# Overview of Monitoring and Measurement System in EuQoS multi-domain network

Marek Dąbrowski[1], Philippe Owezarski[2], Wojciech Burakowski[1], Andrzej Bęben[1]

[1]Warsaw University of Technology, Institute of Telecommunications, Poland
[2]LAAS-CNRS, France
E-mail: [1]{mdabrow5,wojtek,abeben}@tele.pw.edu.pl, [2]owe@laas.fr

## Abstract

Because of the variability of the traffic and the related dynamicity of network resources, providing guaranteed Quality of Service (QoS) in the Internet is still a very big challenge after a decade of research in the area. Given the new capabilities of monitoring tools and recent advances in traffic characterization, modeling and analysis, the lacks of previous researches are understood. It is obvious that the real time information from monitoring and measurement tools can be essential for coping with traffic variability and adapting to network resources dynamicity. This is the approach taken in the EuQoS project [1], which aims at providing end-to-end QoS over heterogeneous multi-domain networks with IP networking level by taking advantage of measurement and monitoring tools. In this paper we present the main features of the Monitoring and Measurement System (MMS) that was developed by EuQoS and deployed in the multi-domain research testbed network. The general purpose for the MMS in EuQoS is threefold: (1) to provide adequate set of tools for measuring QoS at the packet level and in this way to support trials of the EuQoS system (2) to perform measurements supporting the EuQoS system functionalities, and (3) to perform on-line QoS monitoring for the network operator. In the paper we describe the general MMS architecture, containing information about the developed tools related with each of the mentioned MMS objectives.

## Keywords

monitoring and measurements, multi-domain networks, heterogeneous networks, QoS

## 1. Introduction

Providing guaranteed Quality of Service (QoS) is one of the challenges of the evolution of the Internet and it has been one of the most addressed issues in research in networking during last decade. Many solutions have been proposed among which the most famous are IntServ and DiffServ, but none of them has met the need of users and providers (carriers, ISP, etc.). In particular, the proposed approaches have been stymied by the complexity and variability of the traffic and then the related dynamicity of available resources in the network. Such explanation of previous proposals failure has been exhibited in recent monitoring projects, which have been studying, characterizing and analyzing Internet traffic. In particular, it is commonly observed that Internet traffic under normal conditions presents *per se* or *naturally* large fluctuations and variations in its throughput at all scales [2], often described in terms of long memory [3], self-similarity [4], multifractality [5]. Such characteristics imply a large dynamicity of network resources what makes difficult the enforcement of guaranteed and stable QoS. Enforcing QoS in the Internet then requires to re-design networking functions as admission control, fault management, traffic engineering, resources optimization, etc. This is the objective of the EuQoS project [1] which aims at designing, implementing and testing an architecture [6] that provides strict end-to-end QoS guarantees over multi-domain heterogeneous network environment. For assuring QoS guarantees at the packet level, the concept of Classes of Service (CoS) [6] is exploited. Fig. 1 shows an example of multi-domain heterogeneous network consisting of two different access networks (WiFi and LAN/Ethernet) and two core IP networks.

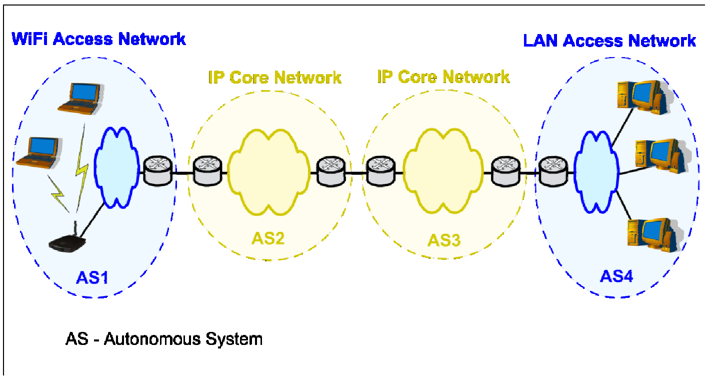



**Fig. 1. Exemplary architecture of multi-domain heterogeneous network**

For coping with network resources dynamicity and traffic variability, the EuQoS architecture is supported by the real-time Monitoring and Measurements System (MMS) [8]. MMS provides support with real-time measurements and information on the traffic, which is needed for adapting to available resources and for better managing them.

The design of this MMS system is really a major issue of the EuQoS system. One of the difficulties is due to the different needs of the networking functions: for instance, traffic engineering functions require information on very coarse scale for appropriately adapting routing strategy and performing resource provisioning. On the other side, for congestion control, it is required to have very fine grain information as the network has to react very fast in case of a large packet burst caused for instance by TCP. As well, the MMS system has to provide information at different levels: connections, flows, packets, bytes, security or failure alerts, etc. The MMS system then is an integrated toolbox which provides all needed information for the new networking functions.

The intension of this paper is to provide an overview of the MMS that was deployed in EuQoS multi-domain network. The main motivations for the MMS are: (1) to provide adequate set of tools for measuring QoS at the packet level and, in this way, to allow performing trials of the EuQoS system (2) to perform measurements supporting the EuQoS system functionalities, and (3) to perform on-line QoS monitoring for the network operator. Hence, the MMS is a multi-function system and is relatively complex with a variety of measurements (different metrics, time-scales, locations etc).

The paper is organised as follows. In section 2 we explain in details the role of MMS in the EuQoS network. The proposed MMS architecture (including short description of tools) is described in section 3, respectively. In section 4 we report the exemplary deployment of MMS. Finally, section 5 summarises the paper.

## 2. The role of MMS in EuQoS

We assume that the primary expectation from the EuQoS MMS is to provide a set of tools that is sufficient for performing trials of the EuQoS system as deployed in the testbeds. In particular, for performing trials with respect to QoS assessment in controlled and repeatable conditions we need the following:

- To load the system by generating artificial traffic profiles corresponding to the tested applications that are representative for particular CoSs. For example, the end-to-end telephony CoS (e.g. [6]) we must load with VoIP traffic. Anyway, two types of traffic are equired: foreground (measured) traffic representing traffic generated along a single connection and background one corresponding to traffic generated by a number of connections (aggregated traffic). Furthermore, the total volume of submitted traffic should load the system to the traffic limit as evaluated by admission control and in this way to create the worst-case traffic conditions in the system.
- To measure packet transfer characteristics illustrating the QoS level offered by the network, that is packet delay (mean value as well as variation) and packet loss ratio.

The next objective of the MMS is to provide the measurements needed for supporting EuQoS system functions. In particular, the long-term and short-term measurements of carried traffic on inter-domain links will provide support for the network provisioning and admission control function, respectively. In addition, we assume that the MMS has also a specific task related with obtaining information about available end-to-end QoS paths established by the EQ-BGP protocol [6]. This information is stored in the routing tables of border routers and it includes the cumulative values of QoS parameters that are guaranteed along the path to given destination domain.

Finally, the last objective of the MMS is to provide adequate tools for monitoring the delivered QoS in the operational network. This task belongs to the Operation, Administration and Maintenance (OAM) area and it is especially challenging in the multi-domain environment, where we encounter problems related with the limited possibility of sharing the measurement information between different providers and their MMS systems.

## 3. The architecture of EuQoS MMS

In this section we present the proposed architecture of the EuQoS MMS. In Fig. 2 we show an example of MMS as deployed in an EoQoS network consisting of two domains interconnected by the core network. The system consists of three parts related with supporting trials, supporting EuQoS system and QoS monitoring.

### 3.1 The MMS for supporting trials

For supporting trials we need a set of measurement tools that is adequate for QoS evaluation in a fully controlled testbed environment. As a basic tool serving this purpose we have selected **Netmeter** [7] which measures the packet level QoS metrics (i.e. IPTD, IPDV, IPLR [6]) using the active measurement method. The Netmeter uses freely available tool **MGEN** for generating the foreground traffic. Thus, it can be regarded as a control entity for MGENs installed in the Measurement Points (MP). The Netmeter implements intuitive Graphical User

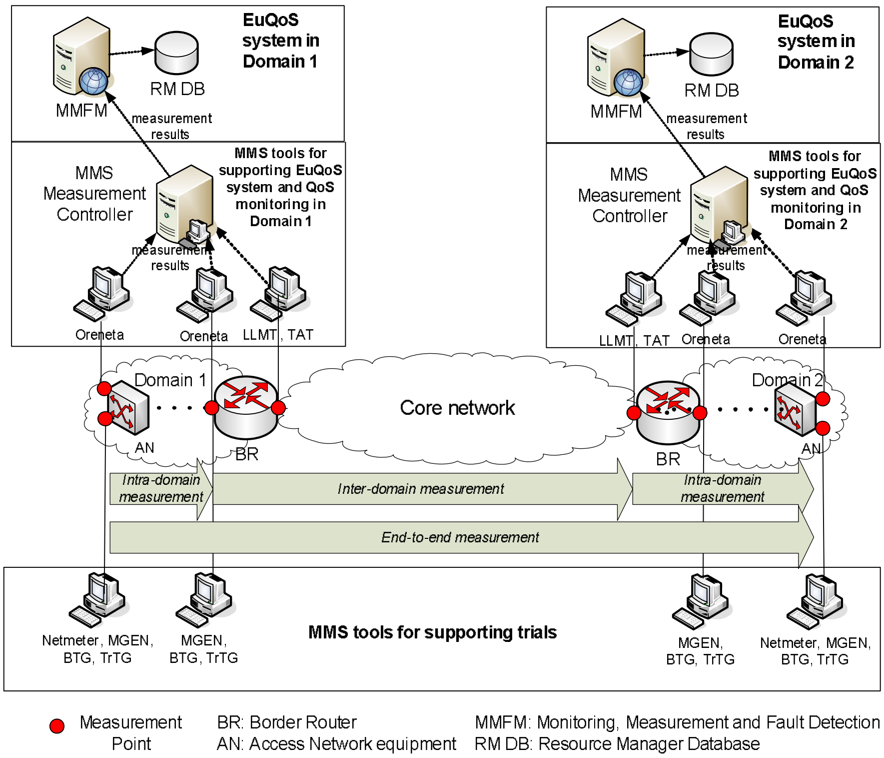



**Fig. 2. The architecture of EuQoS MMS**

Interface (GUI) for managing the tests and allows us for collecting and post-processing results e.g. by calculating the statistical distributions and plotting graphs. Since the Netmeter does not generate the background traffic, we have developed two additional tools for emitting traffic profiles corresponding to the aggregated connections. First, the **Background Traffic Generator Script (BTG)** [8] appropriately configures MGEN in order to generate traffic coming from a number of simultaneously running connections of the Constant Bit Rate (CBR) type. The second one, **Trace-based Traffic Generator (TrTG)** [8], allows us for re-playing the packet-level traces collected during simulation experiments with the EuQoS packet level simulator SIM-EuQoS-PTL [9]. Thanks to it, we can use in the trials the same traffic profiles as assumed in the simulation experiments, like e.g. Poisson, N-state and MMDP models.

### 3.2 The MMS for supporting EuQoS System

Obviously, the MMS tools aimed at supporting EuQoS functionalities must be closely integrated with the EuQoS system deployed in given domain. For this purpose we have developed a custom communication interface, which allows the EuQoS system to control the tools and acquire the measurement results. This interface is implemented between the following architecture entities (see Fig. 2):

- The MMS Measurement Controller (MC), which manages the tools deployed in particular domain, i.e. it initiates and terminates the measurements and collects results from the MPs.
- The EuQoS Monitoring, Measurement and Fault Management (MMFM) module [6], which obtains the measurement results from the MC and stores them in the Resource

Manager Database (RM DB). The RM DB is a common data repository accessible for all EuQoS system modules.

We have developed two measurement tools aimed specially at supporting the EuQoS system functionalities. The first one, **Link Load Measurement Tool (LLMT)** [8], allows us for measuring the traffic carried by particular CoSs on the inter-domain links. This tool takes a tap on a link and sends periodically (periods depends on the needs of the networking function) the amount of traffic that passes through the probe during the last period. For being generic this tool has two components: (1) a LLMT controller, which is generic, and LLMT tap which monitors the traffic. The tap can be based on software or hardware tools as for example the libpcap library or the DAG card respectively.

For retrieving from border routers the information about available end-to-end QoS paths established by the EQ-BGP protocol [6] we have developed the **Topology Acquisition Tool (TAT)** [8]. The TAT runs on the MC and periodically polls all border routers in given domain to collect their routing tables. By appropriately merging the information obtained from all routers it creates a consistent list of currently available end-to-end QoS paths to other domains. This list is conveyed to the MMFM module and to the RM DB.

The above-described tools are adequate for providing all measurements currently required for supporting the EuQoS system functionalities. Anyway, let us remark that the designed flexible and open MMS architecture allows us for integrating new measurement tools if such needs will be identified in the future development of the EuQoS system.

### 3.3 The MMS for QoS monitoring

For QoS monitoring in operational network we need a tool that performs measurements in a continuous way, using e.g. the mechanism of moving measurement window, and allows us for immediate access to the recent results. Unfortunately the Netmeter does not offer such capabilities since it is designed rather for performing off-line scheduled tests. Therefore, on-line QoS monitoring tool called **Oreneta** [8] was integrated with the EuQoS MMS. Furthermore, the Oreneta works according to the passive measurement method, which means that unlike Netmeter it does not introduce additional probing traffic on the monitored path. The **Oreneta meters** running on the MPs collect information about packets crossing given MP, while the **analyser** running on the MC gathers data from the meters deployed along the monitored path and calculates the values of metrics illustrating the current QoS level inside particular CoS. In fixed measurement intervals the results are transferred to the MMFM module and stored in the RM DB.

Let us remark that in the current MMS architecture we support QoS monitoring only of CoSs in a single domain. In this way we imitate the realistic situation where the MC in given domain has no direct access to the MPs located in different independently managed domains. In fact, managing the on-line QoS measurements on multi-domain paths is a complex task, which requires exchanging the measurement information between the MMSs in multiple administrative domains. We plan to deal with this issue in a future work.

## 4. Exemplary deployment of MMS system

In this section we present an exemplary deployment of the MMS system in one of EuQoS testbed and provide exemplary results measured with the aid of designed tools. The testbed, presented on Fig. 3, is dedicated for WiFi technology and consists of a number of wireless stations connected to the access point (AP). The AP through the border router is connected with other EuQoS testbeds.

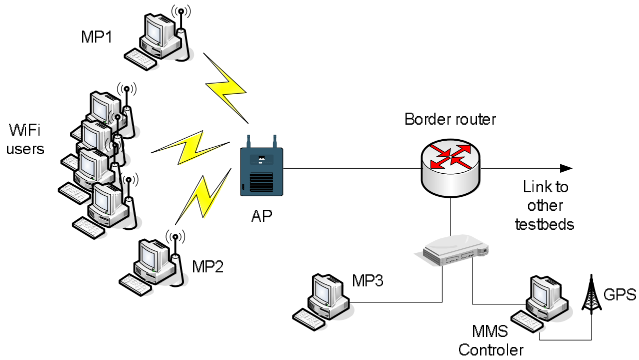



**Fig. 3. Topology of the WiFi testbed**

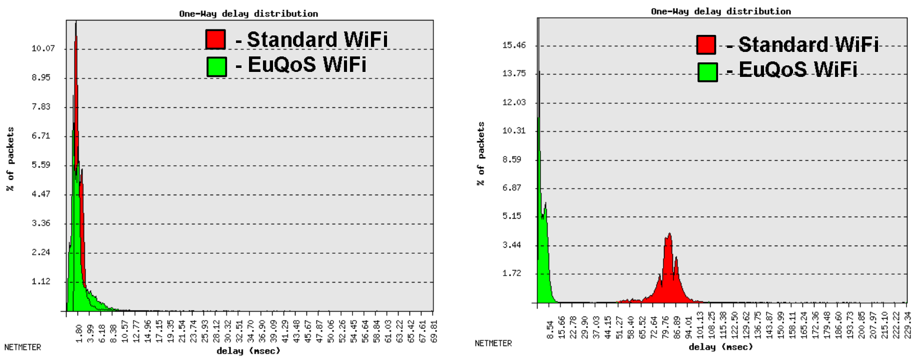
In addition for deploying the MMS system we use the following terminals:

- Three measurement points MP1, MP2 and MP3 with installed MGEN, BTG, TrTG and Oreneta meter software. The MP1 and MP2 are attached to the AP, while MP3 is directly connected to the border router.
- MMS controller that has installed Netmeter, Oreneta analyzer, TAT and LLMT controller software.

Moreover we put LLMT and Oreneta meters on the border router. Such deployment of MMS tools allows us to fulfill expectations put on the MMS system. Below we briefly describe possible measurements and present exemplary results.

### 4.1 Measurements for trials

The objective of trials is to evaluate the QoS level assured by EuQoS system. The general procedure assumes that we measure the QoS level experienced by packets belonging to test connection established between MP1 and MP3 using Netmeter tool under different load conditions. For stressing the WLAN network we use BTG and TrTG tools. The exemplary results corresponding to distribution of OWD measured for standard and EuQoS WiFi are presented on Fig. 4.




**(a) uplink** **(b) downlink**

**Fig. 4 Exemplary results of OWD measured by Netmeter tool**

### 4.2 Measurements for supporting EuQoS system

For supporting EuQoS system functions we design TAT and LLMT tools. The TAT tool provides to the EuQoS system available routing paths taken from the border router. For each entry, the following information is displayed: border router address, route prefix, length of a network mask, DSCP value, route status ("best" or "alternative"), next-hop address, AS path. The exemplary output form TAT is shown on Fig 5.

```
10.203.0.1|10.195.0.0|16|0|BEST|10.195.0.1|65503|N/A
10.203.0.1|10.195.0.0|16|0|ALT|10.202.0.1|65510 65503|N/A
10.203.0.1|10.196.0.0|16|0|BEST|10.195.0.1|65503 65504|N/A
10.203.0.1|10.196.0.0|16|0|ALT|10.202.0.1|65510 65503 65504|N/A
10.203.0.1|10.197.0.0|16|0|BEST|10.197.0.1|65505|N/A
10.203.0.1|10.197.0.0|16|0|ALT|10.202.0.1|65510 65505|N/A
```

**Fig. 5 Exemplary output from TAT tool**

In this example there are four available destinations, each of them with one alternative path.

The LLMT provides measures about traffic carried on inter-domain link. The measurements are performed every 1 sec. The exemplary results from LLMT are presented on Fig. 6.

```
   Fri 07 Oct 2005 12:16:27 PM CEST-963093000
   Total available BW (B/s): 99900000
   Used BW per TOS value (B/s):
   TOS: 0   Used BW: 100000        TOS: 1   Used BW: 0      TOS: 2   Used
BW: 0     TOS: 3    Used BW: 0      TOS: 4   Used BW: 0
```

**Fig. 6 Exemplary output from LLMT tool**

One can observe, that in all intervals the value of measured throughput of traffic with the TOS field fixed to 0 was equal to 100kbytes/s, which is consistent with the emitted traffic.

### 4.3 Measurements for QoS monitoring

QoS monitoring is preformed by Oreneta tool. The presented on Fig. 7 values were measured on border router for packets sent by TrTG tool from MP1. They show the output of Oreneta analyser for one measurement interval.

```
FLOW:0009 L3:IPv4 L4:UDP    10.203.1.10/32954 ->      10.203.2.2/3000

[    MTR     ]  M[1]                     M[2]
[    PPS     ]   |           10 packets/s  |
[THROUGHPUT]     |        15000 bytes/s    |
[    OWD     ]   |     0.002868 seconds    |
[    IPDV    ]   |     0.000000 seconds    |
[   PKLOSS   ]   |            0 packets/s  |
```

**Fig. 7 Exemplary output from Oreneta tool**

## 5. Summary

This paper has presented the current state of the MMS system designed in the EuQoS project, which aims at providing QoS in a heterogeneous and multi-domain network. For this purpose, the main principle of the EuQoS system deals with adapting in real time to traffic variability and resource dynamicity. Information on traffic, resources and actual network QoS is provided by the MMS system. The MMS deals with various objectives of measurements in EuQoS, that is: (1) to provide adequate set of tools for measuring QoS at the packet level and in this way to support trials of the EuQoS system (2) to perform measurements supporting the EuQoS system functionalities, and (3) to perform on-line QoS monitoring for the network operator.

One of the originality of EuQoS MMS is to provide a complex system combining tools for measuring multiple metrics, with various granularities depending on the requirements of the different networking functions. The EuQoS MMS can be regarded as a generic measurement and monitoring system that can fulfill the needs of any kinds of networking functions.

However, at this stage, the MMS system is still devoted to collecting monitoring and measurement information to the single measurement controller in the network, which certainly imposes some drawbacks related with a centralized MMS architecture. One of the goals of future work is to design and develop the measurement control protocol, which should deal with exchange of measurement information between MMSs deployed in different domains. This a key component for a measurement based networking architecture.

## Acknowledgements

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