Novel Adaptive VoIP QoS Provisioning In Integrated UMTS/WLAN Networks

Tomislav Shuminoski[1] and Toni Janevski[2]

Abstract – **This paper introduces a novel concept of adaptive QoS provisioning for wireless/mobile multimedia networks. Moreover, simulation results for this adaptive QoS framework in 3G networks (such as UMTS) and IEEE's 802.11 WLANs have been presented. The aim of this novel framework is presenting new module that shall provide the best QoS and lower cost for a given service using one or more wireless technologies. The analysis of this framework has shown good performances and high level of QoS provisioning in a variety of network conditions. The performance of our algorithm is evaluated using ns-miracle augmented with our dual-mode mobile stations.**

Keywords – **Adaptive QoS module, dual-mode, jitter, PDR, Quality-of-Service (QoS).**

I. INTRODUCTION

With the explosive growth of the wireless and mobile communications and the emergence of the bandwidth-intensive multimedia services (video, data and voice), QoS provisioning for wireless and mobile multimedia networks is becoming increasingly important objective, since it requires great thoughtfulness, scalability and thoroughfull 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 networks are the throughput, packet delivery ratio, call blocking probability, delay and jitter (especially when we use Constant Bit Ratio (CBR) traffic flows).

The preview is focused on adaptive QoS provisioning for VoIP service over integrated UMTS and WLAN 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 802.11b can provide data rate up to 11Mb/s in 2.4 GHz. Furthermore, 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. The hardware requirement for integrating UMTS and WLAN networks is mainly to build dual-mode ME with adaptive QoS module inside, which has the capability of accessing both networks and choose the best connection according to QoS demands for the given service (in our case VoIP).

Moreover, without loss of generality, this adaptive QoS provision can be used in any mobile and wireless IP multimedia 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 and mobile networks on one side, and single ME on the other, then consequently the user of that ME should have 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. In Section II gives an overview of the most relevant research works in this field. Section III briefly presents our ME adaptive QoS module. In Section IV the simulation results have been presented. And finally, the last Section V concludes this research.

II. RELATED WORKS

High level of QoS Provisioning for every given services is a major goal in any wireless and mobile networks, since the fact that the users are the main player from where all business revenues start. 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

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provisioning. Moreover, in [3] the bandwidth of an ongoing multimedia calls can be dynamically adjusted, with the CAC algorithm. Call blocking probability, forced termination probability and call overload probability are the main QoS parameters take in common. But the lack of [3] lays in the fact that only one single class of adaptive multimedia networking has been investigated. Furthermore, in [4] effective QoS provisioning for wireless adaptive multimedia with using a form of discounted reward reinforcement learning known as *Q*-learning is presented. Moreover, the proposed scheme in [4] considered the handoff dropping probability and average allocated bandwidth constraints simultaneously, in order to achieve optimal CAC and BA 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. Here the loose coupling architecture is used; where those two networks are integrated beyond the Core Network (CN) of UMTS (connected through gateways of the Internet). The loose coupling architecture enables the two networks deployed independently but results in longer delay for signaling and vertical handovers. 3GPP has been working on standardization for integrating cellular and WLAN systems in [6] in which interworking architecture and interworking scenarios are described. Moreover, similar to our dual-mode ME node for UMTS/WLAN interworking networks, 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), using every available technology in a same time, is taken from [2]. In [2] is given the main 5G mobile phone concepts and moreover the needs for creating and implementing adaptive QoS management mechanisms have been introduced. To emphasize that in comparison with other related works, our adaptive QoS module is implemented on IP level.

III. ADAPTIVE QOS SYSTEM MODULE

In Fig. 1 is presented 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 (i.e. OSI Layer 1 and 2), the network layer will be IP, but separation of this layer into two sublayers will be necessary; one subleayer for routing and another will be for each interface (different IPv4 or IPv6 addresses). For more details about all this layers see [2]. Furthermore, briefly is presented our adaptive QoS framework in ME. The core of our work is development of novel adaptive QoS Module; we call it QoS-Cross-IP Module (QXIP), defined separately from each wireless technology (e.g. UMTS, WLAN, WiMAX, 3G-LTE, 4G, etc.), which will be able to provide intelligent QoS management and routing over variety of network technologies.

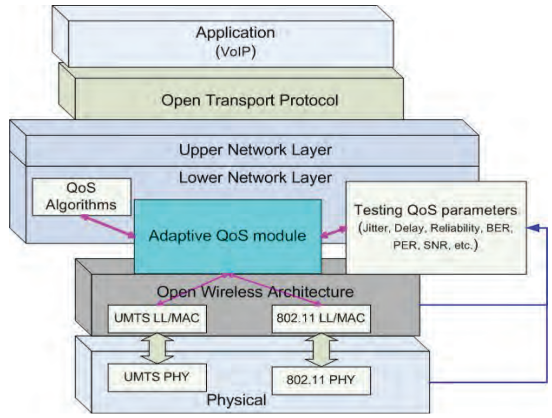

Fig. 1. ME dual-mode Node with Adaptive QoS Module

The QoS parameters (such as delay, jitter, losses, bandwidth, reliability, Packer-Error-Ratio (PER), Signal-to-Noice-Ratio (SNR), Transmission Power (TP), etc.) are continuously, all the time, collecting via cross-layer messages from OSI layer 1 up to Lower Network layer, and stored in a two-dimensional matrix within the QXIP module. The first row of this matrix contains UMTS QoS parameters and second row contains the WLAN QoS parameters, appropriately. Before every transmission of IP packet from QXIP down to UMTS or WLAN LL/MAC modules, the QXIP module is doing service quality testing (testing of collected QoS parameters) in order to choose the best wireless connection upon required QoS. Here, in our current implementation, we are testing only: SNR, PER and TP, which we collected from Physical layer and OWA layer via cross-layer messages. According to the performance analysis in [9], QXIP module always fist try to get admission (in uplink) to the WLAN whenever it is available (i.e. all tested WLAN parameters: SNR, PER and TP, are above their appropriate WLAN thresholds). Second, if QXIP module doesn’t get WLAN admission, he try to get admission to UMTS network (all tested UMTS parameters are above their appropriate UMTS thresholds). Finally, QXIP module sent the packet that come from Upper Network Layer down to the chosen LL/MAC module or dropped if he doesn’t find admission to any of those two networks. In downlink, all packets from all LL/MAC modules are received and send up from QXIP to Upper Network Layer, without dropping them.

IV. SIMULATION RESULTS

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 VoIP traffic (CBR traffic) starts at the beginning of the simulation time, and flows between

Internet through the VoIP gateway, which is wired to Node B and AP, to all MEs, until the end of the simulation time. The general parameters used in our simulation are summarized in Table I. At the first case all MEs are dual-mode UMTS/WLAN, and are equipped with QXIP module. 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 have MEs without QXIP module within, and only with WLAN or with UMTS interface.

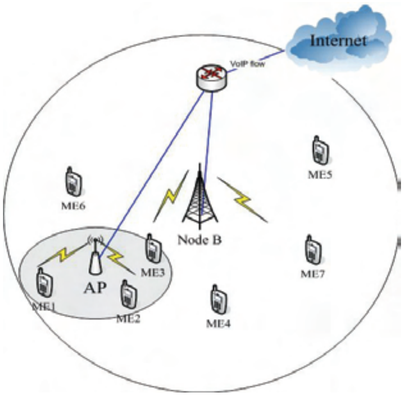

Fig. 2. Simulation scenario

TABLE I
SIMULATION PARAMETERS

Parameters	Values
CBR packet size	160 Bytes
WLAN Data rate	1 Mbps
Phy header	192 bits
MAC header	224 bits
SIFS	10 µs
DIFS	50 µs
Traffic frame interarrival time	4 seconds
CTS, ACK	112 bits + Phy header
WLAN_PER threshold	$7x10^{-11}$ w
UMTS_PER threshold	10^{-6} w
NodeB spreading factor	32
ME spreading factor	16

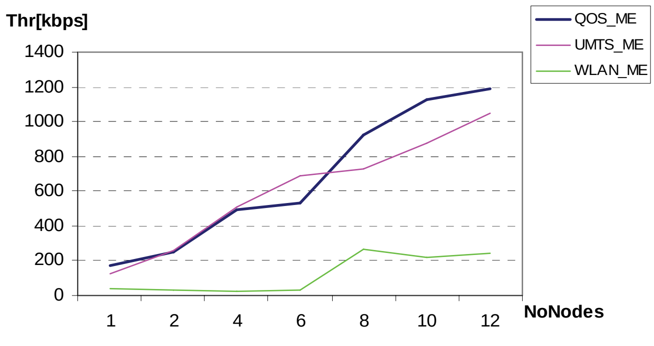

Fig. 3. Average throughput vs number of nodes ($\overline{V}$ =2m/s)

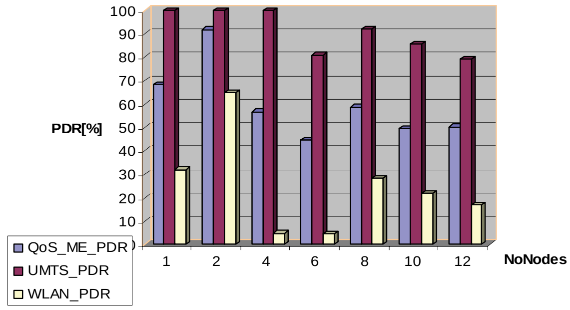

Fig. 4. Average PDR vs number of nodes ($\overline{V}$ =2m/s)

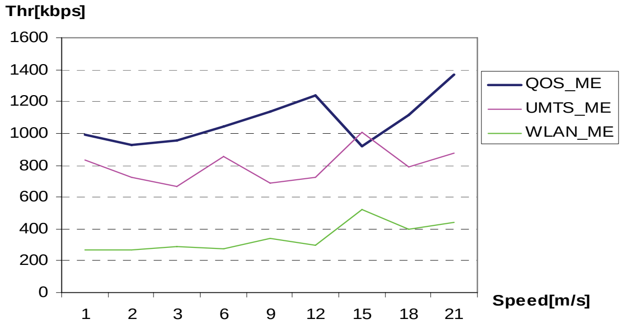

Fig. 5. Average throughput vs velocity (N^0Nodes=8, t_sim=10s)

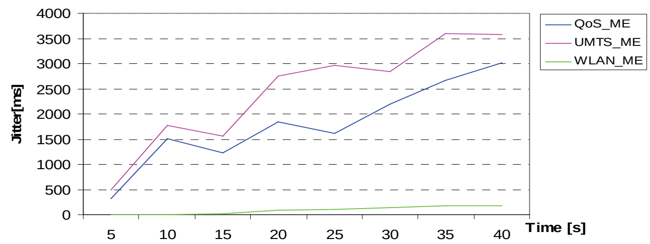

Fig. 6. Average jitter vs simulation time (N^0Nodes=8, $\overline{V}$ =2m/s)

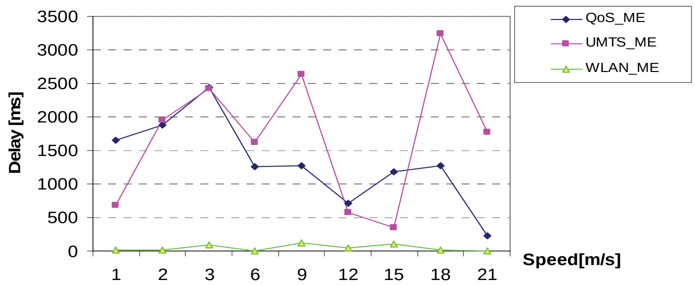

Fig. 7. Average delay vs velocity (N^0Nodes=8, t_sim=10s)

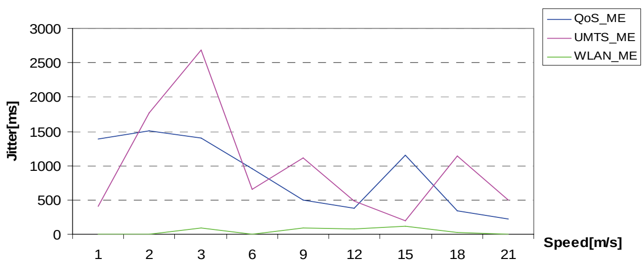

Fig. 8. Average jitter vs velocity (N^0Nodes=8, t_sim=10s)

As we can obtain from Fig. 3, the average throughput for our dual-mode ME with included QXIP module within (QOS_ME), without doubts achieve the greatest values for every number of used nodes, in comparison with the average throughput in the case when we used only WLAN MEs, and equal or greater average throughput values with the case when we use only UMTS MEs. We must to emphasize the fact that we obtain equal (or less) average throughput with the case when we use only UMTS MEs only when we use low number of nodes (less then 7 MEs). This is, more or less, expected due to the fact that when we used just a few MEs with mean speed of $\bar{v}$ =2m/s and the probability some of them to pass through the WLAN area (in simulation time of 10s) is very low, so they achieve only VoIP traffic via Node B.

Moreover, as we see in Fig. 4, the average Packet Delivery Ratio (PDR) values for the first case when we use QXIP dula-mode MEs are very balanced, i.e. our PDR values are somewhere between the PDRs from UMTS and WLAN MEs for every used number of MEs (nodes), and have tendency at some points to reach UMTS ME PDR values. Furthermore, in Fig. 5 is presented average throughput for different mean velocity (form 2 up to 21 m/s) of the MEs, when we have 8 MEs and simulation time of 10 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 cases when we used WLAN or UMTS MEs, for any given average velocity ($\bar{v}$). To emphasize that, when we using our dual-mode QXIP MEs, the average throughput curve has ascending trend due to the fact that with higher average speed of the MEs, more frequently they are passing through the WLAN area and consequently achieves greater average throughput.

Furthermore, in Fig. 6 average jitter values as a function of simulation time 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. As we can see, for our case when we used dual-mode QXIP MEs, in comparison with the case when we use UMTS MEs, lover average jitter values have been achieved, with the similar curve trends. On the other hand we have higher average jitter values in comparison with the average jitter values of WLAN MEs, but this is because of the fact that in WLAN technology we have lower processing time and lower area coverage.

Moreover, in Fig. 7 the average delays for all three cases are presented. In this scenario, the number of MEs is fixed on 8, simulation duration is 10s and we change the MEs mean velocity from 2 m/s up to 21 m/s. As we can see, the statistic of our dual-stack QXIP ME delay curve is between the curves for UMTS and WLAN cases, with lower values then the values of UMTS curve (only for lower average velocity is the same), and higher then the values of WLAN curve. Consequently, with rise of the mean speeds of the dual-stack QXIP MEs their delay curve is descending, because in cases with higher mean speed, more frequently the MEs are entering in the WLAN area, and due to the lower latency of WLAN network, all MEs achieve lower latency values.

Finally, in Fig. 8 are shown the average jitters curves for the same scenario as described before. Similar as previously, the statistic of our dual-stack QXIP ME jitter curve is between the jitter'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 mean speeds of the MEs all three curves are descending. The reason is the same we discussed above about the latency.

V. Conclusion

In this paper a novel simulation results for the key QoS parameters (throughput, jitter, delay and PDR), using novel adaptive QoS module and dual-mode UMTS/WLAN ME, have been presented.

According to the simulation results, our propose dual-stack UMTS/WLAN ME with adaptive QoS module within perform fairly well, even in different network conditions as: various nodal mobility, various background traffic loads and different number of nodes; achieving really well performances in comparison with the cases when only WLAN or only UMTS MEs have been used.

In our future work we will focus on development advance QXIP module, with more simulation results in various network conditions and with more complex scenarios, follow by profound statistical analysis.

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