Adaptive QoS Provisioning for Non-real Time Services in Heterogeneous Wireless Networks

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Abstract — **In this paper we introduce a novel adaptive QoS provisioning for non-real time services in heterogeneous wireless networks. The concept is proven via simulation analysis in integrated environment with 3G and IEEE 802.11 networks. We introduce a novel adaptive module that provides the best QoS and lower cost for a given service by using one or more wireless technologies at a given time. The performance of the algorithm is evaluated using simulation with dual-mode mobile stations. The analysis of this concept has shown overall better performances and QoS provisioning for different multimedia services in a variety of network conditions in heterogeneous wireless/mobile environment.**

Key words — **Adaptive, Heterogeneous, Quality-of-Service (QoS), Wireless Networks.**

I. Introduction

Quality-of-service provisioning for wireless and mobile heterogeneous networks is becoming increasingly important objective, since it requires great thoughtfulness, scalability and thorough full analysis. Since radio bandwidth is one of the most precious resources in wireless systems, an efficient adaptive QoS framework is very important to guarantee QoS and to maximize radio resource utilization simultaneously. Moreover, the most significant QoS parameters in the existing wireless/mobile heterogeneous networks are the throughput, packet delivery ratio, packet error ratio, call blocking probability, delay and jitter.

This paper introduces a novel adaptive QoS provisioning for non-real time service (web, e-mail, ftp, mms, etc.) over integrated UMTS/WLAN heterogeneous systems, in a tight coupling architecture, using novel dual-mode ME node with adaptive QoS module within. Integration of the WLAN and UMTS networks has been intensively studied recently due to their complementary characteristics. The 3GPP has been continuously evolving to support multimedia services which require high data rates in cellular networks. Today, the UMTS network can support services with maximum data rate of 2Mbps. On the other hand, the IEEE 802.11a and IEEE 802.11g can provide up to 54 Mb/s in 5GHz and 2.4GHz bands, respectively. But WLANs have disadvantages of supporting nomadic user movements and of having small coverage (coverage by an access point (AP) is up to several hundred meters in radius) in comparison with a cell covered by a UMTS Node B (usually several kilometers in radius). Such complimentary characteristics of these two popular technologies have stimulated research efforts to integrate UMTS and WLAN networks so that mobile stations can choose the network that has better network quality when they are covered by both networks and have continuous services when they roam in the integrated networks. Nowadays many mobile equipments (MEs) have also a WLAN and Bluetooth interfaces, and in the near future many MEs will have Long Term Evolution (LTE) interfaces too, besides their UMTS, WLAN, WiMAX, Bluetooth, ZigBee etc. radio interfaces. However, when there are different wireless/mobile networks on one side, and single ME on the other, then consequently the user of that ME should have adaptive QoS module included within, with possibility to use all those technologies in the range using his/her personal settings in the ME, or this user can choose only one from all available technologies. For that purpose the Open Wireless Architecture (OWA) in [1] and in [2] is proposed to provide open baseband processing modules with open interface parameters for supporting different wireless communication standards.

The remainder of this article is structured as follows. Section II gives an overview of the most relevant research works in this field. Section III briefly presents our novel ME adaptive QoS module. In Section IV the simulation results have been presented. And finally, Section V concludes this research.

II. Related Works

The major goal in any wireless and mobile network is the high level of QoS provisioning for every given service. The interest for adaptive QoS provisioning is growing together with the tremendous grow of adaptive multimedia services in mobile communication networks, where it is possible to increase or decrease the bandwidth of individual ongoing flows. In [3] is presented bandwidth adaptation algorithm which seeks for high level of QoS provisioning. Moreover, in [3] the bandwidth of an ongoing multimedia calls can be dynamically adjusted, with the Call Admission Control (CAC) algorithms. Call blocking probability, forced termination probability and

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call overload probability are the main QoS parameters on a call level. But in [3] only single class of adaptive multimedia networking has been investigated. Furthermore, in [4] is presented effective QoS provisioning for wireless adaptive multimedia with using a form of discounted reward reinforcement learning known as Q-learning. Proposed scheme in [4] considered the handoff dropping probability and average allocated bandwidth constraints simultaneously, in order to achieve optimal CAC and bandwidth allocation policies that can maximize network revenue and guarantee QoS constraints. Simulation results in [4] demonstrate that the given scheme is high effective. On the other hand, when we focus on architectures for integrating WLAN/UMTS systems they can be grouped into two categories based on the independence between the two networks [5], tight coupling and loose coupling. The loose coupling architecture enables the two networks deployed independently, but it results in longer delays for signaling and vertical handovers. 3GPP has been working on standardization for integration of cellular 3GPP technologies and WLAN systems [6]. Furthermore, schemes for dual-mode ME node for UMTS/WLAN internetworking, have been proposed in [7] and [8], but without emphasized QoS issues. The main motivation that led us to the development of novel adaptive QoS module, which will provide intelligent high level of QoS in any wireless and mobile networks (including integrated UMTS/WLAN networks [9]), using every available technology at same time, is taken from [1]. In [1] the main 5G mobile phone concepts and moreover the needs for creating and implementing adaptive QoS management mechanisms have been introduced. Furthermore, in the next section we elaborate the intelligence of our novel adaptive QoS module.

III. Adaptive QoS System Module

In Fig. 1 we present our novel ME node, which is dual-mode UMTS/WLAN node, with Adaptive QoS module within on IP layer. According to [1] and [2] physical and OWA define the wireless technology, the network layer will be IP, but separation of this layer into two sublayers will be necessary. Upper Network Layer has one unified IP address within, and is nominated for routing as well as for creation of sockets to the upper application layer. The Lower Network Layer may include several different IPv4/IPv6 addresses, one IP address for every physical network interface. Description of this concept is given in [1]. Furthermore, we briefly present our adaptive QoS framework in ME. The core of our work is development of novel adaptive QoS Module; we refer to it as QoS-Cross-IP Module (QXIP), which is defined separately from each wireless technology. It is implemented on Upper Network Layer, which will be able to provide intelligent QoS management and routing over variety of network technologies. Moreover, the QXIP module is able to combine simultaneously several different traffic flows transmitted over the same or different wireless access channels, achieving higher throughput and optimally using the radio resources.

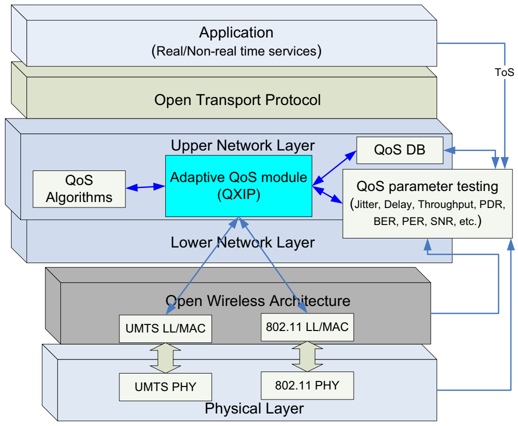

Fig. 1. Dual-mode Node with Adaptive QoS Module.

For the purpose of the QXIP, the ME must collect QoS parameters, such as delay, jitter, losses, bandwidth, reliability, Packer-Error-Ratio (PER), Signal-to-Noice-Ratio (SNR), Transmission Power (TP), etc., continuously, all the time, by collecting the measurement data via cross-layer messages from OSI layer 1 up to Lower Network layer, and then storing the data into two-dimensional matrix within the QXIP module. This two-dimensional matrix is a small QoS DB (database), which can be easy extended, in a more complex multi-dimensional matrix. The first row of this matrix contains UMTS QoS parameters and second row contains the WLAN QoS parameters, respectively. On the other hand, with one cross-layer message, for each send packet, the Type-Of-Service information (ToS field in IPv4 or DSCP field in IPv6) is collected, in order to implement packet scheduling priority. Before every downlink transmission of IP packet from QXIP down to UMTS or WLAN MAC modules, the QXIP module is doing service quality analysis by using the data stored in the QoS DB in the ME for given time period in the past (e.g., seconds, minutes) in order to choose the best wireless connection upon required QoS. Here, in our current implementation, we are testing only: ToS, SNR, PER and Transmission Power, which are collected from Application and OWA Layer (OSI Layer 1 and OSI Layer 2). QXIP module always fist try to get admission (in downlink) to the WLAN whenever it is available (i.e. all tested WLAN parameters: SNR, PER and TP, are above their appropriate WLAN thresholds [7]). Second, if QXIP module doesn't get WLAN admission, it tries to get admission to the UMTS network (all tested UMTS parameters are above their appropriate UMTS thresholds and also the UMTS utility function is tested [7]). Finally, QXIP module sends the packet that comes from Upper Network Layer down to the chosen LL/MAC module or drops it in the case there is no admission to any of the given networks. However, every packet goes through packet priority scheduling, before it is passed to the above mentioned downlink procedure. On the other hand, in uplink, all packets from all LL/MAC modules are received in Upper Network Layer, and send up from QXIP module to Transport Layer, without dropping them. At this point different flow combining is done in the QXIP module.

IV. Simulation Results and Analysis

In Fig.2 the simulation scenario is given, and as can be seen, we create one UMTS Node B and one WLAN Access Point. At the beginning of the simulation, the MEs are randomly scattered within the area of 500x500 m^2. For MEs physical mobility, we adopted the Gauss-Markov Mobility model [10] considering average speeds in the range of 2-21 m/s. The Node B coordinates are: (500,500) which providing coverage for the MEs placed within a distance of about 520 m. On the other hand, WLAN AP is placed at (150,150) which providing coverage for the MEs placed within a distance of about 130 m. The non-real time traffic (VBR traffic) starts at the beginning of the simulation time, and flows between Internet through the gateway, which is wired to Node B and AP, to all MEs. The general parameters used in our simulation are summarized in Table 1. At the first case all MEs are dual-mode UMTS/WLAN with QXIP module within. We use ns-miracle 1.2.2 [11] for creating our dual-mode ME with two interfaces (one for UMTS, another for WLAN network) and with QXIP module (presented in the previous section). Moreover we create novel cross-layer messaging class, for cross-layer communication between the modules. The performance outline in this case is shown with blue lines in Fig. 3-8, and is compared with the simulation outlines in the cases when we use MEs without QXIP module within, i.e. only WLAN MEs (green line) or only UMTS MEs (red line). As we can obtain from Fig. 3, the average throughput for our dual-mode ME with included QXIP module within (QXIP_ME), without doubts achieve the greatest values for any number of used nodes, in comparison with the average throughput in the case when we used only WLAN MEs, or in the case when we use only UMTS MEs. We must to emphasize the fact that we obtain equal average throughput in the cases when we use only WLAN MEs for small number of nodes (up to 3 MEs). This is, more or less, expected due to the fact that when we used just a few MEs with mean speed of 2m/s, the probability some of them to pass through the WLAN area (in simulation time of 15s) are very high. In general, MEs more often are connected on WLAN APs, using the higher WLAN throughput, and from time to time using UMTS access. Moreover, even at times when those two traffic flows are combined, WLAN traffic characteristics are dominant regarding the throughput.

Moreover, in Fig. 4 is presented average throughput for different velocity (form 2 up to 21 m/s) of the MEs, when we have 8 MEs and simulation time of 15 s. First of all, can be clearly obtain that average throughputs of our case (when we used dual-mode QXIP MEs) is much larger then the average throughput from the other two cases, for any given average velocity. To emphasize that for higher velocity values, QXIP and WLAN throughput curves have descending trend, because at those speeds not all MEs have possibility to access WLAN APs (at higher user velocities there is no time for doing UMTS-WLAN vertical handovers). The UMTS throughput curve remains almost constant, due to the full UMTS coverage.

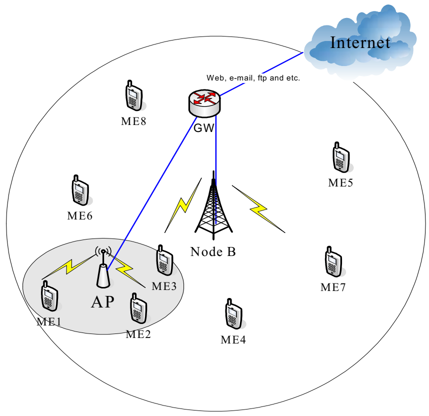

Fig. 2. Simulation scenario for non real-time services.

TABLE 1: SIMULATION PARAMETERS.

Parameters	***Values***
TCP packet size	500 Bytes
WLAN Data rate	1 Mbps
Physical header	192 Bits
MAC header	224 Bits
SIFS	10 µs
DIFS	50 µs
Traffic frame inter-arrival time	4 sec
CTS, ACK	112 bits + Phy hdr
WLAN_PER threshold	$7x10^{-11}$ W
UMTS_PER threshold	$1x10^{-6}$ W
Node B spreading factor	32
ME spreading factor	16

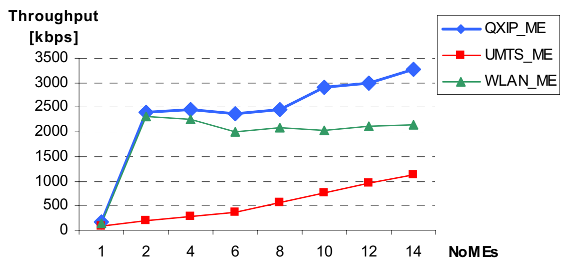

Fig. 3. Average throughput vs. number of nodes ($\bar{v}$ =2m/s)

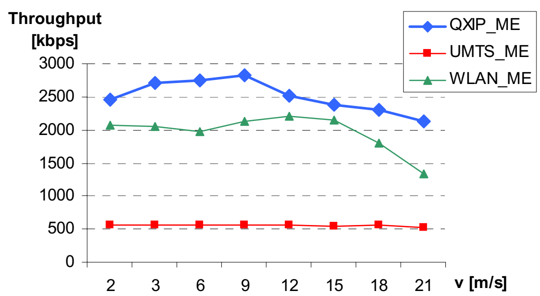

Fig. 4. Average throughput vs. velocity (*NoMEs*=8)

Furthermore, in Fig. 5 average jitter values as a function of TCP packet sizes for any three cases have been presented. In this scenario, the number of MEs is fixed on 8, and the MEs mean velocity is 2 m/s and simulation time is 15 sec. For our QXIP MEs, in comparison with the case when we use UMTS MEs, average jitter is lower. On the other hand QXIP MEs have higher average jitter values in comparison with the average jitter values of WLAN MEs, but this is because of the fact that WLAN technology supports higher TCP packet sizes and offers higher traffic throughputs then UMTS. Moreover, in Fig. 6 are shown the average end-to-end delay curves for the same scenario as described before. Similar as in Fig. 5, the statistic of QXIP ME delay curve is between the delay's curves of UMTS and of WLAN cases, with lower values then the values of UMTS curve, and higher then the values of WLAN curve. With rise of the TCP packet size all three curves are ascending. The reason is the same we discussed for Fig. 5. Furthermore, in Figure 7 average jitter values as a function of average velocity for two cases (when we use dual-mode QXIP MEs and when we use UMTS MEs) have been presented. In this scenario, the number of MEs is fixed on 8, and the duration of the simulation is 15 s. As it is shown, in the case with dual-mode QXIP MEs, in comparison with the case with UMTS MEs, for any particular velocity, lower average jitter value has been achieved. For a lower velocity values, in comparison with the average jitter values of UMTS MEs, around two times lower average jitter values for our QXIP MEs are achieved. As the average ME velocity increase, those two curves achieve similar ascending trends, which is expected on those high speed values. Finally, in Fig. 8 the average delays when we use dual-mode QXIP MEs and when we use UMTS MEs are presented. In this scenario, the number of MEs is fixed on 8 and the MEs velocity is 2 m/s. As we see, during all simulation time, lower delay for our QXIP ME case (0.4 sec less then UMTS ME delay), in comparison with UMTS ME delay values is achieved.

V. Conclusion

In this paper we have presented performance results for the key QoS parameters, using novel adaptive QoS module within a dual-mode UMTS/WLAN Mobile Equipment. According to the simulation results, our propose dual-stack UMTS/WLAN ME with adaptive QoS module performs fairly well, even in different network conditions as: various nodal mobility, various background traffic loads and different number of nodes; achieving better performances in comparison with the cases when only WLAN or UMTS MEs have been used. In our future work we will focus on development of advanced QXIP module, accompanied with performance analysis in more complex wireless scenarios.

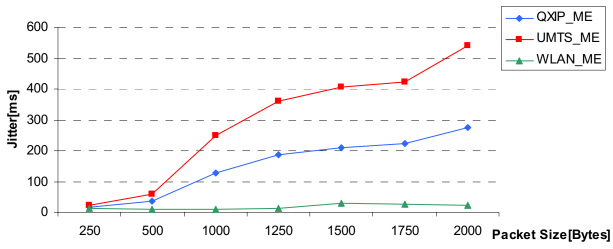

Fig. 5. Average jitter vs packet size ($\overline{v}$ =2m/s; *NoMEs*=8)

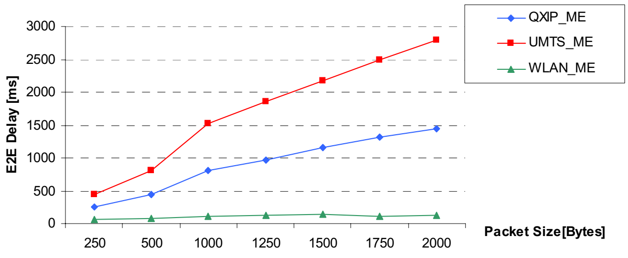

Fig. 6. Average delay vs packet size ($\overline{v}$ =2m/s; *NoMEs*=8)

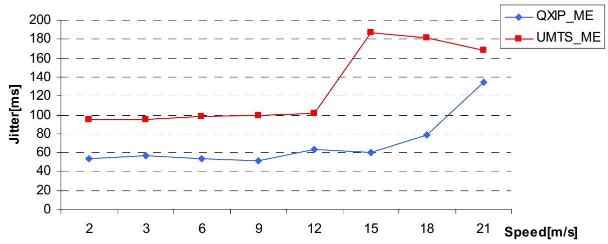

Fig. 7. Average jitter vs velocity (*t_sim*=15s; *NoMEs*=8)

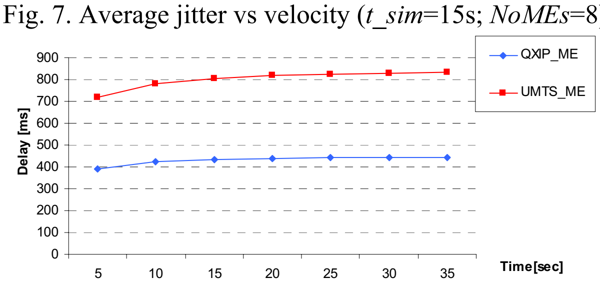

Fig. 8. Average delay vs time ($\overline{v}$ =2m/s; *NoMEs*=8)

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