Mobility Sensitive Admission Control Algorithm for WiMAX-WLAN Vertical Handovers

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Abstract. The admission control in 4G and 5G heterogeneous mobile and wireless networks will be more complex because it will need to deal with many different networks and decide to admit not only new calls and horizontal handovers, but also vertical handover calls. In this paper we propose a mobile sensitive algorithm for admission control in heterogeneous networks for seamless vertical handovers between WiMAX and WLAN. The results show that with the implementation of the proposed admission control algorithm we improve the Quality of Service of the users while moving from WiMAX into WLAN networks.

Keywords: Admission Control, Heterogeneous, VoIP, WiMAX, WLAN.

1 Introduction

Nowadays we have different mobile and wireless networks deployed, and their integration and maximum efficiency is the main subject in the future development in the field of mobile and wireless networks. 4G standardization is already finished in 3GPP radio access with LTE advanced and in non-3GPP radio access with Mobile WiMAX 2.0 (IEEE 802.16m). As the concept of heterogeneous networks already began to implement as an idea in the 4G approach, it is for sure that in 5G approaches [1] mobile users will also have the possibility to access different RATs (radio access technologies) during their sessions without any interruption in the communication process.

The concept of heterogeneous networks deployed in the NGN (Next Generation Networks) requires more control functionalities in the core networks. As each radio access technology has its own radio resource management and own admission control procedure in the radio resource management, when we have different radio interfaces in the new terminals with opportunity to have seamless connection to different RATs, we need more complex admission control during the vertical handovers between dif-

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ferent technologies. Moreover, the seamless network handover and continuous service provisioning to users require admission control mechanisms that will satisfy the experience of the users [2].

There are many recent research papers such as [3-6] that deal with the issues of admission control in wireless networks. There are also recent studies about admission control in heterogeneous networks. In [7] the authors propose a new adaptive admission control algorithm for 4G heterogeneous networks that checks if the session is real time or non-real time, new or handover session. In [8] authors also give the design of a new admission control algorithm suitable for 4G networks that considers network load, user's QoS requirements, user's context and link quality.

But, none of the aforementioned and so far published contributions for admission control in heterogeneous networks, including IEEE 802.21 standard, have taken into consideration the effect of the mobile node terminal speed of users to decide upon vertical handover to WLAN networks from WiMAX, UMTS or LTE networks. WLAN network is more sensitive to higher speeds of the mobile terminals comparing with WiMAX or LTE (UMTS), hence it is very important to consider the speed when deciding whether to admit or reject the handoff calls to WLAN network. This fact raises the need for design of admission control algorithm that will be sensitive to the speed of the mobile terminal nodes when vertical handovers are processed from WiMAX to WLAN networks. Information for the mobile node's speed can be detected from the Doppler spread in the received signal envelope [9]. For this purpose in this paper we propose admission control algorithm that will be dependent upon the velocity of the users and will consider velocity threshold regarding the handoff to WLAN network.

The structure of this paper is as follows. Section 2 explains the vertical handover process between WiMAX and WLAN in heterogeneous networks. Section 3 describes the proposed admission control algorithm. Then, in Section 4 are presented results from the performance evaluation of the proposed solution. Finally, Section 4 concludes the paper.

2 Vertical Handover Process between WiMAX and WLAN

The order of events that occurs between the mobile node and network in the process of vertical handover from WiMAX to WLAN coverage is explained in this section. We assume that a specific mobile node starts to move in a WiMAX cell and in its trajectory WLAN network is detected. When this happens WLAN interface from the mobile node detects beacons from 802.11 and triggers the event "Link Detected". MIH (Media Independent Handover) Agent that is in the mobile node is receiving this event and because it is better interface it gives command to the WLAN interface of the mobile node to connect to the WLAN access point.

After this WLAN interface from the mobile node and the WLAN access point exchange frames with "Association Request" and "Response" in order to make a link between the mobile node and the WLAN cell. WLAN interface triggers "Link Up" event after it receives the "Association Response". This event is received from the

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MIH Agent in mobile node and after that it commands to the MIPv6 agent of the mobile node to request ND (Neighbor Discovery) Agent in order to send an RS (Router Solicitation).

The access point from the WLAN network receives the RS, so it detects that it is a new neighbor. It reacts on that with sending a RA (Router Advertisement) that includes the router lifetime, prefix valid lifetime, network prefix and advertisement interval. The WLAN interface of the mobile node receives the RA and reconfigures its address in dependence on the received prefix. The MIH Agent of the mobile node is notified about this.

The MIPv6 Agent from the mobile node gives command to the WLAN interface to send "Redirect" message to the CN (Correspondent Node) for the purpose of informing the CN about the new location of the mobile node. The MIPv6 Agent of the CN receives then the "Redirect" message and sends after that an Ack (Acknowledge) message that is received by the WLAN interface of the mobile node. It then notifies the MIH Agent of the mobile node.

Now the MIH Agent from the mobile node has the confirmation that CN knows the new address of the mobile node and redirects the receiving of the traffic from the WiMAX interface to the WLAN interface. Hence, the traffic now uses the link between the WLAN interface from the mobile node and the AP.

The MIH Agent from the mobile node gives command to the WLAN interface to send MIH Capability Request to the access point (AP). MIH Capability Response is responded from the AP including the MIHF (Media Independent Handover Function) identification. Consequently, MIH Capability Response is received from the MIH Agent with the identification of the new remote MIHF identification.

When the mobile node is approaching the boundary of the WLAN coverage the WLAN interface is triggering the event "Link Going Down" that is based on the received power of the beacon frames. The probability that the WLAN link is going down starts to increase because of the speed of the mobile node. When it gets a predefined value (usually 90%) and because the WiMAX interface of the mobile node is still active, MIPv6 Agent of the mobile node gives command to the WiMAX interface to send the message "Redirect" to the CN. In this way CN is informed about the new location of the mobile node. MIH Agent of the mobile node also gives a command to the WLAN interface to execute "Link Scan" for searching another WLAN network.

If a "Probe Response" is received only in the channel where the mobile node is currently, MIH Agent from the mobile node is assured that this is the only accessible WLAN network. Then, MIPv6 Agent of the CN receives the message "Redirect" and sends the message "Ack" that is received by the WiMAX interface of the mobile node. MIH Agent is informed about this.

The MIH Agent of the mobile node is having the confirmation that the CN is informed about the new address of the mobile node and is redirecting the reception of the traffic from WLAN interface to the WiMAX interface. The traffic now uses the link from the WiMAX interface of the mobile node and the base station. In the same time WLAN interface of mobile node is triggering the event "Link Down", hence the mobile node is disconnected from the WLAN network.

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3 Admission Control Algorithm

The admission control algorithm determines whether the incoming requests to WLAN network will be rejected or accepted. If the speed of the mobile node while approaching the WLAN network from WiMAX network is above the acceptable threshold for the WLAN network the incoming request for handover will be rejected. If the speed of the mobile node is below the threshold, the user will be admitted to the system and the vertical handover procedure will start. Fig. 1 presents the procedure of the algorithm.

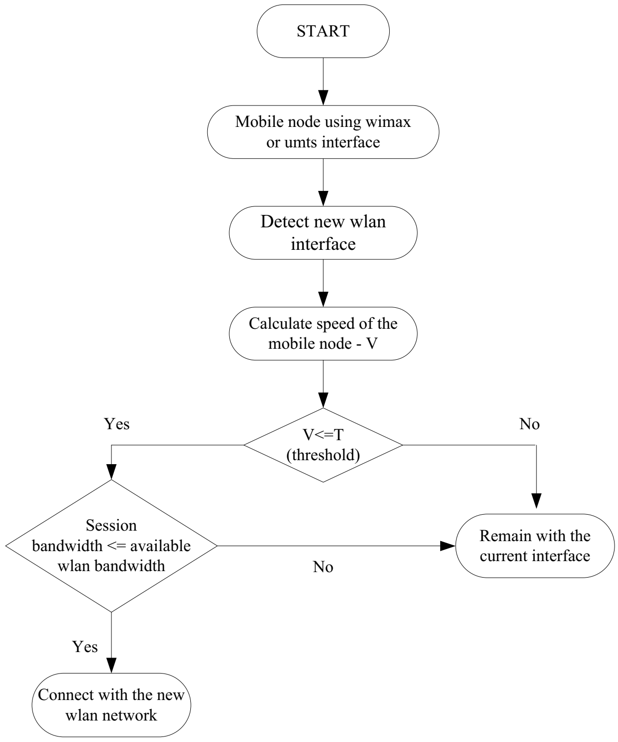

Fig. 1. Admission control algorithm procedure between WiMAX and WLAN.

To achieve better channel utilization of the heterogeneous networks while still satisfying the QoS requirements of the users we designed the following admission control algorithm for handoff calls between WiMAX and WLAN network. Let V be the speed and let T be the threshold speed of the mobile node terminal. Then, the algorithm will be as follows:

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- Wait for vertical handover request arrival to WLAN
- If a vertical handover request arrives
- Calculate speed of the mobile node
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- If V <=T and if Session bandwidth <= available WLAN
bandwidth
- Admit the request call to WLAN
- Else
- Reject the vertical handover request.
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In the above admission control algorithm users that move with speed that is above the acceptable velocity threshold will not be allowed to perform handover to WLAN from WiMAX. Hence, such Mobility Sensitive (MS) admission control algorithm can be implemented in any proposed admission control architecture for heterogeneous networks in 4G and 5G standards.

We have implemented and tested our designed MS admission control algorithm in the IEEE 802.21 standard for Media Independent Handover (MIH) [10, 11]. We have implemented the designed MS admission control algorithm into the handover module in network simulator (ns) by enhancing it with the information about the mobile terminal speed, that is now included when deciding whether to admit or reject the vertical handover session from other networks to WLAN.

4 Performance Evaluation

In our simulations, for the purpose of testing the above proposed admission control algorithm, we use a two-tier heterogeneous wireless network structure that is composed of a WiMAX cell overlaying a WLAN hotspot.

Table 1. Types of Mobile Nodes.

Mobile terminals	Velocity of the MN [kmph]	Type of Movement	Type of traffic
1, 2	3.6	Only in WiMAX coverage	MPEG-4
3, 4	3.6	Only in WiMAX coverage	FTP
5, 6	3.6	Only in WiMAX coverage	Telnet
7-10	5	Starting in WiMAX, crossing through WLAN, ending in WiMAX	VoIP G.711
11-14	10	Starting in WiMAX, crossing through WLAN, ending in WiMAX	VoIP G.711
15-18	15	Starting in WiMAX, crossing through WLAN, ending in WiMAX	VoIP G.711
19-22	20	Starting in WiMAX, crossing through WLAN, ending in WiMAX	VoIP G.711
23-26	25	Starting in WiMAX, crossing through WLAN, ending in WiMAX	VoIP G.711
27-30	30	Starting in WiMAX, crossing through WLAN, ending in WiMAX	VoIP G.711

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The simulation study was conducted by simulating 30 mobile terminal nodes attached to the WiMAX network. 6 mobile terminals are moving only in WiMAX coverage and they are using MPEG-4, FTP and Telnet traffic. The other 24 terminals are moving across WLAN network and they are performing vertical handovers between WiMAX and wireless LAN. Detailed characteristics of the mobile node terminals are explained in Table 1. The network topology and types of the trajectories of the mobile nodes are shown in Fig. 2 and Fig. 3. Using this model each node moves along a straight line from some starting point to end point. We use 4 types of traffic in the simulations as examples of conversational, streaming, web and background traffic. They are VoIP G.711, MPEG-4, Telnet and FTP sessions. VoIP G.711 traffic is simulated with a packet size of 160 bytes at application layer and inter-arrival packet time of 20 ms.

The propagation model is TwoRayGround, considering both the direct path and a ground reflection path. The total simulation time is 200 seconds.

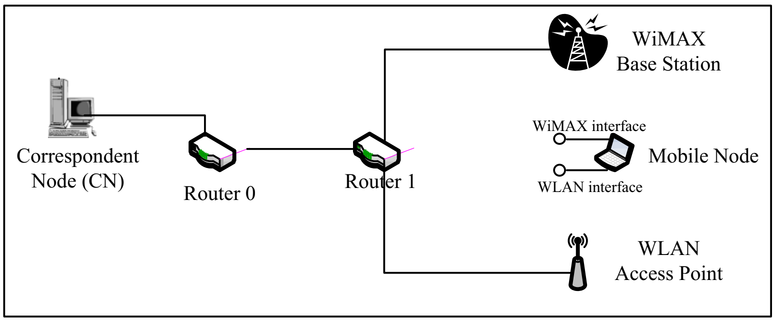

Fig. 2. Heterogeneous network topology.

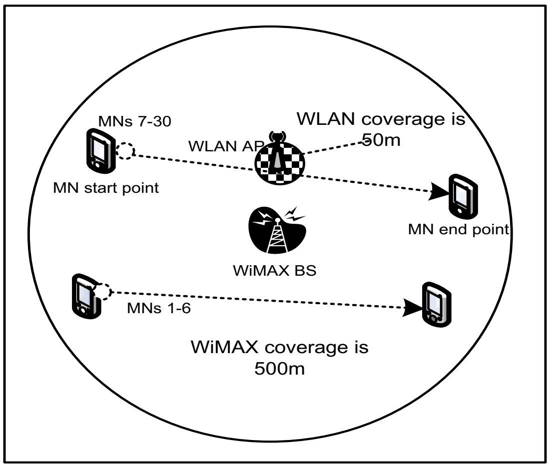

Fig. 3. Heterogeneous network scenario with 30 mobile terminals.

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Firstly, the simulations are done without applying our designed algorithm. After analysis of the results we repeated the same simulation scenario with previously applied MS admission control algorithm. The compared results of the QoS performances of average throughput, packet loss and vertical handover latency are shown in Fig. 4, Fig. 5 and Table 2.

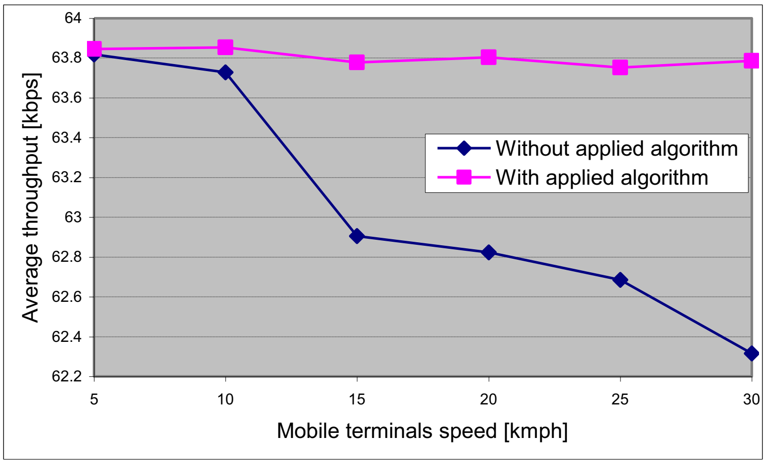

Fig. 4. Average throughput of the VoIP users with and without MS admission control algorithm.

Analyzing the results using the 802.21 simulator from NIST 24 vertical handovers are triggered between WiMAX cell and WLAN hotspot. After implementation our admission control algorithm this number of vertical handovers is decreased to only 8. It occurred only for the mobile terminal nodes that are moving with speed equal or below the threshold speed. We set the threshold speed on 10 kmph. Decision for setting this threshold speed was made because when mobile users move with higher speed than 10 kmph it is wasting of the resources and time to process vertical handover to small cells like a WLAN. In this case mobile users will be covered in a short time period. Furthermore, WLAN network is more sensitive to higher speeds of the mobile terminals. This is confirmed in Fig. 4 where average throughput of the users decreases when they move with speed above 10 kmph.

The performance study implementing our algorithm was done considering the metrics vertical handover latency expressed in milliseconds, packet loss expressed in % and average throughput expressed in kbps. The handover performance study implementing our algorithm was done considering the metric vertical handover latency. Vertical handover latency is defined as the difference between the time when the mobile node is last able to send or receive an IP packet by way of the previous WiMAX network, and the time when the mobile node is able to send or receive an IP packet through the new WLAN network.

Fig. 4 shows average throughput of the mobile users that use VoIP G.711 traffic (7^{th} to 30^{th} mobile terminal) while they are crossing WLAN network. After applying

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the algorithm the users that move with speed above 10 kmph are staying in WiMAX network when they are detecting the WLAN coverage. It is obvious from the graph that if we don't apply our algorithm average throughput of the users that move with speed above 10 kmph in WLAN network degrades. Implementing the speed sensitive algorithm improves the results for average throughput of the users moving above 10 kmph. We have to put an accent on the fact that improved results for average throughput as a result of the applied algorithm for speeds above 10 kmph in the Fig. 4 are when mobile terminal is using WiMAX network. Without our applied algorithm when mobile terminals move in WLAN network with speeds from 15 to 30 kmph (from 15th to 30th user) results for average throughput are decreasing. This happens because WLAN technology is sensitive when users move with higher speeds. This fact and the improved results for average throughput justify the benefit of applying our algorithm.

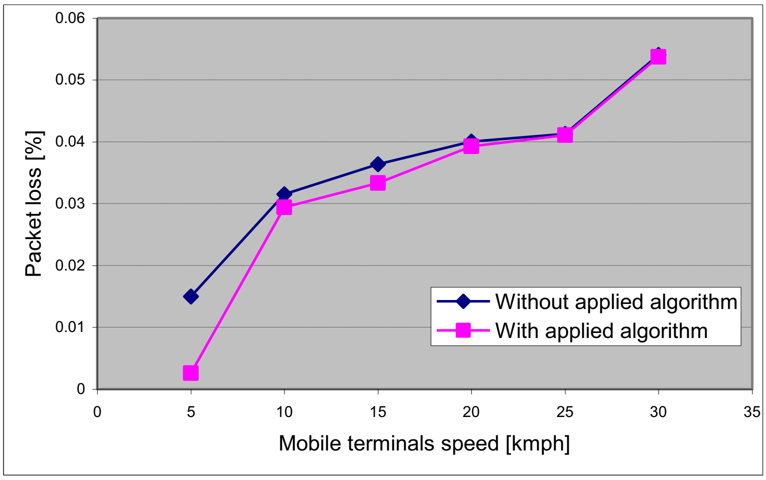

Fig. 5. Packet loss of the VoIP users with and without MS admission control algorithm in the WiMAX network.

As we can see from the analyzed results, we analyze the benefit of applied algorithm on different aspects of the simulated scenario. Packet loss in Fig. 5 is analyzed for the VoIP users only when they are attached to WiMAX network. The averaged results for all speeds of the mobile terminals are presented before and after the implementation of the mobile sensitive algorithm. The comparison results show that implemented algorithm improved the packet loss of the VoIP traffic while mobile terminals are using WiMAX network. Because the number of vertical handover processes in the specific scenario is decreased from 24 to 8 after implementing the algorithm, vertical handover duration for the users moving with 5 and 10 kmph is decreased. This leads to better packet loss performances of the users moving with 5 and 10 kmph, while they are still attached to WiMAX base station during the vertical handover procedure. Difference of the packet loss improvement with applied algorithm compared without applying the algorithm is lower at higher speeds in Fig. 5. This happens due to the fact

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that the influence of the speed on packet loss is higher at higher speeds and the effect of the improvement of the packet loss results as a consequence of decreasing the number of vertical handovers is then lower.

Table 2. Average vertical handover latency for VoIP users.

Averaged results for 24 VoIP users	Without our applied algorithm	With applied algorithm
Vertical handover latency between WiMAX and WLAN [ms]	323.67	298.57

Table 2 compares the average values for vertical handover latency without and with our added MS admission control algorithm during the vertical handover process. The values are averaged for all 24 mobile terminals that use VoIP traffic before implementing our algorithm and after implementation of the algorithm the values are averaged only for the 8 mobile terminals that are moving with 5 and 10 kmph. The other 16 vertical handovers hasn't been triggered between WiMAX and WLAN after adding our algorithm, so we cannot compare them. The results in Table 2 show that implemented admission control not only decreased unnecessary vertical handovers of the users, but also decreased the vertical handover latency, which is very important for delay sensitive traffic like VoIP.

This happens due to the fact that more users in the same time must perform vertical handover process from WiMAX to WLAN. Because of this vertical handover latency for some of them will increase because of the congestion. When some users start to perform vertical handover other users are already in the process of vertical handover, and they must wait for more time to finish the procedure of disconnecting from WiMAX and connecting to WLAN coverage. When fewer users perform vertical handovers, probability of this kind of problems decreases.

5 Conclusion

The handover target selection in future heterogeneous wireless and mobile networks should be done through combination of mobility and resource management mechanisms such as admission control. That is why in the media independent handover services in [10] in the set of parameters required for performing admission control and resource reservation for the MN at the target network information about the MN speed should be added. After adding the parameter of MN speed in the RequestedResourceSet of parameters in [10], our admission control algorithm can be integrated with IEEE 802.21 technologies.

We have successfully simulated the effect of the proposed admission control algorithm for 4G and 5G heterogeneous networks using IEEE 802.21 standard on WiMAX (802.16) and WLAN (802.11) access technologies. We applied admission control algorithm that reacts on mobile node terminal speed and admits or rejects the vertical handover triggers to WLAN network from WiMAX (as in our simulation case), UMTS or some other wireless technology.

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The contribution of this paper is the design of the admission control algorithm that can be easily implemented in the resource management for heterogeneous networks. Furthermore, we practically applied the algorithm in the already existing NIST simulation tool for 802.21 and practically tested with 24 VoIP users that are crossing from WiMAX to WLAN network. We proved that implementing this speed sensitive algorithm we avoided unnecessary vertical handovers to WLAN network and improved the QoS of the mobile node terminals that are using VoIP traffic expressed in vertical handover latency, throughput and packet loss which are very important metric for real time sessions.

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