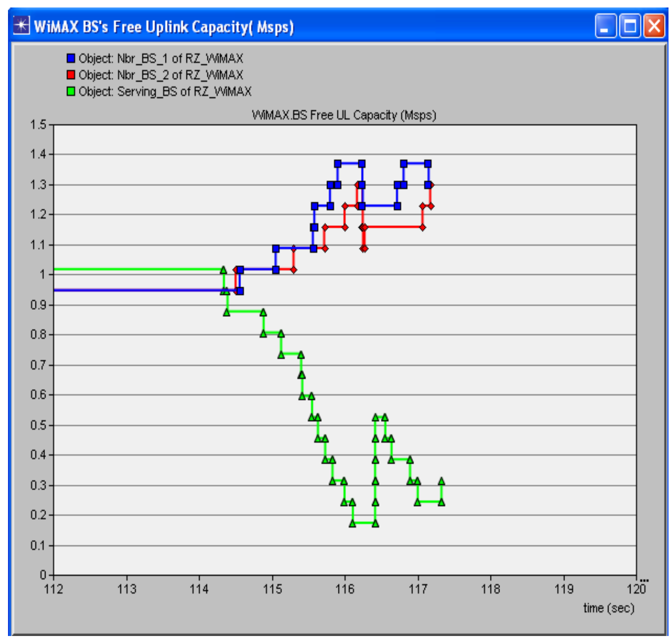

Figure 15. Forced Handover Scenario

Figure 15 is obtained from Figure 14 after zooming for the portion from 110 to 120 seconds. It is obvious from Figure 15 that as the capacity of Serving_BS crosses over 80% and a MS from neighboring BS wants to join it then the Serving_BS invokes the program and MS that fulfill the criteria are handoff to the neighboring base stations.

Finally Figure 16 shows that all MSs retain their voice connection at around 64 Kbps after handover and none of them drop their signal as compared to the case of conventional WiMAX set up.

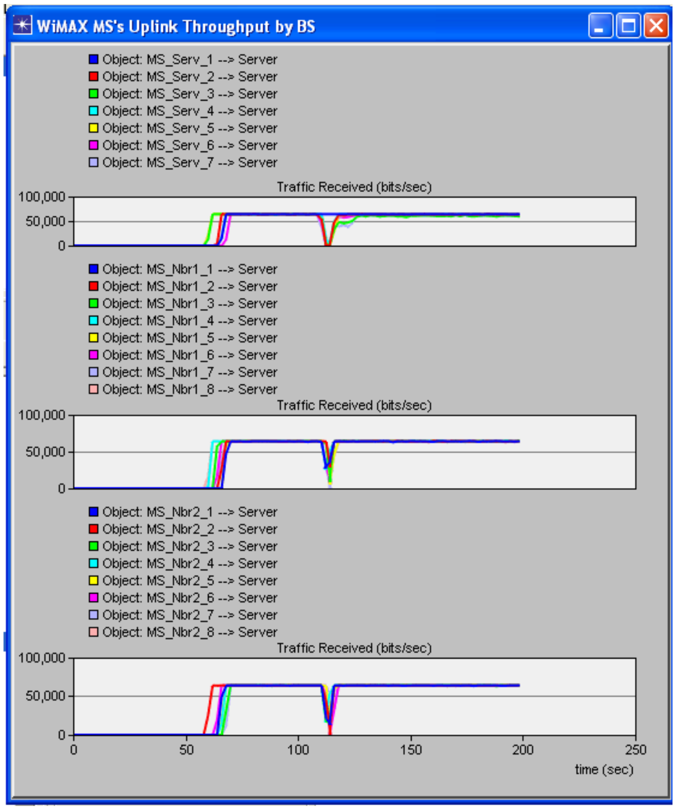

Figure 16. Forced Hadover Results

V. CONCLUSION

Seamless handovers is vital for next generation wireless networks. Although Mobile WiMAX has a number of attractive features, its handover framework has required significant improvement. In this paper the proposed forced handover method in the existing and next generation WiMAX mobility framework improves performance and capacity handling of a given base station.

ACKNOWLEDGMENT

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