Improving Vertical Handovers for Real-Time Video Traffic between UMTS and WiMAX Networks

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Abstract – Nowadays we have heterogeneous wireless environment with several wireless access technologies which can provide to the users seamless and continuous Quality of Service. For real-time applications is crucial to have satisfying QoS during vertical handovers between different wireless and mobile networks, for different velocities of the mobile users. In this paper we propose a solution for improving the QoS during vertical handovers between UMTS and WiMAX networks for real time video applications. The analyses have shown that performance parameters, such as delay and throughput, are strongly dependent upon the speed of the mobile terminals, showing higher delays and bigger throughput gap as velocity increases. Hence, we have proposed optimized solution for vertical handovers between WiMAX and UMTS networks for video traffic, which have been tested for different video traffic types. The results showed lower delays and smaller throughput gaps with implementation of the proposed optimized solution for vertical handovers.

1. Introduction

Fourth Generation of mobile and wireless systems (4G) is focused towards integration of different mobile and wireless access technologies because of the growing demand of the mobile users to access various services anywhere and anytime [1].

4G wireless networks integrates diverse but complementary cellular and wireless technologies, which coexist in a heterogeneous wireless access environment and use a common IP core to offer a diverse range of high data rate multimedia services to the end users. WiMAX (Worldwide Interoperability for Microwave Access), i.e., IEEE 802.16 networks, can be used as a complementary option to Universal Mobile Telecommunications System (UMTS), 3G cellular wide area network, for different types of services over IP, including voice and video. With higher bit rates available in the access part of the 3G networks (e.g., High Speed Packet Access – HSPA) and mobile WiMAX, which can provide up to several Mbps to the mobile users (of course, it is dependent upon the number of users on a given area and the installed mobile network capacity), there is paved ground for video services via mobile networks. Hence, broadband mobile networks provides capabilities (bit rates) for video services, as well as they need video services so the user will demand the broadband mobile access, either via 3G, 4G, mobile WiMAX, WiFi, LTE, or next generation mobile networks.

However, mobile terminals must be capable to seamlessly reconnect to the “best” access network without interruption to an ongoing communication (e.g., video session) when more candidates wireless networks are available. This capability to handover between heterogeneous networks without any interruption is recognized as seamless vertical handover [2]. IEEE 802.21 standard provides the overall framework to support protocols for creating seamless vertical handovers [3].

In the case of vertical handover between two different access networks, the most important is minimization of the data loss and interruption time during the handover. The end user may or may not become aware of the replacement of the access network, but handover should be transparent to the application (e.g., video player at the mobile terminal). Vertical handovers can also result in modification in service quality provisioning due to the different characteristics of the wireless access networks. For instance, IEEE 802.16 standard [4, 5] addresses this problem, thus supports the nomadic and mobile clients when crossing the extended coverage area of cellular network.

Generally, heterogeneous wireless networks differ from each other in coverage, data rates, signal strength, latency, and loss rate. Hence, each of them supports different groups of services and devices with different QoS. However, all of them have IP-based core network, integrating the different wireless networks into a single platform (e.g., 4G network), allowing mobile users to use the best available access network according to their requirements. In this way, specific characteristics of the heterogeneous wireless networks that complement each other are overcome through integration into a single 4G system. Per example, combining complementary characteristics of UMTS (wide coverage and slower data
rate) and WiMAX (low latency and costs, and higher data rates compared to UMTS), we obtain more integrated broadband wireless access for the mobile users with multimode terminals. Thus, users can utilize different services with different requirements, including real-time services, audio and video streaming, videoconference, gaming, broadcasting etc. Some of them demand high bandwidth, some demand high processing power of the terminal, and other demand low latency.

Inter-networking approach of the converged next generation multi-access network can make the best use of the advantages of the different wireless networks and eliminate their weaknesses. UMTS, WiMAX and WLAN networks can complement each other in term of geographical coverage and QoS.

One of the possible scenarios where the above three heterogeneous networks can be used is shown in the Figure 1. While the vehicle moves on the road, the wider area is covered only with UMTS. The metro zones are covered additionally with WiMAX, while hotspots have also WiFi. Different access networks may be ranked by the operator (if they are owned by single one) or by the mobile user, for given services.

As the user in the vehicle approaches the city, besides UMTS, WiMAX (IEEE 802.16e) becomes available, so vertical handover between UMTS and WiMAX can occur. Vertical handover among these different networks can take place when QoS is poor for the current wireless access network, or due to service management either by the network provider or by the user.

For the purpose of analysis of impact of vertical handovers between UMTS and WiMAX for video traffic, we use the following three streaming video technologies: HDTV (High Definition TV), MPEG-4 and H.261. Each of these applications requires different bandwidth. Each wireless technology has a limit on the maximum supported user velocity. Also, user mobility influences the behavior of the wireless access network and the video stream transmitted over such network [6].

Empirical analyses of vertical handovers between UMTS, WiMAX and WLAN for real time traffic types have shown that the most critical is the vertical handover between UMTS and WiMAX, which gives poor vertical handover latency, obtained using the NIST mobility package simulator for IEEE 802.21 [7]. The aim of this work is to investigate the reasons for such behavior and to improve the vertical handovers in the case of streaming video traffic, and hence to reduce the latency, to reduce the number of vertical handovers and throughput gap between UMTS and WiMAX networks.

The paper is organized as follows. Section 2 presents the previous work related to the IEEE 802.21 standard vertical handover processes and criteria. Section 3 describes in details the simulation setup and obtained results. Finally, last section concludes the paper.

2. IEEE 802.21 – Media Independent Handover Services

Intersystem or vertical mobility represents the movement of a user among different types of networks. Vertical handover is one of the most important challenges for seamless vertical mobility, where handover is the process of keeping uninterrupted a mobile user’s active connections while it changes its point of attachment. IEEE 802.21 standard is one of the 4G approaches that deal with vertical handovers. It began with development in 2004 and defines the media independent handover function (MIHF) that helps mobile devices to roam across heterogeneous networks.

IEEE 802.21 framework uses the process of network discovery and selection to exchange network information in order to connect to the most appropriate network based on certain mobile policies. Three services are defined to facilitate inter-technology handovers: MHS – media independent information service, MICS – media independent command service, and MIES – media independent event service. One of the major aspects of MIH (Media Independent Handover) in IEEE 802.21 is the fact that it uses two types of handovers: network controlled handovers and user controlled handovers. Using network controlled handovers we have lower user battery consumption, but huge signaling overhead and high processing load in the network elements. In user controlled handovers the user initiates appropriate actions, but there is high battery power consumption.

2.1. Overview of the vertical handover processes

Vertical handover process takes place between points of attachment supporting different network technologies, for an example, between a UMTS network and IEEE 802.16. Vertical handover process can be divided in three phases: handover decision, radio link transfer and channel assignment [8]. Handover decision deals with the selection of the target point of attachment and the time of the handover. Radio link transfer is the process of developing links to the new point of attachment. Channel assignment phase arranges the allocation of channel resources.

Vertical Handover Decision (VHD) algorithms assist mobile terminals to select among the all available access networks in the current moment, the best network to connect to. Horizontal handover algorithms mainly consider Radio Signal Strength (RSS) as the only criteria for handover decision. In contrast to it, VHD algorithms may need to take into consideration cost of service, velocity of the users, power consumption in order to maximize users’ satisfaction [9].
Because IEEE 802.21 standard supports two types of vertical handovers, handovers initiated by the network and handovers initiated by mobile terminals, events related to handovers can be originated at the MAC (Medium Access Control) or MIHF (Media Independent Handover Function) layer located in the node or at the point of attachment to the network [10].

ND (Neighbor Discovery) module. When the MN receives the RA (Router Advertisement) message, it builds a new address and redirects the flow on to the WiMAX interface, because the WiMAX interface is considered available for application traffic. With this the vertical handover process is completed.

2.2. Performance evaluation metrics for vertical handovers

Vertical handover process can be qualitatively and quantitatively measured under various usage scenarios by measuring the number of handovers, the mean and maximum handover delays, and the overall throughput of a session maintained over a specific mobility pattern.

Frequent vertical handovers can cause wastage of network resources. So, decreasing the number of handovers is very beneficial for better efficiency of the resources. A handover is considered unnecessary when, after a short time [13, 14], a handover back to the original point of attachment is needed. This kind of handovers should be minimized.

Handover latency is the time duration between the initiation of the vertical handover process and its completion. Handover latency is related to the complexity of the VHD (vertical handover decision) process. Reduction of the handover latency is very important for delay-sensitive multimedia sessions.

The throughput is measured with the data rate that is transmitted to the mobile terminals on the network. Vertical handover to an available access network with higher throughput is usually desirable.

3. Description of the Simulation

3.1. Scheme Implementation in NS-2

The aim of the simulations is to research the performance metrics during vertical handovers in heterogeneous networks with real-time video traffic, to analyze the impact of the mobile terminal speed on the performance metrics for real time traffic and to find a solution to improve the results of the performance metrics during vertical handovers between UMTS and WiMAX networks (as the worst case), especially when the increase of mobile terminal speed degrades the QoS of real time applications. Simulations are done with the NIST mobility package based on NS-2 implementation.

3.2. Simulation Scenario

Simulation topology presented in Figure 4 is based on a scenario shown in Figure 1, which consists of a UMTS, WiMAX and WLAN cell located on a 2000x2000 meters coverage area. UMTS cell covers the whole simulated area, WiMAX cell has 500 meters radius and WLAN cell covers area with 50 meters area. Simulations are made with four mobile terminals moving across the three networks with speeds of 10, 20, 30 and 40 kmph, respectively. Each of the four mobile terminals uses different type of real-time video traffic, as given in Table 1.
The real-time video traffic (H.261, MPEG-4 and HDTV) is simulated as constant bit rate traffic. The simulation process time is 500 seconds and all nodes start their transmission at the 10-th second of the simulation time. Simulations are done with two different scenarios of the mobile terminal nodes start and end points (Tables 2 and 3).

First scenario with given coordinates of the mobile nodes and video traffic types is shown in Table 2. According to the positions of the mobiles, the first vertical handover between UMTS and WiMAX is made by mobile terminal node with MPEG-4 traffic, then follows the node with H.261 traffic and the last node that makes vertical handover between UMTS and WiMAX is the node with HDTV traffic.

Second scenario is shown in Table 3, and it makes opposite schedule of the vertical handover occurrence between UMTS and WiMAX, when compared to the first scenario. Coordinates of the WiMAX base station are: X=1100, Y=1000.

For each scenario we have performed 20 simulations with ±10 meters difference from the coordinates in Table 2 and Table 3.
of 0.649 seconds for 10 kmph speed and 4.15 seconds for 40 kmph speed. Hence, dependency of the vertical handover latency between UMTS and WiMAX from the mobility is very high.

Analysis of the routers configurations and link threshold parameters, using all possible combinations of the periods for RA messages as well as DCD and UCD intervals in WiMAX, have point to a solution for significant improvement of the vertical handover latency during the vertical handovers between UMTS and WiMAX networks. That is, appropriate combination of parameters on layer 2 (MAC layer), such as DCD and UCD in WiMAX part, and layer 3 parameters such as frequency of router advertisements. The outcome solution for the improvement of the vertical handover latency is combination of the following parameter settings:

- Agent/ND set minDelayBetweenRA_ 0.03
- Agent/ND set maxRADelay_ 0
- Mac/802_16 set dcd_interval_ 1
- Mac/802_16 set ucd_interval_ 1

When the above parameters are used in simulation the obtained vertical handover latencies are much lower, as it is can be seen from Figure 5 (optimization is done for MPEG-4 traffic) and Figure 6 (optimization is done for HDTV traffic). With the optimal parameters the vertical handover latency is below one second even at the mobile speed of 40 kmph.

Parameter that has the greatest impact on the degradation of the vertical handover latency, according our simulation results are the synchronization DCD and UCD intervals. They are set to 1 second in our improved parameter combination.

Throughput results during the vertical handover process for both scenarios are presented in Figure 7 and Figure 8. Throughput gap between UMTS and WiMAX is measured during the vertical handover process. Similar to the conclusion regarding the latency, we can notice that the throughput gap is decreased with our solution compared with standard parameters.

So, the outcome gives the strong correlation between the parameters for handling the IP mobility on the network layer and parameters on the MAC layer which are dependent upon a given wireless standard (such as DCD and USD intervals in WiMAX). On other side, if we use very short intervals between consecutive router solicitation messages in the wireless access networks, we may have huge control traffic load, which will reduce that available data rates for the video traffic. The same discussion may be given for the WiMAX synchronization intervals. So, optimal setting of these parameters has crucial impact on real-time services with demand for higher data rates, such as video traffic.

4. Conclusion

In this paper, we focused our analysis on performance evaluation metrics for vertical handovers done with different real time video streams in heterogeneous wireless scenario, with focus on vertical handovers between UMTS and WiMAX networks.

We have used IEEE 802.21 protocol for vertical handovers and we have evaluated performance metrics (vertical handover latency, and throughput during vertical handover process) for real time video (H.261, MPEG-4, HDTV). The analysis have shown that handover latency and throughput gap during vertical handovers between UMTS and WiMAX networks is increasing almost linearly with the mobile user velocity.

The analysis on the router configuration and link threshold parameters, have given as outcome the best combination of the parameters that give significant improvement by reducing the vertical handover latency for the real time video traffic during UMTS/WiMAX vertical handovers. Also, the optimized parameters solution provided smaller the throughput gap between UMTS and WiMAX networks for different velocities, thus resulting in better QoS for the mobile users with video streams.

Finally, the results showed that we can improve the behavior of certain real-time applications, such as video, during vertical handovers, by appropriate settings of the parameters on link and network layers regarding the router advertisements and link synchronization, respectively. However, such approach will increase the control and signaling traffic in the wireless networks. Finally, one needs fine tuning of the wireless networks, which is dependent upon mobile services used by mobile users.

References


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