Enhancing Quality of Experience in Wireless Heterogeneous Networks

Ognen Ognenoski, *Student Member, IEEE,* Valentin Rakovic, *Student Member, IEEE,* Filipo Sarevski, *Student Member, IEEE*, Daniel Denkovski, *Student Member, IEEE*, Vladimir Atanasovski, *Student Member, IEEE*, Liljana Gavrilovska, *Senior Member, IEEE*

Abstract — **Wireless Heterogeneous Networks are envisioned as evolved wireless network infrastructure that provides continuous service regardless of the underlying technology. The Quality of Experience (QoE) level perceived by users for their applications in such networks can be maintained only by making the roaming between the component networks in seamless fashion. This can be achieved by providing mechanisms that will serve the users with the required system resources during and after their switching to different networks in the system. This paper investigates the effects of transition (horizontal and vertical handover) in broadband wireless systems for different types of applications. In case of horizontal handover it shows how the QoE for the user's applications can be enhanced by managing system parameters on MAC layer of the WiMAX technology. Furthermore, it shows how the decision for performing vertical handover WLAN/WiMAX made by the terminal can affect the application performances. The overall results can be used as guideline for managing the resources of component networks in coexisting platforms. They also pave the way for building cross layering solutions for efficient resource management in future wireless networks**.

***Keywords* — System Handovers, Quality of Experience, WiMAX, WLAN**

I. Introduction

During the last two decades various radio access technologies have been developed in order to better compromise the emerging need for mobility and high speed connectivity of the users. Current leading trend in the area of wireless technologies is the development of heterogeneous wireless networks with coexisting radio technologies and seamless roaming support between different wireless networks. These networks are envisioned as platform for realizing the paradigm of ongoing users' session continuity, no service disruption and higher level of quality of experience [1].

Delivering such paradigm is a challenging task. It invokes design of different solutions that tend to satisfy the variety of application demands, in terms of end-to-end delay, throughput, probability of packet loss and jitter. The complexity of such solutions is also and important aspect as real time requirements must be satisfied. Serving the session during and after the handover, must be fast and effective in terms of resource allocation and decision making either in horizontal or vertical handover procedure.

All authors are with the Faculty of Electrical Engineering and Information Technologies, Ss. Cyril and Methodius University of Skopje, Macedonia (phone: 389-2-3099114; fax: 389-2-3064262; e-mail: liljana @feit.ukim.edu.mk).

The horizontal handover procedure denotes the switching of the terminal between BSs from the same technology whereas the vertical handover implies switching between Points of Attachment (PoA) from different technologies. The handover procedure degrades the application performances hence intelligent management should be deployed. Besides having insight of the system condition (network load, signal to noise ratio in the terminal receiver side, capacity, power consumption, etc) these mechanisms should take into consideration the application specific characteristics as relevant factor during and after the handover process. High QoE for the user's applications can be achieved with optimal allocation of the available network resource and the resources needed for the user's applications.

This paper investigates the effects of horizontal and vertical handover in broadband wireless systems (IEEE 802.16e mobile WiMAX [2] / WLAN network [3]) for different types of applications. It shows how the application QoE can be enhanced by managing system parameters on MAC layer of the WiMAX technology for the horizontal handover. For the vertical handover WLAN/WiMAX it shows how the decision made by the terminal for selecting the target BS effects on the QoE.

The rest of the paper is organized as follows: Section II gives an overview of current handover decision mechanism in WLAN/WiMAX heterogeneous systems together with horizontal handover in mobile WiMAX environment. Section III shows the simulation results for both horizontal and vertical handover and effect of the managed parameters on the application QoE. In the end, section IV concludes the paper and gives directions for future work.

II. Related Work

Several Handover decision mechanisms considering the vertical handoff are already proposed in literature. In [4] the authors propose a vertical handover mechanism based on fuzzy control theory, which takes into consideration power level, cost and bandwidth, processed as weight vector. The proposed handoff scheme in [5] is formulated as a fuzzy multiple attribute decision making problem, organized in two steps: the first step is to process multiple criteria by using a fuzzy logic inference system, and the second step is to apply a Fuzzy MADM (Multi Attribute Decision Making) access network selection function to select a suitable network. There are two classical MADM approaches investigated: SAW (Simple Additive Weighting) TOPSIS (Technique for Order Preference by

Similarity to Ideal Solution). This two MADM approaches together with GRA (Gray Relational Analysis) and MEW (Multiplicative Exponent Weighting) are overviewed and respective performance analysis of each algorithm is conducted in [6]. Handoff decision mechanism given in [7] performs optimization based on a cost function which depends on the bandwidth, delay, and power requirement. Authors in [8], propose a Trusted Distributed Vertical Handover Decision (T-DVHD) scheme, which formulates the handover decision also as a MADM problem, taking into account parameters such as network condition, bandwidth, power consumption, cost, latency and security. Moreover, a Trust-test function is proposed as a solution to the problem of falsification of Network Quality Vector (NQV), which may affect the mobile nodes' handover decision. A dynamic decision model for vertical handoffs in heterogeneous networks is proposed in [9]. This mechanism, which is based on the dynamic parameters – Received Signal Strength (RSS) from the network and the velocity of the mobile node, and the static parameters – Usage Expense, Link Capacity and power consumption, aims to select the best network and the best time to perform the handover process. In [10] a vertical handover decision mechanism, which balances the overall load among all points of attachment (BSs and APs), is proposed and its performances are evaluated. Moreover, this handover decision algorithm tends to maximize the collective battery lifetime of the mobile nodes.

III. Handover Performance Analysis

The simulations are performed in QualNet [10] simulator as a platform that provides various libraries and possibility for building heterogeneous wireless environment. It also enables a configuration of multi interface terminal capable of vertical and horizontal handover in the wireless environment. The performances of such handover procedures are tested for two types of applications (constant bit rate and file download) with different configuration parameters (packet size, bitrate). The analysis shows how adaptive management mechanisms should be designed depending of the applications and the network condition to achieve high QoE during and after the handover procedures.

A. Performance of Horizontal Handovers

The scenario is set up in an area 8000x8000(m) where two base stations enabled to serve mobile WiMAX users are set with parameters as in Table 1.

Table 1: Configuration table

WiMAX	Antenna gain [dBi]	Transmission Power[dBm]	Antenna Height [m]
BS	*18*	*43*	*35*
Node	*0*	*23*	*1,5*
Channels	*3.3 GHz*		
WiFi	Antenna gain [dBi]	Transmission Power[dBm]	Antenna Height [m]
802.11b	*8*	*15*	*1,5*
channels	*2.4 GHz*		

The terminal can "hear" the two working channels of the base stations and measures the signal strength on each channel. When the scenario is started the BS1 serves the terminal on channel 1 (because of the higher SNR) while the terminal transits in the environment according to random waypoint mobility model.

The environment is configured with modeling the working channels with simple two ray path loss model and shadowing factor of 4dB. As the terminal follows the mobility model, it moves away of the BS1 and moves towards BS2 thus the signal strength level from BS1 decreases whereas the one from BS2 increases. When certain threshold level (-86dBm) is reached the terminal performs horizontal handover procedure.

Different application types with different demands are tested in order to measure performances in terms of *handover duration* and *packet loss* during the horizontal handover procedure. Managed parameter during this analysis is the *duration of the downlink frame* which is adaptive according to standard. Higher values for the downlink frame duration correspond to reservation of more system resources. Fig. 1. depicts the results for the *handover duration* for CBR and FTP application with different configuration. This parameter is defined as the time difference between the time when the BS is selected as target (start of handover procedure) until the handover procedure finishes. The results show that the application demand for CBR does not have significant influence on the handover duration when more resources are allocated in the system. However, more resources result in small decay of the handover duration when the CBR application was investigated. The FTP application does not show such regularity. For small frame duration (up to 10ms) the handover duration parameter is constant for different demands of the FTP application. However, when the system allocates more resources FTP with larger packet size are more suitable and yield lower handover duration times. This is due to the fact that larger packets more quickly fill the downlink frame reserved by the scheduler at the BS in contrast to smaller packets thus the handover duration drops. The optimal values that minimize the handover duration time are 10ms and 12ms for the FTP applications. This is how the downlink frame should be set when FTP application with such packet size are started. It is a valuable input for cross layering design of resource management mechanism.

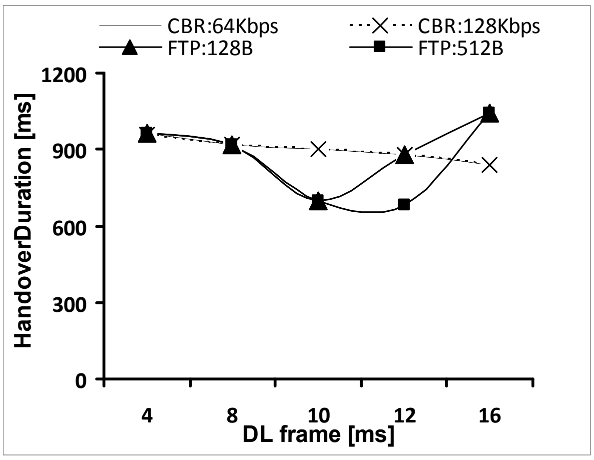

Fig. 1. Handover duration for different applications

During the horizontal handover *packet loss* is imminent. The packets scheduled in the serving base station scheduler will be lost when the terminal switches to its target base station. This parameter is investigated with simulations depending of the resource allocation for the user and Fig. 2. depicts results for CBR applications while Table 2. presents results for the FTP applications. Table 2 shows insignificant changes in packet loss when the FTP applications are established with different packet size. It also shows that the packet loss is very low for the FTP since it runs on TCP on transport layer.

Table 2: Packet loss for FTP: BS is empty

Dl frame [ms]	4	8	10	12	16
FTP:128B	*3*	*3*	*3*	*3*	*3*
FTP:512B	*3*	*3*	*3*	*3*	*3*
FTP:1024B	*3*	*3*	*3*	*2*	*2*

Fig. 2. depicts the results for the CBR applications run on UDP at transport layer. The packet loss is imminent and it yields higher values when the application demands are higher. For small application demands (64Kbps and 128Kbps) the packet loss is relatively constant depending of the downlink frame duration. However, when the CBR application is more demanding (512Kbps) allocating more resource during the handover is not efficient because large number of packets will wait in the scheduler to fill the downlink frame, and when the handover occurs they will be lost in the serving base station.

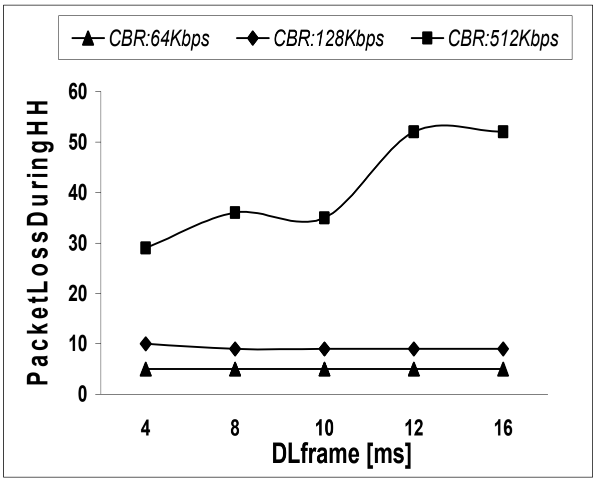

Fig. 2. Packet loss during the HH procedure for CBR applications: BS is empty

In the previous simulations the base station is serving only the referent user, and schedules packet transmission only for its session. In practice, this kind of set up is not the case. Fig. 3. shows the dependences of the packet loss parameter for the CBR applications when the base station serves variable *number of users* with random sessions. The DL frame is fixed at 10ms.

For the FTP applications there is no significant packet loss even when the serving base station serves users because of the TCP. The table for the packet loss when the BS is serving users is not presented as it corresponds to Table 2. when BS is not serving users.

Contrasting this effect, the CBR applications are prone to increasing packet loss when the number of serving users by the base station is increasing especially for higher application demands where this effect becomes more evident.

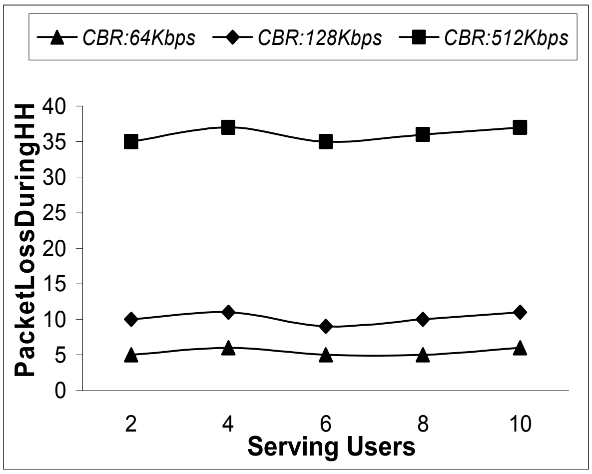

Fig. 3. Packet loss during HH procedure for CBR applications: BS is serving users

B. *Performance of Vertical Handovers*

The scenario set up is the same area 8000x8000(m) where AP configured with parameters in Table 1. is serving the session of the referent terminal. A mobile WiMAX base station configured according to the configuration table is the target candidate in the vertical handover procedure. The session on the terminal that follows the same random waypoint model starts on the AP and when the terminal receives signal with enough strength level from the mobile WiMAX station (at this point the AP signal is weak) it switches the session to the WiMAX network. The environment is configured as in the previous case for the path loss and shadowing factor. The terminal is configured in the simulator in such manner to support functionality on both interfaces and can perform vertical handover between the two technologies.

For the vertical handover only the CBR application is tested due to simulation limitations. The FTP works with TCP and in the simulator makes vertical handover in the make after break fashion. This is similar like turning the interface off, and restarting the application on another network which is not a handover issue.

The analysis of the vertical handover procedures differs from the one for the horizontal handover in terms of parameters of interest and its use case. For the vertical handover from WiFi to WiMAX the effect of the decision for target WiMAX BS is of interest. Three decisions are possible according to the proposed three base station configurations: BS that is not serving users and gives low SNR at the decision moment for the terminal; BS that is not serving users and gives high SNR at the decision moment for the terminal; and BS that serves large number of users and gives high SNR at the decision moment for the terminal.

Parameters of interest are the *end to end delay* of the established session and the *handover latency.* The end to end delay includes the delay in the WiFi and WiMAX links and gives insight about the quality of the overall session. The handover latency is defined like a time difference between the last packet received on WiFi and the first packet received on the WiMAX interface. It gives insight about the quality of the session transition in terms of preserved session continuity.

Fig. 4. depicts the results for the end to end delay of the different CBR sessions that experience vertical handover. Managed parameter is the different decision that the MN makes about the target BS. When the application demands are higher, the end to end delay increases for every decision the MN makes. When the BSs are empty (not serving users), the end to end delay follows regularity and gradually increases for higher application demands. The target BS with higher SNR shows better performances independently of the application demands. When the target BS provides high SNR for the terminal, but is overloaded with users, the end to end curve does not follow regularity like in the previous cases. It depends of the application demands in more dynamic fashion: yields higher end to end delay even compared with the decision for low SNR target BS. The delays for lower application demands are generally similar to the ones yielded with the different decision. Consequently, when application with large CBR demand is started the nature of the traffic load the target BS already serves influences the overall end to end delay, hence the decision should depend on the base station current condition.

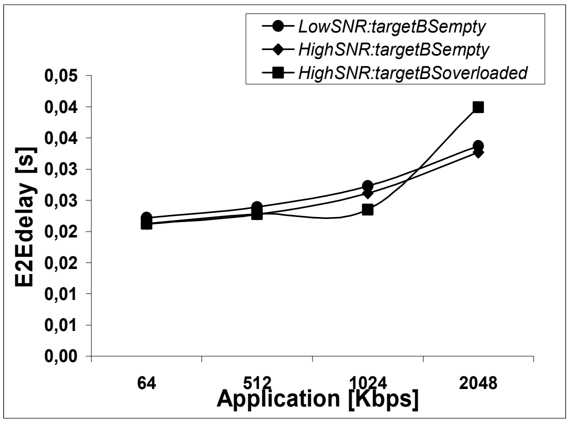

Fig. 4. End to End delay for different CBR application

Fig. 5. depicts the result for the handover latency when decision about the base stations with low and high SNR that are empty. The case with overloaded BS that provides high SNR is not investigated since the dynamics of scenario reflects in out of sequence packets that arrive on both interfaces, hence handover latency can not be accurately calculated.

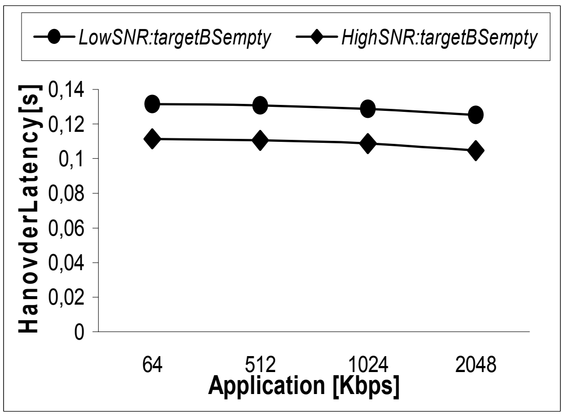

Fig. 5. Handover latency for different CBR applications

The results show that different application demands only yield small difference in the total handover latency depending on the time the handover is triggered. The BS with higher SNR for the referent user provides better performances for all CBR applications. Minimizing the handover latency can be achieved when target BS provides high SNR to the user.

IV. CONCLUSION

The analysis of both horizontal handover and vertical handover for different types of application and different demands can be used as input for building cross layer mechanism for resource allocation in future wireless systems [11]. The decision for selecting target BS when the user moves from WiFi towards mobile WiMAX network should not be straightforward based on SNR. Target BSs with high SNR for the user are preferable, but the user QoE can not be guaranteed just on this parameter since the BS current traffic load from currently serving user effects the overall QoE for the application. When the user is admitted in the WiMAX system, depending of the application type and demand, the modifications on MAC layer (e.g. downlink frame duration) can enhance the QoE for the user application during horizontal handovers. Combining these two techniques in joint fashion provides valuable input for one use case scenario for the design and functionality of the cross layer mechanism for serving users in future wireless systems. The future work will include design of such cross layering mechanisms.

REFERENCES

[1] David Soldani, Man Li and Renaud Cuny, *QoS and QoE Management in UMTS Cellular Systems*, John Wiley & Sons Ltd 2006
[2] IEEE 802.16e Standard for Local and Metropolitan Network, Part 16: Air Interface for Fixed and Mobile Broadband Access, http://standards.ieee.org/getieee802/download/802.16e-2005.pdf
[3] IEEE 802.11b Standard for Local and Metropolitan Networks, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher Speed Physical Layer Extension in the 2.4 GHz band, http://standards.ieee.org/getieee802/download/802.11b-1999.pdf
[4] Hongwei Liao, Ling Tie, and Zhao Du, "A Vertical Handover Decision Algorithm Based on Fuzzy Control Theory" in Proc. of the First International Multi-Symposiums on Computer and Computational Sciences (IMSCCS'06), Hangzhou, Zhejiang, Society.
[5] Enrique Stevens-Navarro and Vincent W.S. Wong, "Comparison between Vertical Handoff Decision Algorithms for Heterogeneous Wireless Networks", IEEE - VTC 2006.
[6] W. Chen and Y. Shu, "Active Application Oriented Vertical Handoff in Next Generation Wireless Networks," in Proc. of IEEE WCNC'05, New Orleans, LA, March 2005.
[7] Rami Tawil, Jacques Demerjian and Guy Pujolle, "A Trusted Handoff Decision Scheme for the Next Generation Wireless Networks", International Journal of Computer Science an d Network Security (IJCSNS), VOL.8 No.6, June 2008.
[8] Pramod Goyal, and S. K. Saxena, "A Dynamic Decision Model for Vertical Handoffs across Heterogeneous Wireless Networks", World Academy of Science, Engineering and Technology 41 2008.
[9] SuKyoung Lee, Kotikalapudi Sriram, Kyungsoo Kim, Yoon Hyuk Kim, and Nada Golmie, "Vertical Handoff Decision Algorithms for Providing Optimized Performance in Heterogeneous Wireless Networks", IEEE Transactions on vehicular technology, January 2009.
[10] "QualNet 4.5 User's Guide" Scalable Network Technologies, Inc.,March 2008.
[11] L. Gavrilovska and V. Atanasovski, "Resource Management in Wireless Heterogeneous Networks (WHNs)," *9th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services (TELSIKS 2009)*, Nis, Serbia, October 2009.