Using Forced Handover as Load Balancing Technique in IEEE 802.16e/WiMAX Networks to Ensure QoS Guarantees

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ABSTRACT

Wireless networks perform handover to enable MS (Mobile Stations) to move from one BS (Base Station) to other BS during a session and without hiccups. Handovers are performed for many reasons such as, MS movement, varying radio conditions and capacity offloading to achieve negotiated service quality. Network congestion is generally observed at popular business places (like downtowns) and during busy hours, when load on network increases sporadically.

We propose forced handover, as a load balancing technique to handle such congestion in IEEE 802.16e networks. Existing approaches like adding more channels, forming sectors, increasing channel duration and using relay stations etc. to overcome congestion are not cost effective solutions, in situations when there is episodic increase in network load; moreover such techniques are always encumbered by the modifications that involve both licensing and cost.

Our strategy to cater situations of periodic congestion is to enforce BS initiated handover of MSs at cell boundaries, observing acceptable SNR (Signal to Noise Ratio) from one of the neighboring BSs with enough capacity and thereby freeing resources for MSs that cannot be switched from one cell to another (observing high SNR for being near to BS). The proposed mechanism is tested using OPNET environment using Wireless Modeler. Performance analysis validates the proposed strategy and its effectiveness to overcome such sporadic congestion is confirmed through observable improvement in traffic statistics.

Key Words: Load Balancing, Handover, SNR, Quality of Service.

1. INTRODUCTION

The major benefit of anywhere anytime Internet access, has spurred the deployment of Mobile WiMAX- an IEEE 802.16 based broadband Wireless Network [1]; revised standard published in September 2005, innovates the previous version IEEE 802.16-2004 [2] published in October 2004 by adding mobility feature to fixed and nomadic access in 802.16-2004 [3-4]. With the introduction of mobility feature moving user is no further required to establish a new network connection as and when cell border is overrun.

Handover are performed in two possible situations; first when the MS moves and needs to change the BS it is currently connected to in order to maintain required signal

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quality; secondly when MS can be served with higher QoS (Quality of Service) at another BS. In most cases the MS triggers the handover request, but the network (through BS) may also initiate the handover. Generally the decision to handover is based on various attributes which includes network condition, system performance, application type, power requirement, MS location, security etc.

Network operations could be improved and committed SLA (Service Level Agreement) could be assured by shifting the load of heavily occupied BSs through forced handover of MS at cell boundaries observing acceptable SNR from neighboring BSs with lesser network load.

We propose continuous monitoring of BS traffic load statistics and if such sporadic congestion is observed then forced handover of MSs at cell boundaries to neighboring BSs offering similar SNR, is to be initiated. The policy enforces BS initiated handover to allow distribution of mobile nodes between neighboring base stations. According to our scheme BS can trigger a handover if it detects bandwidth resources being reduced to a certain threshold (resources available<20% for a particular BS). Mobile nodes that are positioned at the cell boundaries will be considered preferred candidates for BS initiated handover. This is only because of their higher possibility of observing similar SNR conditions from a nearby BS as compared to MS closer to BS.

According to IEEE 802.16 standard a mobile client can acquire over-the-air link information, about the neighboring base stations and report back to the serving base station during handover. This information extraction and transport is achieved by intra/inter ASN (Access Service Network) backbone and ASN-CSN (Connectivity Service Network) procedures to complete a handover. In [5-6] authors have however proposed the concept of relay stations for exchange of management messages during scanning before handover.

2. HANDOVER IN WIMAX

Similar to other mobile wireless technologies WiMAX also require HO (Hand Over) to allow the MS to seamlessly roam while in session. The IEEE 802.16e specifications innovates mobility factor for Mobile WiMAX.

From Fig. 1, MS is initially served by BS1 and as the result of MS movement in the direction of BS2 at a certain instance it cannot communicate with BS1 well, since the received signal degrades to the level that MS can no further get services through its initial serving BS. Signal quality threshold is a system parameter and need to be defined once. This maybe minimum CINR (Carrier to Interference and Noise Ratio) level, for example when the MS station received CINR drops below the set threshold, the MS undergo handover to the new target base station to get the service.

Mobile WiMAX supports two types of handovers; "Hard HO" and 'Soft HO".

2.1 Hard Handover

In hard HO the connectivity is established with new BS just after the breaking of existing connectivity with serving BS (Fig. 2). Thus for a very short time MS is not connected to any BS.

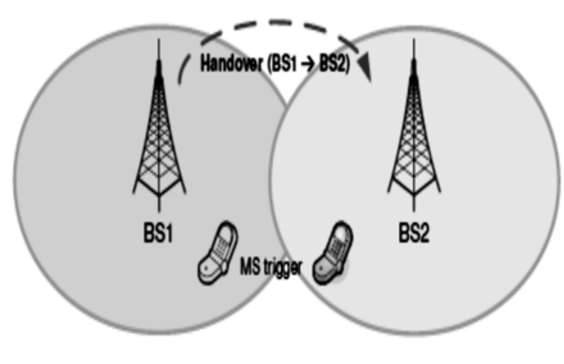

FIG. 1. HANDOVER DUE TO MS MOVEMENT

2.2 Soft Handover

In soft HO the connectivity is established with new BS without breaking of existing connectivity with serving BS. In this type of HO for an instance MS maintain its connectivity with both BSs. Both the BSs do communicate via core network for smooth transition of services from BS1 to BS2. Two types of soft handover are:

2.2.1 Fast Base Station Switching (FBSS)

In fast HO the mobile station acquire services from new BS within a set of base stations without completing the entire network entry procedure. The MS need to communicate with Anchor BS for UL, DL and management messages (Fig. 3).

2.2.2 Macro Diversity Handover

In MDHO (Macro Diversity Handover) MS simultaneously communicate with Anchor BS and other Active BSs of diversity set for both UL and DL and management messages (Fig. 4).

2.3 Handover in WiMAX- Initiation

Both MS and BS can initiate HO. Generally BS initiated HO is used for load balancing across the network, whereas MS initiated HO is executed when MS moves away from serving BS to the coverage area of adjacent new BS.

2.3.1 Base Station Handover Initiation

Base stations may trigger a handover to offload traffic. It happens when BS approaches its capacity limits. BS initiates handover (MOB_BSHO-REQ) and selects one or

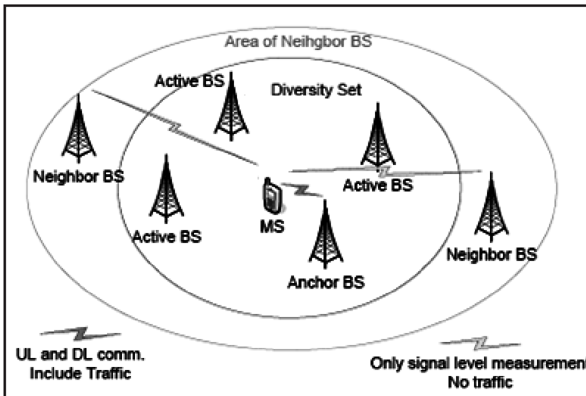

FIG. 3. FAST BASE STATION SWITCHING [6]

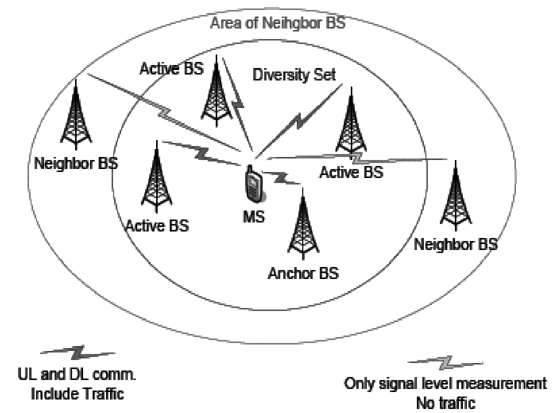

FIG. 4. MACRO DIVERSITY HANDOVER [6]

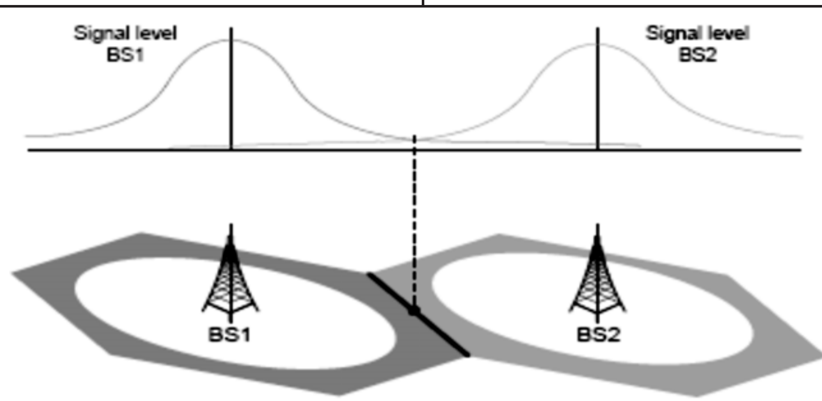

FIG. 2. HARD HANDOVER [6]

more possible target BSs. Moreover, the serving BS communicates with the core network to check the available (over the core network) resources of neighboring BS to ensure service quality while HO process (Fig. 5). MS responds with a mobile handover indication message (MOB_HO-IND) indicating the start of HO process.

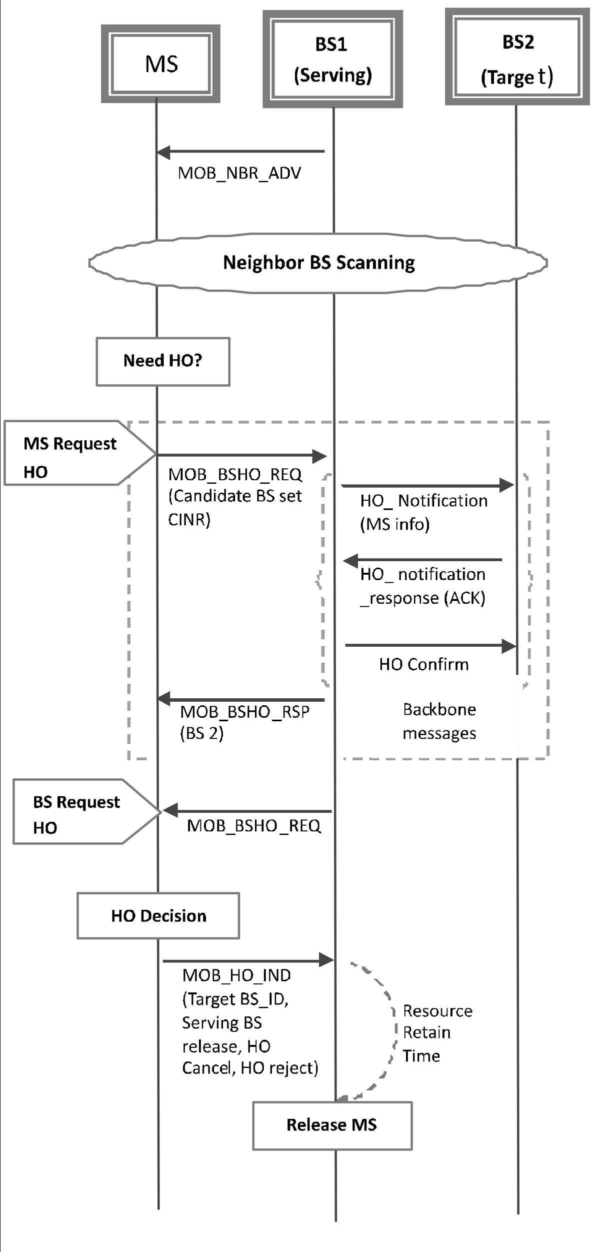

FIG. 5. HO PROCESS IN WIMAX

2.3.2 Mobile Station Handover Initiation

MS may initiate HO to seamlessly acquire services form new BS when it moves away from serving BS to the coverage area of adjacent new BS. MS initiates handover request message (MOB_MSHO-REQ) to the BS with one or more possible target base stations. MS calculate CINR of target BSs through previously performed scanning activity. BS respond with a base station handover response (MOB_BSHORSP) message and the handover will commence when the mobile station sends (MOB_HO-IND) the mobile station handover indication message.

2.4 Handover Process

The handover is composed of three processes; network topology acquisition, handover process, network re-entry. In the network topology acquisition/advertisement process, the MS gets the neighbor BSs information and makes the handover decision using the acquired neighbor BSs information. In the Mobile WiMAX networks, the CINR is decisive parameter of target BS selection. In the handover process, the MS performs BS change from serving BS to target BS. Then, in the network re-entry, the MS performs ranging process, authorization and registration. Then the MS receives the service from new BS.

2.4.1 Network Topology Advertisement

Serving BS broadcasts Neighbor Advertisement (MOB_NBR-ADV) message at least once every 30 seconds to identify potential candidate BSs for current and future HO. Further serving BS collects synchronization profiles for all candidate BSs over the core network and send to MS to assist with ranging and synchronization process for pending or future handovers; thus eliminates the requirement of MSs to monitor transmission from the neighbor stations and to acquire ranging and synchronization information.

Scanning: MS search and screen to identify suitable BSs as handover candidates. The time to scan for suitable neighbor BSs is called scanning interval. Scanning interval is allocated by serving BS to MS. On identification of a particular BS as a suitable candidate for MS to handover and acquire services, synchronization with BS DL transmission profile is initiated. Moreover, physical channel QoS statistics are also estimated.

Association: Association is an optional initial ranging procedure to enable MS to obtain and record ranging parameters and service availability information. This information collection will help choose better HO target BS.

With the completion of network topology acquisition stage the HO process starts with acquiring radio resources for MS from new target BS and releasing the radio resources of serving BS. The process includes following steps:

(a) *Cell Reselection:* The information of suitable candidate BSs as HO target gathered through network topology acquisition stage is analyzed by MS to evaluate its interest in handover to a particular BS.

(b) *Handover Decision and Initiation:* This decision may be initiated by serving BS or MS. The decision is taken to offload capacity from a particular BS (due to radio resource limitations) or due to MS movement away from serving BS.

(c) *Synchronization:* In HO process MS synchronizes with DL profile of target BS to acquire DL and UL transmission parameters (such as DL-MAP and UL-MAP). If the target BS has received HO intimation from serving BS via core network, the target BS will provide a non-contention-based initial ranging chance to expedite the process of synchronization.

(d) *Ranging:* The target BS gets communication profile/statistics from the serving BS via core backbone network. MS and target BS will then undergo initial ranging or handover ranging to set up communication.

(e) *Termination of MS Context:* In this step MS completely relinquish radio resources of serving BS and establish communication through target BS.

(f) If a MS remains unsuccessful to establish communication through target BS and stops communicating with its serving BS, it is a drop. If a mobile station drops, it can either attempt network re-entry with the target BS through the normal sequence of steps as previously described, or it may resume services from serving BS by sending the mobile handover indication (MOB_HO-IND) message and a request to cancel the handover [7].

3. REALTED RESEARCH REVIEW

Several researchers have studied the Handover process in WiMAX. Significant research contributions on BS initiated HO decision are made but are mainly based on mobile station movement, changing radio conditions (based on CINR), power consumption of MS. Research material lacks to address the issue of sporadic congestion through forced HO. Most of the contributions are mainly focused on HO process and its optimization. In [6] authors introduce HO delay timer so as to avoid number of unnecessary handover initializations, which are caused by inaccurate signal level assessment. Choi S., [8] presented a fast HO scheme to reduce data transmission delay & packet loss probability for real-time downlink service in IEEE 802.16e BWA Systems. In [9] authors address redundant parts in HO process and have proposed target BS estimation algorithm using mean CINR and arrival time difference to reduces neighbor BS scanning process and avoid unnecessary scanning. Yong-Hoon Choi [10] presents a cross-layer handover scheme based on movement prediction in mobile WiMAX environment. In [11] authors propose the changes in the diversity set and anchor BS updating procedure to optimize HO. In [12] authors have presented a scheme for WiBro so as to reduce the number of HOs between internal BS and external BS; by considering the location of MS. Paramvir in [13] presents the phenomenon of Cell Breathing for WLANs on the basis of power management for controlling the coverage of access points to handle dynamic changes in client workloads. In [14] authors have presented a load balancing scheme for overlapping cells in WLAN, Hsieh, R., [15], Tseng, C., [16] and Akyildiz, I., et. al. [17] introduce prediction-based approaches to reduce handover latency and common goal is to predict the future location of mobile user according to the previous movement patterns and to optimize HO delay. Rouil and Golmie [18] presented Adaptive Channel Scanning algorithm; mainly focused on time to perform scanning by calculating scanning interval.

Boone, P., et. al. [19-20] have formulated strategies that reduce the time required for scanning and ranging operations. In [21] authors have presented a scheme for optimized resource utilization in heterogeneous wireless networks based on periodic measurements and forced handover technique. Authors [22] illustrate the advantages of the load-balancing approach and have presented a radio resource management algorithms based on call admission control, adaptive transmission, horizontal handover, and dynamic bandwidth allocation algorithms to jointly maximize network capacity and guarantee users quality-of-service requirements. Lee, S., et. al. [23] has proposed a HO between multiple frequency assignments for load balancing and thus to reduce HO latency, unnecessary scanning, and network re-entry.

4. PROPOSED STRATEGY-FORCED HO

Handover procedures are characteristically initiated by MS as a result of their own measurement of the quality of the signal from the neighboring BS. Handover procedure can also be initiated by the network (serving base station) under special circumstances like capacity offloading, load balancing, etc.

A situation where BS initiated HO may be deemed helpful is analyzed. Our strategy enforces BS initiated handover to allow distribution of mobile nodes between neighboring base stations. The BS can trigger a forced HO if it detects bandwidth resources are being reduced below a certain threshold. Mobile nodes that are positioned at the cell boundaries are considered preferred candidates for BS initiated handover. It is assumed that the BS initiating handover for a certain MS has information about neighboring BS. If a neighbor BS with enough capacity is found SNR for candidate MS at both serving and target BS is compared to assure that forced HO may not be executed at the cost of disconnection or QoS. If the neighbor BS measurement is no more than 5 dB less then serving BS, the neighbor BS is selected as a target BS for the current MS. This is done for all neighbor BS nodes with enough capacity, and in the end the one that overrides the previous selection (with better SNR measurement) will be selected.

4.1 Methodology

To analyze the effectiveness of forced HO as load balancing technique and to further verify its usability in situations of episodic congestion in BWA networks we developed couple of scenarios in OPNET environment using wireless modeler to carryout comparative analysis of network response before and after implementation of proposed strategy.

The following steps were followed to analyze the network response with a and without new capability:

(a) Develop a scenario for testing the Forced handover effect on load balancing.

(b) Observe the behavior of the MS and BS nodes prior to the addition of new handover policy. For example, observe application performance and base station capacity.

(c) Implement the mechanism to balance the MS nodes across neighbor base stations.

(i) Implement the policy that evaluates available bandwidth resources of the BS.

(ii) Implement/observe an algorithm that finds which MS nodes are good candidates to be switched to a neighbor BS.

(iii) Implement/observe the function that notifies all candidates about the "forced" handover.

(d) Observe and analyze the results with the new handover policy.

(e) Compare network performance statistics of the two scenarios and verify the effectiveness of proposed HO policy to overcome sporadic congestion.

4.2 Proposed HO Policy-Flow Chart

We have presented a Forced HO policy that is based on traffic load on a certain BS approaching to threshold (Fig. 6).

Contrary to the existing policies our strategy enforces BS initiated handover to allow giving out of mobile nodes between neighboring base stations. The BS can trigger a forced HO if it detects that bandwidth resources for a certain BS are being reduced below threshold. Mobile nodes that are positioned at the cell boundaries will be considered for BS initiated HO.

4.3 Simulation Setup

WiMAX network is composed of three cells; with different number of MS nodes being served by each. Blue cell has 8 MS nodes, Red cell has 4 MS nodes and Green cell has 4 MS nodes. All MS are running voice traffic over UGS (Unsolicited Grant Service) connections (in the uplink). The destination for all the traffic is the server node. Blue MS nodes are static, Red and green MS nodes have trajectories that start movement at 110 seconds. Their movement converges at the blue cell between 115 and 120 seconds (Fig. 7).

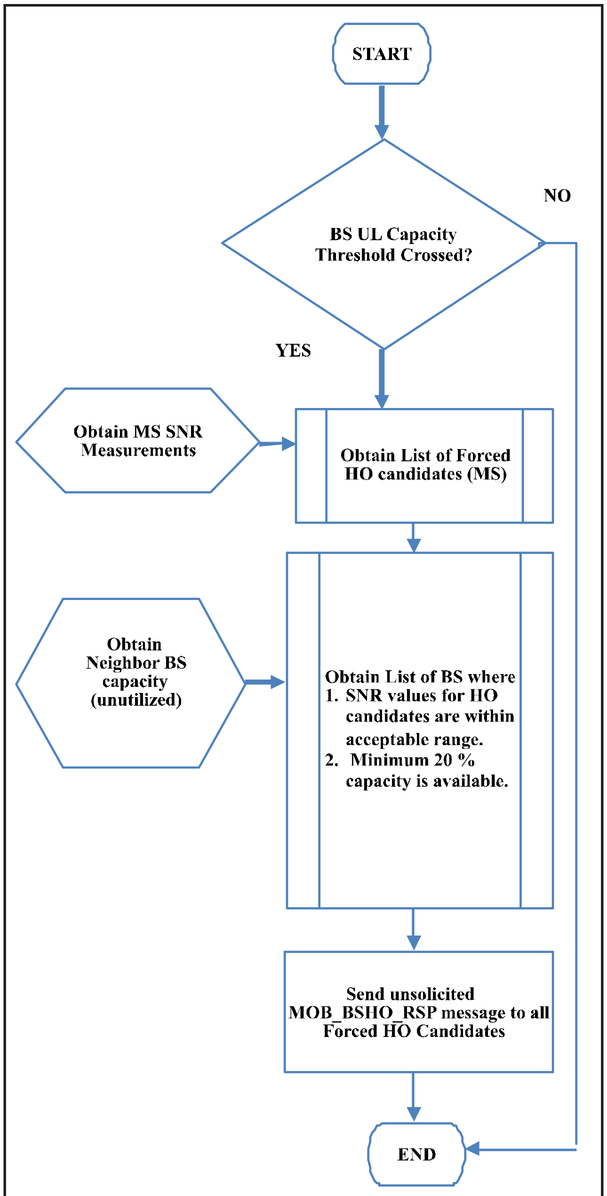

FIG. 6. PROPOSED HO POLICY-FLOW CHART

5. PERFORMANCE ANALYSIS

We have used parametric research paradigm to analyze the effectiveness of forced HO based load balancing technique to overcome episodic congestion in network due to immediate rise in network load at popular business places and during business hours. We have already build up the postulate that BS load statistics need to be exchange between neighbor BS so that BS suitable for forced HO in such conditions should be immediately identified; According to IEEE 802.16 standard a mobile client can acquire over-the-air link information, about the neighboring base stations and report back to the serving base station during handover. This information extraction and transport is achieved by intra/inter ASN backbone and ASN-CSN procedures to complete a handover; thus the postulate build in start is also supported by standard document.

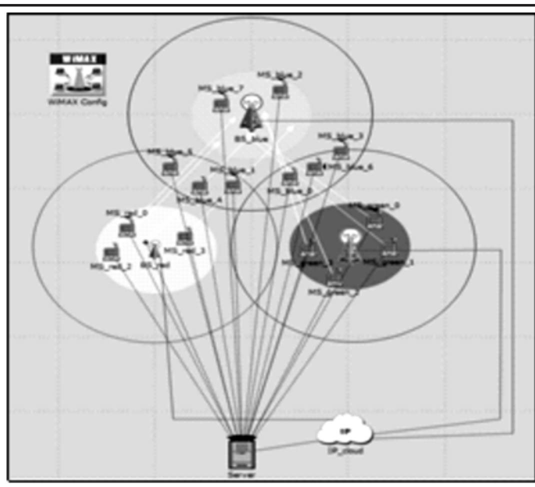

FIG. 7. SIMULATED NETWORK

5.1 Before Implementation of New HO Policy for Load Balancing to Assure QoS Guarantees

Before analyzing effect of new introduced HO policy we analyze the behavior of the MS and BS nodes prior to the implementation of new handover policy. Before the implementation of proposed scheme, if the resources are exhausted for a particular BS, it will reject all new UGS connection requests.

The graphs in Fig. 8 gives statistics of MS attached with a particular BS during simulation interval. Every BS is given a distinct ID (BS_Blue: ID=0; BS_Red: ID=1; BS_Green: ID=2). Referring to the graphs in Figure 08, Blue MS nodes are attached to the BS with ID 0 (BS_Blue) during the entire simulation interval. Green MS nodes are initially attached to the BS with ID 2 (BS_Green). At approximately 115 seconds; they move towards the blue cell and switch to BS ID 0 (BS_Blue). Red MS nodes are initially attached to the BS with ID 1 (BS_red). At approximately 115 seconds, as they move towards the blue cell, they switch to BS ID 0 (BS_blue).

At Bs_blue each MS requires approximately 70 Ksps (kilo symbols per second) for its UGS uplink connection. The UL resources are exhausted at around 116 seconds

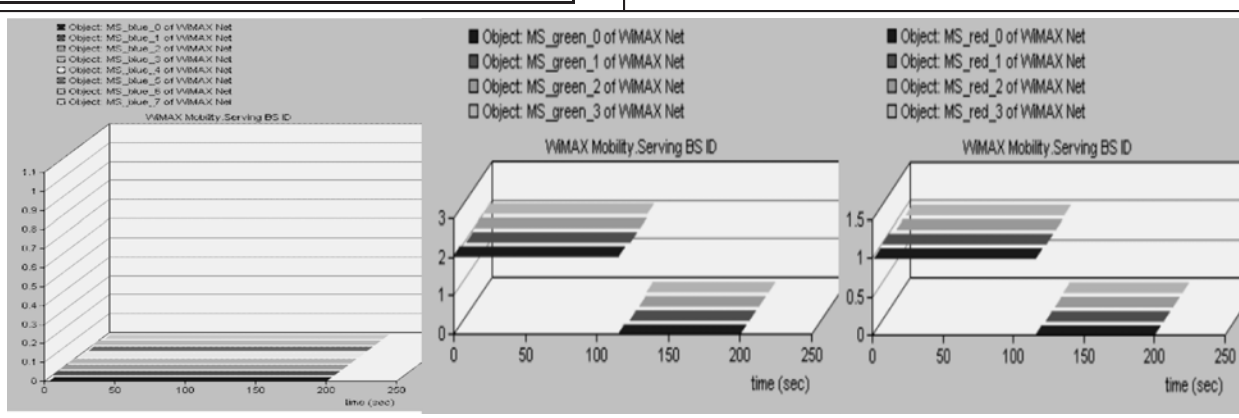

FIG. 8. SERVING BSS BEFORE IMPLEMENTATION OF HO POLICY

(Fig. 9). At BS_green and BS_Red UL resources start freeing up capacity as MSs leave BS_Red and BS_ Green and move to coverage area of BS_Blue and acquire resources there. Thus at that particular instance the free resources are increased at BS_Red and Green but at the same time available resources are exhausted at BS_Blue.

Referring to the network statistics summarized in Fig. 10; at about 115 seconds when Green and Red MS have observed HO and have moved to Blue BS serving area connections are no further accepted from two MS nodes previously served by BS_Green; also all requested connections by MSs moved from serving area of BS_Red to BS_ Blue are rejected as free resources have already exhausted at BS_Blue therefore all solicited UGS connections were rejected at BS Blue. Fig. 9 which further confirms that uplink free capacity at BS_Blue exhausted at around 116.5 seconds. It corresponds to an event where a DSA-REQ is received by the BS but rejected due to the lack of resources. UGS connection requests were rejected momentarily for Blue MS nodes when the other MS nodes joined Bs_blue; as it is clear from "BS Uplink Free Capacity for BS_Blue" graph, resources are exhausted at around 116 seconds. Since Blue MS nodes are already camping in BS_blue they are not affected by the lack of resources, however their new UGS connections observed rejection momentarily but restored shortly.

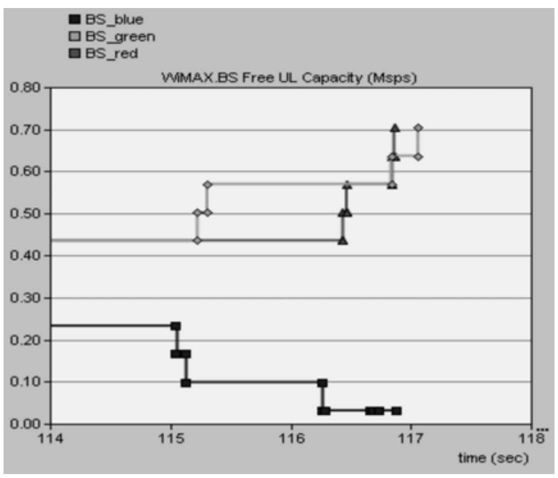

FIG. 9. BS UL FREE CAPACITY BEFORE IMPLEMENTATION OF NEW POLICY

The reason behind this reduction in throughput is the interference caused by the green and red MS node as they approach to enter in the blue cell. Just before they complete their handoff towards BS_blue, they are very strong interferers to the blue MS nodes. MS_blue_2 is immune to this effect because of its situation very near to BS_blue.

5.2 After Implementation of new HO Policy for Load Balancing to Assure QoS Guarantees

Referring the statistics grouped in Fig. 11; serving BS ID values for the green and red nodes are the same as in the previous simulation. The Serving BS ID values for the blue MS nodes are different compared to the previous results. In the previous results the blue MS nodes were

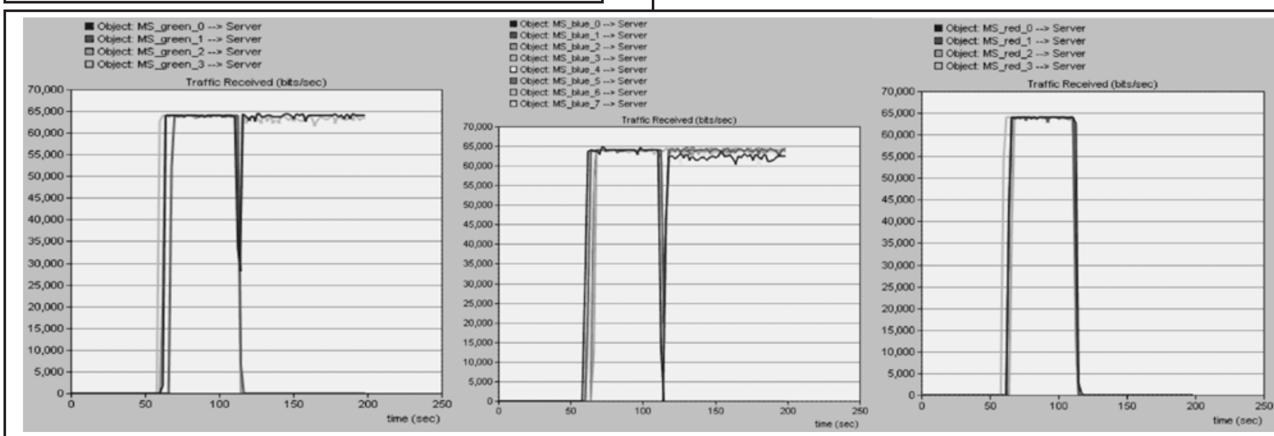

FIG. 10. TRAFFIC RECEIVED MS-TO-SERVER, BEFORE IMPLEMENTATION OF NEW HO POLICY

remained associated with BS_blue during the entire simulation interval. With the new capability of forced HO when resource starvation was observed due to the arrival of MS nodes from BS_Green and BS_Red five of the MS nodes served by BS_Blue but situated at cell boundaries performed handoff to either BS_red or BS_green which ever offered acceptable SNR (no less than 5db as compared to SNR from parent BS i.e. BS_Blue. MS_blue_0, MS_blue_3 and MS_blue_6 switched to BS_green, which was its closer BS after BS_blue. MS_blue_1 and MS_blue_5 switched to BS_red, which was its closer BS after BS_blue.

MS_blue_4 initially handover to BS_Red at time 0 sec as it was observing better SNR from Bs_Red. MS_blue_2 and MS_blue_7 did not switch serving BS because the offered SNR from both BS_red or BS_green did not qualify the condition and SNR difference was observed more than 5 db.

Thus the new capability of forced HO, however, provides a mechanism of load balancing between adjacent BSs. It's worth to add here, that proposed load balancing mechanism is based on statistics of SNR offered by target BS; so as to assure maintaining service quality. Moreover it ensures optimized resource utilization and a dynamic resource sharing mechanism to overcome episodic load situations. Also, introduction of this new capability do not result in any continuous overhead as it triggers only in response to periodic rise in load and handles sporadic congestion without increasing resources.

Referring the graph in Fig. 12; since each MS node requires ~70Ksps of uplink resources at ~115 seconds BS_Blue reduces its capacity by ~140 Ksps as BS_Blue admits two green MS nodes. BS_Green frees up similar amount of resources. At this instance the new forced handover mechanism is triggered (remember that it is triggered if granted resources increases beyond 80%). 100% uplink resources is ~0.704 Msps, then 80% would be 0.563 Msps. This means ~0.141 Msps in free resources. At around 116 seconds the forced handover mechanism sends unsolicited MOB_BSHO_RSP messages to the three MS nodes MS_blue_0, MS_blue_3, MS_blue_6 to target BS_Green and MS_blue_1, MS_blue_4, MS_blue_5 to target BS_Red. Eventually BS_blue release the resources for those six nodes, thus blue line moves up from 0.10-0.38 Msps. At the end of the simulation: BS_blue has ten MS nodes, BS_green and BS_red has three nodes each.

Referring to the results grouped in Fig.13 it's evident that with the introduced capability the throughput is recovered for all MS nodes after they switch their new BSs as the result of forced HO event. Only MS_blue_3 has reported low throughput due to high inter cell interference, being

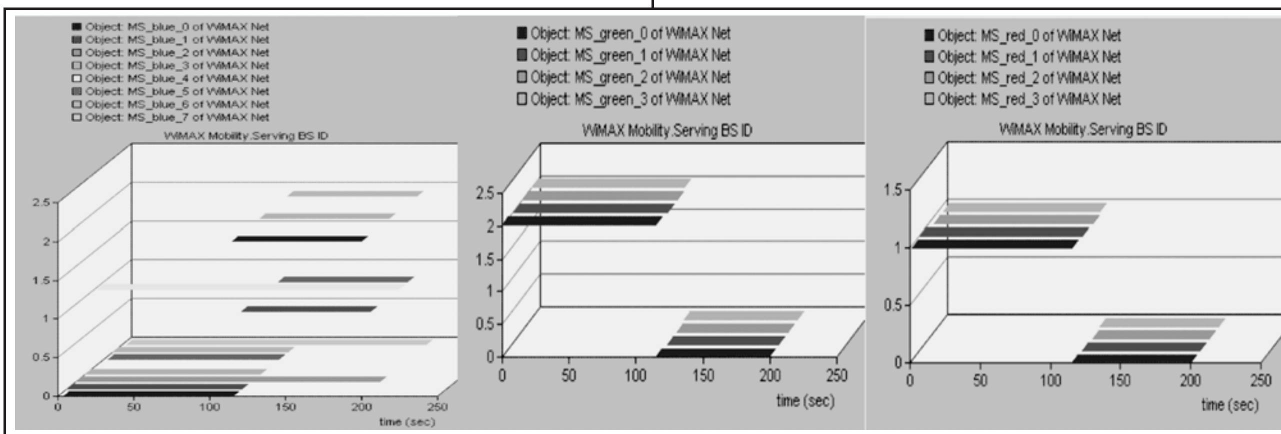

FIG. 11. SERVING BSS AFTER IMPLEMENTATION OF NEW HO POLICY

at cell boundary. BS_blue released resources by forcing all MS nodes in the overlapped area (between three cells in simulation) to handover to a neighbor BS with free bandwidth resources and offer acceptable SNR. Thus resources got relinquished (form MS who have established new connections with BS_Red or BS_Green and allocated to MS who have moved in to the serving area of BS-Blue to establish connections successfully. The uplink capacity of all of three BS nodes is thus optimally utilized by network nodes.

6. CONCLUSIONS

The proposed mechanism to address the issue of sporadic congestion, takes advantage of MS nodes at cell boundaries that observe similar SNR/CINR from various BS nodes, by switching them to a neighbor BS with more capacity available; and thereby releasing more free resources for MS nodes that cannot be switched for being close to BS and do not find any BS that can offer acceptable signal quality. The simulation results validate the effectiveness of proposed mechanism to overcome situations wherein network throughput is affected due to episodic rise in network load. SNR difference between serving BS and HO candidate BS delineate the overlapped area, where the MS candidates for forced HO will be selected. SNR difference between serving BS and neighbor BS is the key parameter that decides between BS nodes where the MS candidates will be switched.

If we set this SNR difference larger (within acceptable range to maintain QoS) there will be more candidates for target BS and will result in better load balancing. If such difference is set to very small by operator, it may result in high inter cell interference. However, if this difference is too large it may cause a poor performance for the MS nodes that are forced to execute handoff.

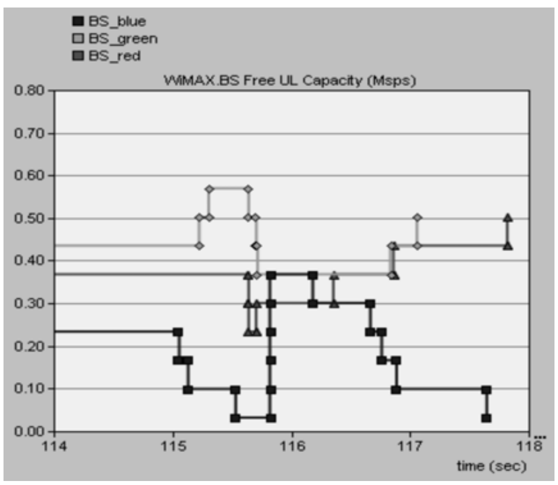

FIG. 12. BS UL FREE CAPACITY AFTER IMPLEMENTATION OF NEW POLICY

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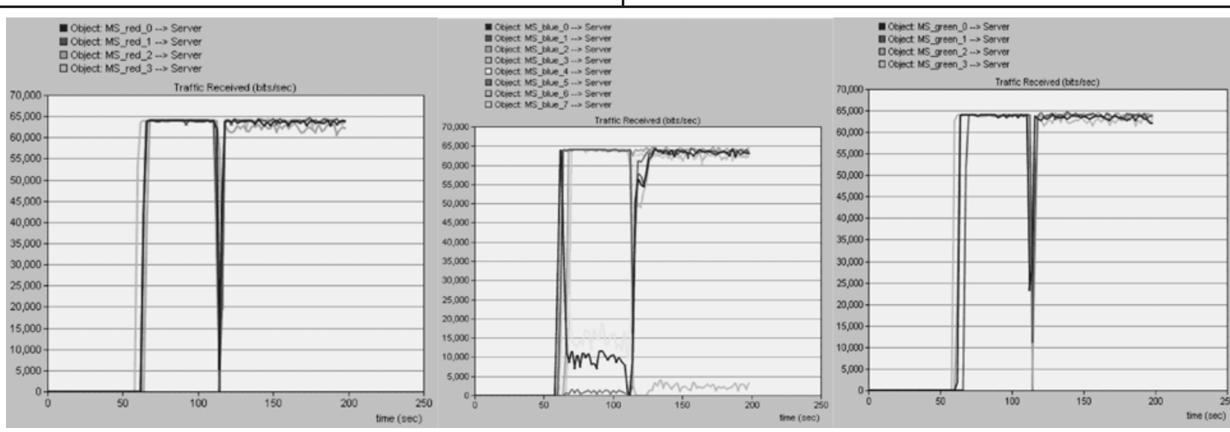

FIG. 13. TRAFFIC RECEIVED MS-TO-SERVER, AFTER IMPLEMENTATION OF NEW HO POLICY

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