QoS Support in UMTS Networks

Performance Evaluation and Perspectives towards an Autonomic Resource Management

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***Abstract*—In order to enhance the QoS support inside UMTS network architecture, this paper brings the perspective of a QoS support for self-managing resources based on knowing the service requests and the network capabilities. The originality of this approach lies in the perspective of certain integrated functionalities that will provide autonomy for the components of the managed system in terms of internal decisions and configurations. The analysis of the results will highlight the benefits of an autonomic resource management mechanism compared with native UMTS QoS support.**

Keywords-UMTS; QoS support; autonomic management.

I. INTRODUCTION

The success of Internet architecture, as evidenced by the variety of many types of applications and network technologies, has proven its centrality through the way it has influenced, and often determined the daily life. Internet's ubiquity has brought a number of shortcomings that the current architecture cannot solve, hence a multitude of solutions to approach problems as addressing, routing, congestion, resource management or traffic precedence have been developed.

We can distinguish two major trends in the way of the scientific community understood solving this set of problems, namely: the complete remodeling of the Internet architecture (i.e., 4WARD [1], AUTOI [2], 4D [3], GENI [4]), respectively the gradual improvement of functionalities in the existing architecture [5] (i.e., Self-NET [6]).

The complete remodeling of the Internet architecture offers a purist approach, a clean slate kind of modeling the new architectural elements. On the other hand, the gradual development of network architecture, ruled by a pluralistic approach, considers that the leap towards a new Internet architecture indifferent to the existing technologies is impossible.

Promoting the functionality promised by a clean slate approach (flexibility, reliability, fault-tolerance, autonomy and manageability), the authors of this paper believe however that passing to an architecture that will integrate all these features is progressive, at least for two reasons: the perspective of operators and Internet service providers on radical changes in the network and the difficulty in testing, evaluating and validating the proposed new architectural elements.

Beyond the need for new legislative and normative agreements between Internet service providers and network operators, agreements required by fundamental architectural changes, a major issue in the revolutionary innovation of the Internet architecture is the difficulty of assessing the new concepts in real experimental scenarios.

In [7], Peterson disputes the promotion of new architectural ideas, calling the scientific community to test the proposed solutions in the experimental testbed sites (i.e., PlanetLab platform with the Measurement Lab "M-Lab" back-end platform [8]) validation site completely different from what means the evaluation by simulation or emulation.

Although the reality of testing on an experimental platform is undeniable, just not to focus the proposed solution on an single extremely narrow issue, the authors of this paper believe that prior to live testing phase there are several steps that must be completed by simulation and emulation, namely: monitoring and highlighting critical situations to identify network problems, testing the effect of local parametric adjustments on the whole system, development and gradual integration of scalable features in a new architecture. Therefore, stepping towards a revolutionary architecture is a matter of time; the new capabilities added to the existing architectural elements represent the prerequisites for success in this matter. Because of this, we believe that it is impossible to jump towards an architecture which is independent of the existing technologies, the argument of this motivation being found in the evolutionary pluralist concept.

Starting from these premises, which combine the requirements of a clean slate paradigm with current technological reality, the paper aims at investigating and testing the benefits of integrating autonomic resource management capabilities into UMTS (Universal Mobile Telecommunications System) architecture to support QoS.

Besides analyzing the QoS parameters like average end-to-end delay, throughput or average jitter experienced by time-critical applications in the UMTS radio access network [14], the paper enhanced and extends the QoS support even

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to the UMTS IP sub-network segment of through virtualization.

As the UMTS QoS support acts only on the radio access network, by knowing the requirements of the source application, a best end-to-end performance could be offered through network virtualization in the core network. The analysis tool is QualNet 5.0.2 network simulator [13].

Thus, while in Section 2 the capabilities of the UMTS network to provide a QoS support to applications that have stringent requirements concerning the time component are tested, in Section 3 the premises of an autonomic resource management that ensures a higher quality support in the network are investigated. This fact is revealed by the ability to select an alternative route between entities SGSN (Serving GPRS Support Node) and GGSN (Gateway GPRS Support Node) based on knowing the source application requirements. Finally, Section 4 presents the conclusions of the realized study by showing the perspective of an autonomic management of network resources that is based on the conjunction of application requirements and network context.

II. QoS SUPPORT IN UMTS NETWORKS

In order to achieve a certain QoS support, UMTS network has defined a so-called "Bearer Service". A bearer service includes all aspects needed to enable the provision of a contracted QoS. These aspects are among others the control signaling, user plane transport and QoS management functionality. Various types of bearer service were established between different parts of UMTS network. More than that, each bearer service on a specific layer offers its individual services using services provided by the layers below. It is worth mentioning that bearers covering only a certain part of a system and being closer to the physical connection always have more stringent QoS requirements.

In order to solve the QoS problem, UMTS defines four types of traffic classes: Conversational (CO), Streaming (ST), Interactive (IN) and Background (BK).

The main difference between these QoS classes is the transfer delay value. Conversational QoS Class includes real-time applications that require stringent limits for delay value, while Background QoS Class is the most delay insensitive traffic class. Table I shows the main characteristics of the above mentioned QoS classes and examples of corresponding applications.

TABLE I. MAIN CHARACTERISTICS OF UMTS QOS CLASSES

Traffic classes	Characteristics	Application
Conversational (CO)	low delay, low jitter, symmetric traffic, no buffering	speech, VoIP, video
Streaming (ST)	moderate delay, moderate jitter, asymmetric traffic, buffering allowed	video streaming, audio streaming
Interactive (IN)	moderate jitter, asymmetric traffic, buffering allowed, request response pattern	web browsing
Background (BK)	destination doesn't expect data within a certain time, preserve payload content, asymmetric traffic, buffering allowed	email, file downloading

In order to define the traffic characteristics, UMTS architecture introduces a set of QoS attributes. It must be mentioned that a particular type of traffic class is itself a QoS attribute.

There are attributes specific to all classes (i.e., maximum bit rate, delivery order, maximum SDU (Service Data Unit) size) and some attributes that are applied only for a specific class (i.e., transfer delay is applied only for conversational and streaming classes; traffic handling priority is applied only for interactive class).

A. Performance Evaluation of the UMTS QoS Support

In order to evaluate the QoS support implicitly provided by an UMTS network, a scenario including a PLMN (Public Land Mobile Network) was simulated using QualNet 5.0.2 network simulator, a widely used platform in the defense and telecommunication network design and evaluation [13].

The network scenario includes eight UE (User Equipment) nodes: four source nodes (UE nodes 6, 8, 10, and 12) and four destination nodes (UE nodes 7, 9, 11, and 13), as presented in Fig. 1.

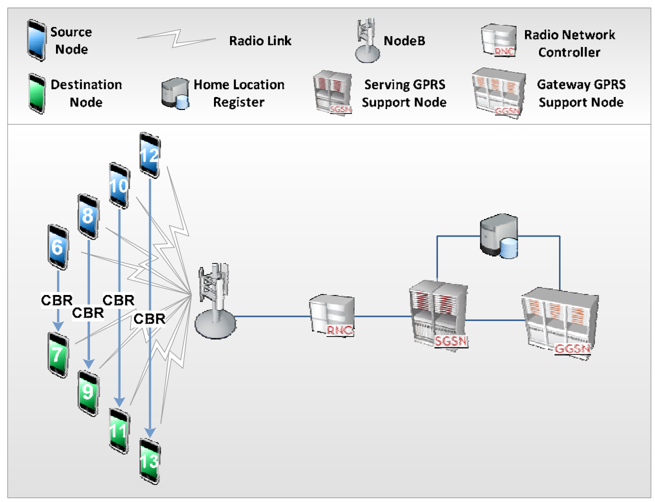

Figure 1. UMTS evaluation scenario

Global parameters configured at the physical (PHY) network layer of the simulation are given in Table II. It should be noticed that two different radio channels were used in order to access the network resources. The frequency values of these channels were chosen accordingly with European 3G bands for UMTS 2100 recommendations [11].

TABLE II. PHY LAYER CONFIGURATION PARAMETERS

Parameter	Value
Up-link channel frequency	1.95 [GHz]
Down-link channel frequency	2.15 [Ghz]
Path Loss Propagation Model	Two Ray
Shadowing Model	Constant
Shadowing Mean	4 [dB]
Propagation Limit (UE Sensitivity)	-150 [dB]

Between the source nodes (SN) and destination nodes (DN), four CBR (Constant Bit Rate) applications, each of them corresponding to one QoS class defined by the UMTS network, were considered. The characteristics of all applications are summarized in Table III.

TABLE III. CORRESPONDING QOS CLASS FOR EACH CBR APPLICATION USED IN THE EVALUATION SCENARIO

Application Type	SN	DN	Items to Send	Item Size [bytes]	Interval [s]	QoS Class
CBR	6	7	1000	32	0.1	BK
	8	9				IN
	10	11				ST
	12	13				CO

The results of the simulations concerning average end-to-end delay, average jitter and throughput for each QoS supported class are synthesized by Table IV.

TABLE IV. UMTS QOS PARAMETERS EVALUATION

UMTS QoS Class	Average end-to-end delay [s]	Average jitter [s]	Throughput [bits/s]
BK	3.493082507	0.068259929	2699
IN	0.180157479	0.053124915	1420
ST	0.130232583	0.022149065	1412
CO	0.103871283	0.016113024	2076

The average end-to-end delay results for each QoS support class are presented in Fig. 2 and the results regarding average jitter are illustrated in Fig. 3.

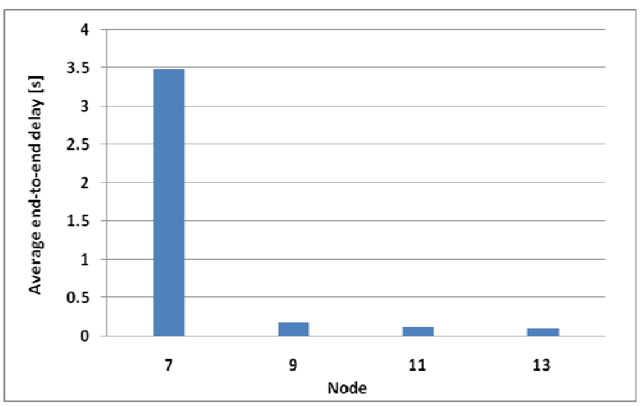

Figure 2. Average end-to-end delay experienced by the test applications in each QoS support class

Analyzing the obtained results, it can be noticed that application which corresponds to the Conversational and Streaming QoS class is characterized by the lowest value of average end-to-end delay and jitter delay, as expected for the type of application corresponding to this class (speech, VoIP, video or audio streaming).

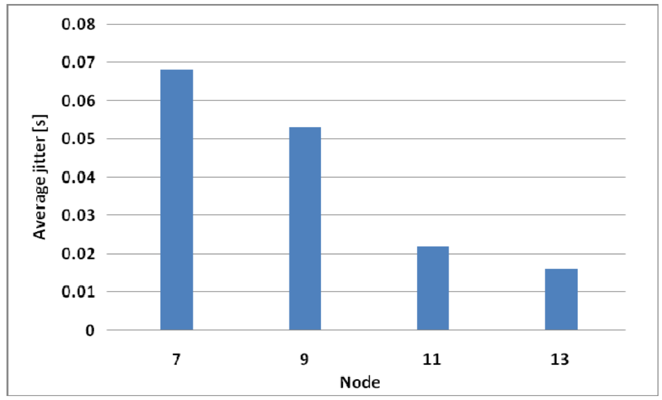

Figure 3. Average jitter experienced by the test applications in each QoS support class

If throughput values are compared, it can be seen that the application from Background QoS class has the highest value of this parameter, but it also has the highest value for the average end-to-end delay and the average jitter.

Summarizing, the network complies with the priority level imposed on the test applications that were modeled by CBR-type traffic sources, and this is reflected in the average values of the end-to-end transmission delays and in the jitter for each QoS priority class.

Correlating end-to-end transmission delays with the transmission flow rate and with the time interval between transmitted packets one can notice the increased flow rate in the case of Background class, which is due to transmitting a reduced total number of packets in a very short transmission time interval.

III. PERSPECTIVES TOWARDS AN AUTONOMIC RESOURCE MANAGEMENT IN A UMTS NETWORK

Developed within the 3GPP (3rd Generation Partnership Project), the 3G standard suggests an end-to-end QoS support based on a policy management system (Policy-Based Network Management) [9].

The network architecture presented by the first 3GPP public versions has evolved to an architectural model SAE (System Architecture Evolution) [10], which ensures the convergence of different access network categories such as UMTS, 3GPP, WLAN (Wireless Local Area Network) or any other non-3GPP radio access technology.

The latest public 3GPP version considers the IMS (IP Multimedia Subsystem) [11] network architecture to be completely separated from the access technology, having the specific access functions completely isolated from the core network.

In order to manage QoS resources, the SAE architecture integrates an informational QIF (QoS Information Function) function that interacts with all individual network models included within the IMS platform. This QoS resource management solution is an external part of the network, based on the use and interaction between a central entity and periferic elements.

Although in the clean slate approach the resource management and the QoS support are considered an integrated part of communications networks, this fact is not reflected in the characteristics of current systems or by the UMTS network architecture.

Therefore, the perspective of an autonomic resource management in an UMTS network proposed in this paper suggests the necessity of adding additional information at the level of the central UMTS network elements using virtualization technique.

Network virtualization represents a high level abstraction process that overlaps the implementation and physical network configuration details. Allowing co-existence of multiple virtual architectures overlaid on a common substrate physically shared, network virtualization promises flexibility and security, promoting diversity and increased management capacity [12].

In this way, UMTS core network nodes act autonomously, being able to sense the environment, to perceive the changes, to understand internal changes and to react in an intelligent manner by selecting the optimal path according to application requirements.

To demonstrate this, native UMTS QoS support is analyzed by comparison to the potential of the autonomic management offered through network virtualization, using QualNet network simulator [13].

Thus, in the case of an autonomic management system, the proposed analysis scenarios highlight the ability of selecting the best route according to the source application constraints in terms of maximum acceptable end-to-end delay.

A. *Scenario description*

According to [15], it is possible for an UMTS network to have multiple SGSNs and GGSNs entities which can be co-located or can be interconnected via an IP subnetwork in order to increase the geographical area served by an operator.

Considering the second approach, it was developed an evaluation scenario in which the SGSN and the GGSN are interconnected via a simple IP sub-network that consists of ten generic routers denoted R1 to R10, as depicted in Fig. 4.

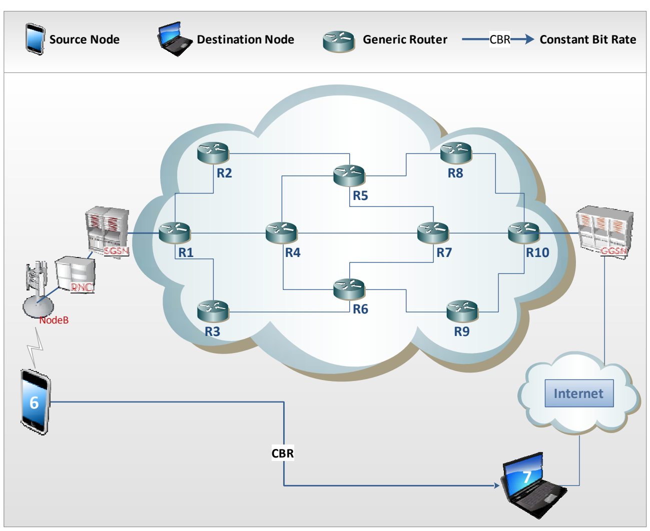

Figure 4. The architecture of the evaluation scenario

Obviously, in a real-life UMTS IP sub-network would be more complex, the motivation for this topology was to better illustrate the problems that may arise and the proposed solution.

In this evaluation scenario a CBR test application corresponding to Conversational QoS class (highest priority QoS class) was considered. Main parameters that describe the characteristics for the tested application are indicated in Table V.

TABLE V. CHARCTERISTICS OF THE MODELED APPLICATION

Application Type	SN	DN	Items to Send	Item Size [bytes]	Interval [s]	QoS Class
CBR	6	7	1000	32	0.1	CO

As we have already mentioned, the motivation behind this evaluation is to highlight the benefits of the autonomic management offered through network virtualization process.

In our case, the virtualization process could be illustrated by controlling, through the configuration files, the parametric values that characterize network architectural elements.

Knowing the values of these parameters, it is possible to indicate a dedicated virtual network that offers the best path form the source towards destination in terms of minimum average end-to-end delay, maximum throughput, packet loss rate on selected route or other stringent requirements specific to a certain type of application.

B. *Performance Evaluation*

In order to emphasize the path selection mechanism between SGSN and GGSN, core nodes of UMTS IP sub-network, two different cases were evaluated: a native UMTS QoS support selection compare to QoS network support provided by an autonomic network management selection, as a result of dedicated virtual network generation.

When it defines the links between two intermediate generic routers in the UMTS IP sub-network, the simulator allows the association of specific transmission throughput and delay on each link, as presented in Fig. 5.

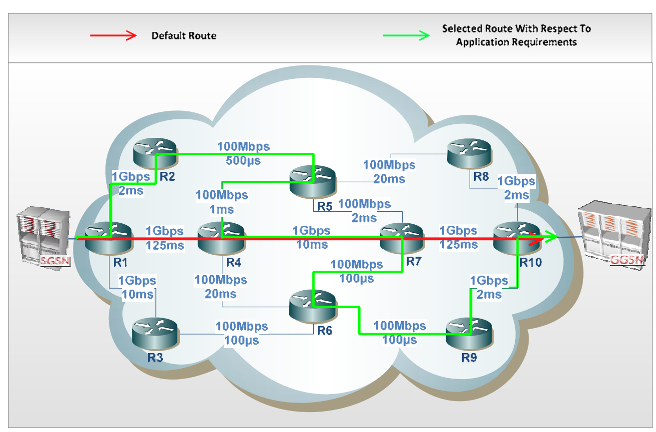

Figure 5. UMTS IP sub-network path selection

Broadcasting the test application scheduled as Conversational (CO) by the native UMTS QoS support in the access network, the default path from router R1 to router R10 in the IP sub-network was selected via routers R4 and R7, as illustrated in Fig. 5. This path selection was based only on the routing protocol mechanism (i.e., minimum hop count).

An autonomic network management QoS support should consider and accommodate both differentiated application requirements and dynamic network context. This mandatory integrated capability of the Future Internet (FI) network elements is performed based on network virtualization.

The objective of network virtualization process is to generate virtual networks and make each of these virtual networks appear to the user as a dedicated network infrastructure, with dedicated resources and services available for application requests. Therefore, the network virtualization process invokes a mode of selecting the virtual network that best integrates and satisfies the application requests at the physical network level.

It must be mentioned that for the generated virtual network, in our case, only the value of average end-to-end delay and jitter are considered as critical parameters for the source application.

Results of the simulations validate a virtual path from the router R1 to router R10 via routers R2, R5, R4, R7, R6, and R9, a corresponding physical network infrastructure that offers best performances in terms of requested average end-to end delay and jitter.

Parametric results of the average end-to-end delay, average jitter, and throughput, both for native UMTS QoS support and autonomic resource management QoS support, are summarized in TABLE V.

TABLE VI. PARAMETRIC EVALUATION OF QOS SUPPORT

Selected path in UMTS IP sub-network	Average end-to-end delay [ms]	Average jitter [ms]	Throughput [bits/s]
Native QoS support in UMTS access network			
R1→R4→R7→R10	307.19	21.26	2580
Autonomic resource management based on network virtualization			
R1→R2→R5→R4 → R7→R6→R9→R10	57.42	20.79	2575

As illustrated in Fig. 6, the UMTS IP sub-network decisively influences the applications performances in terms of average end-to-end delay and jitter.

Simulations results validates the perspective towards an autonomic resource management QoS support that makes the conjunction between the application's requests and the network context by choosing an alternate route in a virtualized environment.

The potential of the autonomic resource management is reflected by the capacity to identify an optimal path between the source node and the destination node, according to the imposed QoS constraints.

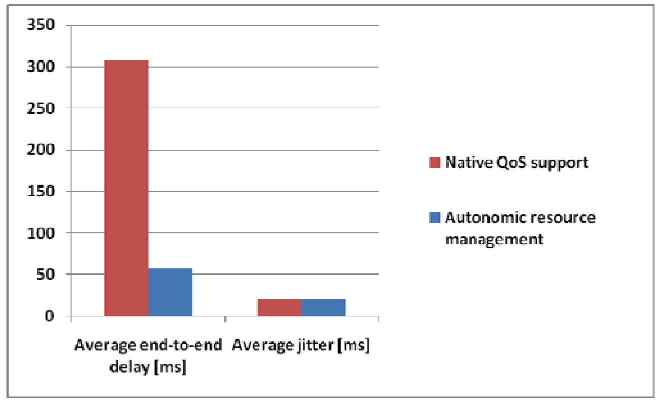

Figure 6. UMTS IP sub-network path selection

Some critical conditions or cost constrains could limit the resource optimization while using the QoS support only on the UMTS radio access network. These situations request for adaptation of the source application parameters to the network available resources in order to still broadcast the information on the channel.

An implemented and tested solution (i.e., virtualization algorithm, virtualized parameters, in-network message flow, and source adaptation) for the network virtualization concept is offered in [16]. The conjunction between the source application requests and the network context is achieved through the QoS profiles message exchange and it represents the process of network virtualization.

As long as this solution uses Multiprotocol Label Switching (MPLS) for route maintenance, it could be applied just in the UMTS IP-sub network. It could not offer an end-to-end QoS support because of the UMTS radio access which does not offer MPLS support. For the further work, the authors intend to extend this solution also for the radio access network in cellular networks.

As in [16], the paper assumes the network overflow by probing each UMTS IP sub-network link. In spite of that, the potential of the autonomic resource management is reflected by lower average end-to-end delay and lower jitter.

IV. CONCLUSIONS

This paper aimed to investigate the potential benefits that could reside from the integration of the virtualization process in current UMTS IP sub-network architecture.

In a first stage, the upper limit of native UMTS QoS support was analyzed in terms of average-end-to-end delay, average jitter, and throughput. Then, the efficiency of this QoS support was compared to the QoS support resulted from the usage of autonomic resource management implemented through network virtualization.

The obtained results suggest that such an approach could enhance the native UMTS QoS support by assuring an autonomic resource management that will allow overcoming the situations in which the existent QoS support would not permit even the service itself.

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