Radio Network Aggregation for 5G Mobile Terminals in Heterogeneous Wireless Networks

Tomislav Shuminoski[1], Toni Janevski[2]

Abstract – **In this paper we introduce a novel design concept for advanced mobile terminals with radio network aggregation capability and enhanced QoS provisioning for multimedia services in heterogeneous wireless and mobile networks. We establish a new module that provides the best QoS and lowest cost for any given multimedia service by using simultaneously all available wireless and mobile networks for a given traffic. The performance of our proposal is evaluated using simulations with multimode mobile stations carrying multimedia traffic in heterogeneous environment with coexistence of multiple Radio Access Technologies, such as 3G, 4G as well as future 5G radio access networks.**

Keywords – **5G, Aggregation, Heterogeneous, Quality of Service, Radio Access Technology, Throughput.**

I. Introduction

We are all witnesses of a tremendous development of the heterogeneous wireless mobile network technologies which are going to provide a broad range of multimedia services to mobile users, with ubiquitous mobility, enormous processing power of the mobile equipment, advanced QoS support, as well as bigger memory space and longer battery life. Moreover, they will provide enough storage capability for control information and enormous spectrum for advanced capabilities. Currently we have operator-centric approach implemented in 3G mobile networks such as UMTS/HSPA, IEEE 802.16e, and service-centric approach in 4G mobile networks, which are (according to the ITU IMT-Advanced umbrella): LTE-Advanced (LTE Release 10 and beyond) and Mobile WiMAX 2.0 (802.16m), [1]. In the future mobile networks, the 5G, we are moving towards the user-centric concept [2-5]. The user-centric approach is accepted as a basis for the work in the paper. In the future the mobile terminals will have access to different wireless technologies (through their different interfaces) at the same time and the terminal should be able to combine different flows from different technologies using advance QoS algorithms and control protocols. On the other side, the existing wireless and mobile networks are going towards an all IP-based principle, which means that all data and signalling traffic will be transferred via IP on network layer.

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Different Radio Access Technologies (RATs) may exist together (older RATs and newer RATs: LTE-Advanced and Mobile WiMAX 2.0), however the common “thing” for all of them as a unifying technology is IP. That is the main reason why the main changes and improvements we are proposing in the network layer of the mobile terminal (MT). The key goal of this paper is to propose a novel radio network aggregation technique for future 5G mobile networks by maximization of radio access throughput, with high level of QoS support and advanced QoS routing algorithm. Therefore, in our proposal we have not tied to any of existing RATs. However, 5G MT will not be attached to one RAT, but to multiple RATs simultaneously.

II. Related Works

Due to the relatively new area of 5G research, there is limited number of published research papers. However, the main motivation for our framework could be found in [2-9]. Evermore, our framework and design of a novel MT is a next step from our previous works on adaptive QoS provisioning in heterogeneous wireless and mobile IP networks [10-12]. In those papers was introduced an adaptive QoS provisioning module that provides the best QoS and lower cost for a given multimedia service by using one or more wireless technologies at a given time. The performance of our adaptive QoS algorithm was evaluated using simulation with dual-mode UMTS/WLAN mobile equipments. The analysis of this concept and the simulation results has shown overall better performances and QoS provisioning for different multimedia services in a variety of network conditions in heterogeneous wireless environment. Moreover, our Dual-mode ME architecture and adaptive QoS algorithm was used and enhanced in [13] for QoE-driven User-centric solution for VoD services in urban vehicular network environments. This environment relies on a multi-homed hierarchical P2P and vehicular ad-hoc network architecture. However, the drawback of such adaptive QoS framework is of its applicability to single RAT at a given time, even in the cases when it is probably the best connection for a given service. In that way, one step forward is made by using simultaneously all available wireless technologies at a same time by combining different flows from different technologies. Additionally, in this novel framework for 5G MT, we use other advanced QoS-based routing algorithms, which are described in more details in the following section. Furthermore, in [14] an adaptive multiple attribute vertical handoff decision algorithm is presented, which enables wireless access network selection at a MT using fuzzy logic concepts and a genetic algorithm. Similar concepts we used in

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our advanced QoS routing algorithm for advanced MTs, but in this case for simultaneous access to different wireless network at the same time for a given service. Another paper [15] is dealing with a network selection algorithm based on Fuzzy Multiple Attribute Decision Making. That algorithm considers the factors of Received Signal Strength (RSS), monetary cost, bandwidth, velocity and user preference. It defines a network selection function that measures the efficiency in the utilization of radio resources in given networks. Again, there is a selection of only one network. The main base for developing our advanced QoS routing algorithm for our advanced MT can be found in [16]. The proposed general scheme is trying to solve the access network selection problem in the heterogeneous wireless network and has been used to present and design a general multicriteria software assistant that can consider the user, operator, and/or the QoS view points. Combined fuzzy logic (FL) and genetic algorithms (GAs) have been used to give the proposed scheme the required scalability, flexibility, and simplicity. The simulation results (as given in [16]) are showing that the proposed scheme and software assistant have better and more robust performance over the random-based selection. On the other side, [17] presents a joint radio resource management strategy based on reinforcement learning mechanisms that control a fuzzy-neural algorithm to ensure certain QoS constraints. Three RATs, namely UMTS, GERAN and WLAN are considered as common available RATs for selection. Also, membership functions used in [17] are adaptive so that a desired performance only in terms of the probability of user satisfaction can be guaranteed.

III. System Model and QoS Algorithm

Our novel 5G oriented MT is multi-mode MT, with several interfaces, each for different RAT. The advanced QoS routing algorithm is set within the advanced QoS routing module on IP layer. According to [2] and [3] physical and OWA define the wireless technology. Without doubts, the network layer will be IP, but separation of this layer into two sublayers will be necessary. The Upper IP Network Layer (UIPNL) has one unified IP address within, and is nominated for routing as well as for creation of sockets to the upper open transport layer and to the application layer. The other sub-layer, Lower IP Network Layer (LIPNL) may include several different IPv4 (or IPv6) addresses, one IP address for each of the radio interfaces, while each of these IP addresses will be mapped with unified IP address of the UIPNL. In the middleware between the UIPNL and LIPNL will be address translation module, which shall maintain and translate IP addresses. Moreover, for 5G mobile terminals will be suitable to have Open Transport Protocol (OTP) that is possible to be downloaded and installed. Such MEs shall have the possibility to download (e.g., TCP, modifications and adaptation of TCP for the mobile and wireless networks, RTP, Stream Control Transmission Protocol - SCTP [18], some future transport protocol, etc.) version which is targeted to a specific wireless and mobile technology installed at the base stations. The reason of implementing SCTP in OTP layer within our advanced mobile terminal lies in SCTP's attractive features such as multistreaming and multihoming. The core of our work is development of novel adaptive QoS Module with adaptive QoS routing algorithm. We will refer to it as Advanced QoS Routing Algorithm (AQoSRA), which is defined independently from different wireless and mobile technologies. It is implemented between UIPNL and LIPNL, which will be able to provide intelligent QoS management and routing. Moreover, the AQoSRA module is able to combine simultaneously several different traffic flows from different multimedia services transmitted over the same or different RAT channels, achieving higher throughput, and optimally using the heterogeneous radio resources. For the functionalities of the AQoSRA, the mobile equipment must have mechanisms to collect the following data (using different protocols at different protocol layers in the MT): user velocity information, battery life-time, price of service over available RAT, and the QoS parameters. This task is executed periodically at given time intervals. After collecting the above mentioned data they are stored in the QoS DB (database) into multi-dimensional matrix connected on the AQoSRA module. Further, the AQoSRA module is also connected to the QoS Algorithm database, where are located biologically inspired algorithms (GAs) that are used in the AQoSRA process. Furthermore, after AQoSRA module executes its algorithm and gets the most adequate decision for routing, it sends the packet that comes from UIPNL down to the appropriate LIPNL interface, towards the chosen RAT LL/MAC module for a current service or drops it in the case there is no admission to any of the given RATs in the heterogeneous environment. This is the current procedure for only one packet for one service, but at the same time there are several packets which are coming from several different multimedia services and which are simultaneously processed through AQoSRA module. On the other hand, in uplink, all packets which are coming from all RATs interfaces are received in LIPNL, and sent from AQoSRA module to the UIPNL, then sent to OTP. Finally, all packets are delivered to the peer application. In the downlink direction, the UIPNL is sending the application data (received from the application via the OTP) through the appropriate RAT interface determined with AQoSRA logic. The AQoSRA algorithm building components are shown in Fig. 1. The data measurements for different selection criteria, including user requirements, QoS requirements, operator requirements, as well as radio link conditions in different RATs present in the user's moving area are inputs for the n sets of parallel criteria functions (CFs), one set per each RAT (from RAT 1 up to RAT n). One RAT CF is shaping and filtering the outputs from the previous four components into four interior threshold functions: the first is shaping the QoS parameters, the second is shaping the service price if the service stream is going over that RAT, the third is shaping velocity support and the last is shaping the signal strength detected in mobile terminal from RAT base station(s). Any of those four threshold criteria functions is giving on its output only one value (as a real number within the limits of [0, 1]). The central component is AQoSRA module, which as inputs uses: the outputs of the n sets of parallel criteria functions (CFs), four values from each RATs ($4*n$ in total) and the output of the threshold CF for battery support (1 value).

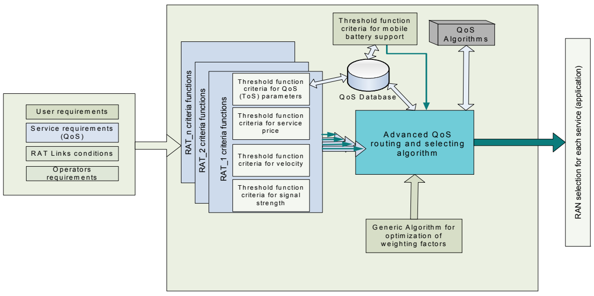

Fig. 1. Advanced QoS routing and RAT selection algorithm

This central component of AQoSRA algorithm is in continuous communication and interaction with: the Generic Algorithm (GA) module, QoS algorithm module and the QoS database. The GA module is doing the optimization of weighting coefficients of different input criteria for each RAT for a given multimedia service. That is, each criterion may have different weight that depends upon the assumption of its impact on the best RAT selection process. The reason for using GA for access network selection is justified by the fact that GA is proven to provide better results and to be more robust compared to random-based selection algorithms and other examined algorithms from this affiliation [16]. Finally, the AQoSRA module is targeted for the selection of wireless and mobile networks in heterogeneous environment, so the decision as an outcome should select the best RATs (among all present RATs at the moment for a given user and given service) and will rank them in certain order. The ranking order accrues from the ranking value that have each of the RAT ranking functions. If we calculate the inputs from the threshold CFs as a real numbers, then the RAT ranking functions can be calculated as follows:

$$RF_{RAT\_i} = \frac{QoSt_i * W_{QoS} + Ct_i * W_C + Vt_i * W_V + SSt_i * W_{SS} + Bt_i * W_B}{W_{QoS} + W_C + W_V + W_{SS} + W_B}, \quad (1)$$

where $1 \le i \le n$ and $W_{QoS} + W_C + W_V + W_{SS} + W_B = 1$, (2)

where W_{QoS}, W_C, W_V, W_{SS}, W_B are assigned weight factors for the criteria functions of: QoS parameter, service price, velocity of the mobile terminal, signal strength and mobile terminal battery support, respectively. Those values of weight factors are assigned using a particular method of optimization, i.e. GAs, where their value is obtained through the process of moving the genetic optimization algorithm to the pre-specified goal. On the other hand, after passing the four interior threshold functions for *i*-th RAT CF, the outputs (shaped values) from QoS parameters are $QoSt_i$, from service price are Ct_i, from velocity support are Vt_i, and from detected signals strength are SSt_i. The shaped output value of the threshold CF for battery support is Bt_i. So, the final step is selection of the best RAT for a given service (with the highest value for the ranking function) for a given service.

IV. SIMULATION RESULTS AND ANALYSIS

In this section we show the obtained simulation results for average system throughput, as well as multimedia access probability (MAP) values are presented for different network conditions. Our simulation scenario is consisted of three RATs. All base stations (from all RATs) are positioned in the center of the simulation area, with coordinates (0, 0). RAT1 has diameter of the coverage area of 1 km, RAT2 cell has radius of 540 m and RAT3 cell has radius of 300 m. Network capacity for the given three RATs is set to: RAT1_C = 15040 kbit/s, RAT2_C = 16128 kbit/s, and RAT3_C= 17088 kbit/s. The values are arbitrarily chosen and are not related to certain standardized RAT with aim to obtain general conclusions from the proposed solution. At the beginning of the simulation, the mobile terminals (MTs) are randomly scattered within the area of 500x500 m^2. For MTs physical mobility, we used the Gauss-Markov Mobility model [19] considering average speeds in the range of 30-120 km/h (Vmean), and providing high level of randomness for user mobility. This simulation scenario provides total network coverage for all MTs (RAT1, RAT2 and RAT3 coverage, or minimum RAT1 coverage). The multimedia traffic flows (Constant Bit Ratio and Variable Bit Ratio traffic) are defining the type of services and their representation among the users in the system. The multimedia service model in the proposed form predicts the existence of three types of services that are defined by its required bit rate and its starting time and duration, respectively given in the Table I. During the simulation for a given number of ordinary active mobile users N, each user is randomly assigned to one of the three types of services defined above. On the other side, when the users have advanced MT with AQoSRA module within, for each user are randomly assigned all three types of multimedia services (minimum two, maximum all three services). Furthermore, Fig. 2 provides results on the average throughput versus number of MTs. The average velocity of the MTs is set on 40 km/h and the total simulation time is 50 seconds. As can be noticed, the throughput for our Advanced MT (AMT), with included AQoSRA module, for any number of used MTs, is much higher than the average throughput values in the case when we used only MTs that can access only RAT1 (R_RAT1_MT), or in the case when we use only MTs that access RAT2 (R_RAT2_MT) or RAT3 (R_RAT3_MT). As one can notice, until the saturation of all RATs the throughput for the AMT is increasing. When all RATs are saturated then also the maximum ATM throughput is achieved (with 140 users in this simulated scenario). So, using the radio networks aggregation in AMTs we obtain an aggregate throughput which includes the throughputs of all available RATs to the mobile terminals. Furthermore, in Fig. 3 are presented the average MAP ratio (Pm_acc) values for different number of MTs with average speed of 40 km/h and simulation time of 50 seconds. The MAP ratio is calculated as the number of successful access per service divided with the total number of access. For the first case when we use AMTs with AQoSRA modules the average MAP ratio values are the highest until the network becomes congested (with larger number of active MTs). So, the gain by using AMT is evident for not congested wireless networks. In case of congested networks the gain from the radio network aggregation regarding the multimedia access probability is reduced. However, Pm_acc values in AMT case are superior in comparison with other RAT MAP values, which furthermore affect the bit error and packet error ratio, as well as throughputs.

TABLE I
PARAMETRIC VALUES FOR THE MULTIMEDIA SERVICE TYPES

	Bit rate [kbit/s]	Starting time [s]	Duration [s]
VoIP service	64	Poisson distributed with mean value 7 sec	End of simulation
Video-streaming service	256	Poisson distributed with mean value 6 sec	Poisson distributed with mean value 50 sec
Data service	512	Poisson distributed with mean value 6,5 sec	End of simulation

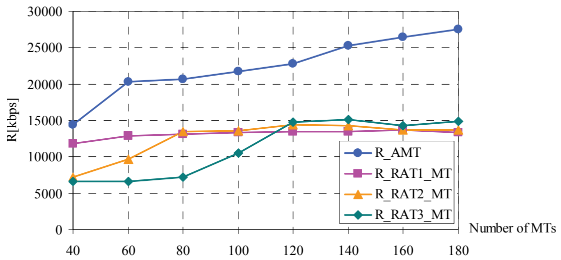

Fig. 2. Average throughput versus number of users

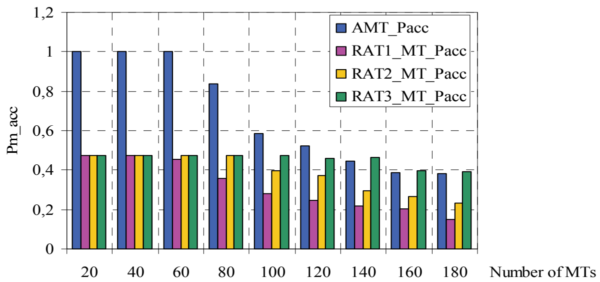

Fig. 3. Average multimedia access probability vs number of MTs

V. CONCLUSION

In this paper we have proposed a novel 5G mobile terminal design based on radio network aggregation in so-called AMT with AQoSRA which is providing highest level of multimedia access probability, throughput, highest number of satisfied users, with minimal cost per service and optimal utilisation of network resources. The analysis showed that the performance gain with AQoSRA module in the MT can be easily generalized in multi-interface heterogeneous wireless network scenario, including any present and future RATs.

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