# Reference Measurement Points for validation end-to-end QoS in heterogeneous multiple domain network

Andrzej Bęben, Wojciech Burakowski, Marek Dąbrowski

*Warsaw University of Technology*
*Institute of Telecommunications*
E-mail: `{abeben, wojtek, mdabrow5}@tele.pw.edu.pl`

**Abstract**

*The paper proposes the reference measurement points for Monitoring and Measurement System (MMS) in a network, which offers end-to-end QoS (Quality of Service) and consists of a number of domains, possibly build using different network technologies, as assumed for IST-EuQoS project [1]. In particular, the discussed network technologies are: IP QoS DiffServ, WLAN, LAN/Ethernet, UMTS and xDSL. The objective of the MMS is to provide the network operators information about the state of particular domains and inter-domain paths (including end-to-end connections). This information is useful for validation of QoS provided by the network, as well as for supporting several network functions like traffic engineering, fault detection etc.*

*The paper discusses the important issues of proper locations of measurement points and effective methods for managing measurements. We propose the reference locations of measurement points that allow us to measure QoS offered on both intra- and inter-domain paths, as well as between connected terminals (end-to-end path). Next, as an example, we present deployment of the MMS in the network assumed by the EuQoS project [1]. Finally, we discuss different management schemes for controlling measurements.*

## 1 Introduction

Monitoring and Measurement System (MMS) is currently becoming an important part of the network, especially in IP-based networks like the Internet. The objective for the MMS is to obtain information about the current state of the network, which can be done by performing special measurements corresponding mainly to the network resource utilisation. The role of the MMS is essential in IP QoS networks, due to difficulties in proper traffic characterisation, network provisioning and tuning of the employed QoS mechanisms, which mainly operate on the aggregated streams.

The objectives of the MMS are twofold: (1) to support validation of the QoS level assumed for the system, and (2) to perform specific measurements that can support traffic control mechanisms/algorithms like admission control, traffic engineering etc.

In this paper we focus on the reference measurement points for deploying the MMS in a network, which offers end-to-end QoS and consists of a number of domains, possibly build using different network technologies, as assumed for IST-EuQoS project [1]. In particular, the discussed network technologies are: IP QoS DiffServ, WLAN, LAN/Ethernet, UMTS and xDSL. Exemplary inter-domain network scenario that could be supported by discussed MMS system is depicted in Figure 1.

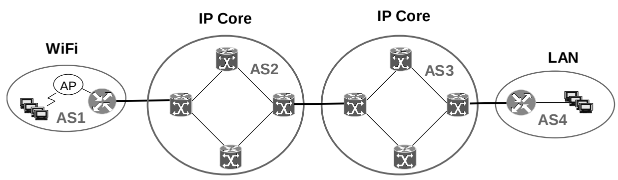



**Figure 1. Exemplary multi-domain, heterogeneous network supported by the discussed MMS system**

The issue of QoS measurements was previously considered in several European IST projects. For example, the AQUILA project has developed the Distributed Measurement Architecture (DMA) [2] for a single-domain IP QoS network. The DMA successfully supported the trials performed for validation of QoS level offered by each of the AQUILA network services [3]. In particular, the system allowed for performing measurements of the packet level QoS parameters such as One Way Delay (OWD), IP Packet Delay Variation (IPDV) and packet loss ratio. The AQUILA measurement tools were focused on validating the QoS offered by the AQUILA network services and did not allow for direct monitoring of QoS experienced by user-generated flows. The issue of the location of the measurement points and deployment of equipment in the trial network was addressed, but only for a single IP DiffServ domain.

The main objective of IST INTERMON project [4] was to define architecture for management of QoS measurements in multi-domain networks. In particular, the proposed INTERMON architecture assumes, that the Global Controller (GC) manages the measurements performed by the tools deployed in particular domain. Performing inter-domain measurements requires special protocol for communication between GCs in different domains, which adds additional complexity to the system.

GEANT [5] is a European research network, offering QoS service named Premium IP. Several different tools are used in GEANT for QoS measurements. However, the tools are not integrated in the form of a MMS. The planned future GEANT architecture assumes implementing the Domain Tool [6], which performs similar functions as the INTERMON GC. However, the discussed system is not currently implemented in GEANT and, as a consequence, its effectiveness has not yet been verified.

## 2 Reference locations of measurement points

In this section we present the recommended locations of the Measurement Points (MP) in the multi-domain network scenario, as assumed for the EuQoS project. A MP is just the point in the network, where we perform the tasks related with monitoring and measurements. It is obvious that we should fix a number of such points for collecting information about the QoS offered on particular paths in the network. The starting point for our proposal is to recommend the reference locations of MPs, i.e. without taking into account the potential limitations coming from the implementation barriers, like in some cases limited access to the internal mechanisms in the routers.

Since our goal is to measure end-to-end packet-level QoS metrics, the MPs should be located between the source and the destination, along the path. Notice, that the special focus is put on the case where the source and the destination are in different domains. In this case we should measure the offered QoS level not only in end-to-end relation, but also in each separate administrative part of this connection. In order to properly measure the inter-domain connections, we should measure the QoS offered by each of the domains, and the inter-domain links.

Taking into account that domains can be built using different technologies and can offer different QoS services, we should consider both the intra- and inter-domain QoS services (which are offered on the peering links between neighbouring domains). In general case, these two types of services could slightly differ, but the requirement is that both of them should assure consistent QoS level. Moreover, the implementation of QoS services on each of the inter-domain links can also differ. In our solution we intend to have deeper insight into QoS level offered by each part of the connection. This requires locating the MPs in such way, which allows us for measuring QoS delivered to traffic handled by both intra- and inter-domain services.

Since we are interested in measurements of QoS level for heterogeneous network, our approach is not to perform measurements that are technology specific, but to focus only on inter-networking IP layer, which is common for the border routers and the IP interfaces of the terminals. For instance, if the access network is UMTS, we do not intend to measure any characteristics inside UMTS network, but just to measure the IP packets transfer characteristics between the UMTS terminal and egress of the UMTS domain.

We follow the general idea of fixing the MPs in the points, where a domain, or an inter-domain link, begins and ends. In particular, we consider that a domain “begins” where its network services begin to operate, which happens in this point in the *ingress* border router, where the classification process of packets into network services is performed. The domain “ends” at the input port of the egress border router. On the other hand, the inter-domain link “begins” when the inter-domain network services begin to operate, which is in this point in the *egress* border router, where the classification process of packets into network services is performed. The inter-domain link “ends” at the input port of the ingress border router of the successive domain. The assumed boundaries of intra- and inter-domain network services are illustrated on Figure 2.

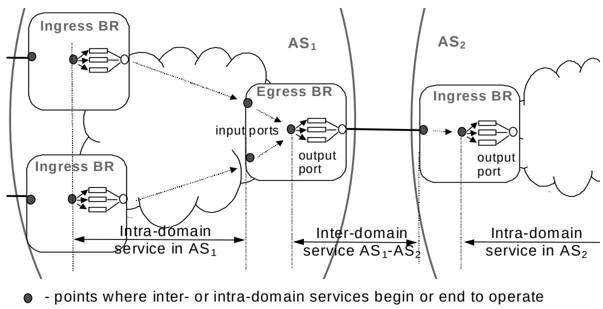



**Figure 2. Illustration of intra- and inter-domain network services**

For defining the reference locations of MPs, we consider a simplified model of the multi-domain network that is derived from the point of view of a single end-to-end connection of point-to-point type. According to this model, each domain is described simply by: (1) a core network as a cloud with an ingress and egress border routers, and (2) an access network as a cloud with a border router and a terminal. In addition, we assume that the processing times in border routers are negligible and, as a consequence, do not affect the packet transfer characteristics of interest. Fortunately, these times are usually in the order of microseconds, while the observed packet transfer delays (propagation + transmission + waiting in the router queues) are measured in milliseconds.

**Table 1. Reference locations of MPs in core domains ($AS_X$, X=2,3)**

| *MP* | *Location* |
|---|---|
| **$MP^X_a$** | Input interface of the ingress border router. In this point traffic enters the domain $AS_X$ from $AS_{X-1}$. This is the end point of inter-domain service between domains $AS_{X-1}$ and $AS_X$ |
| **$MP^X_b$** | Entrance to the queue on the output interface of the ingress border router. This is the starting point of the intra-domain service in $AS_X$ |
| **$MP^X_c$** | Input interface of the egress border router. This is the end point of the intra-domain service in the domain $AS_X$ |
| **$MP^X_d$** | Entrance to the queue on the output interface of the egress border router. This is the starting point of the inter-domain service between domains $AS_X$ and $AS_{X+1}$ |

**Table 2. Reference locations of MPs in access domains ($AS_X$, X=1,4)**

| *MP* | *Location* |
|---|---|
| **$MP^X_t$, $MP^X_t$** | IP interface of the user terminal. |
| **$MP^X_c$** | Input interface of the egress border router. In this point traffic leaves the access network in domain $AS_X$ |
| **$MP^X_d$** | Entrance to the queue on the output interface of the egress border router. This is the start point of the inter-domain service between domains $AS_X$ and $AS_{X+1}$ |
| **$MP^X_a$** | Input interface of the ingress border router. This is the end point of the inter-domain service between the domains $AS_{X-1}$ and $AS_X$ |
| **$MP^X_b$** | Entrance to the queue on the output interface of the ingress border router. In this point traffic enters the access network in domain $AS_X$ |

Now, we will explain the strategy for fixing the reference locations of MPs, considering exemplary network consisting of 4 domains, $AS_X$, X=1,…,4 (see Figure 3). In this case we have the domains $AS_1$ and $AS_4$ that are access domains, while $AS_2$ and $AS_3$ that are core domains and we consider the connection starting in access network $AS_1$ and ending in $AS_4$. The reference locations of MPs for each core domain ($AS_X$, X=2,3) are presented in Table 1.

Consequently, we follow similar strategy for recommending locations of reference MPs in the access domains ($AS_1$ and $AS_4$). The proposed locations of MPs in this case are presented in Table 2.

With such reference locations of MPs the MMS can perform the following QoS measurements:

- *Between $MP^X_t$ and $MP^X_c$*: measurements of QoS in the access network (uplink direction).
- *Between $MP^X_b$ and $MP^X_t$*: measurements of QoS in the access network (downlink direction).
- *Between $MP^X_b$ and $MP^X_c$*: measurements of QoS delivered by the intra-domain service in $AS_X$. The measured path usually includes multiple multiplexing stages, where packets can be delayed or lost.
- *Between $MP^X_d$ and $MP^{X+1}_a$*: measurements of QoS delivered by the inter-domain service on the peering link between $AS_X$ and $AS_{X+1}$. The measured path consists of a single multiplexing stage on the inter-domain (peering) link.
- *Between $MP^X_t$ and $MP^Y_t$*: measurements of end-to-end QoS.
- Additionally, we can measure the QoS experienced on the paths consisting of multiple domains and inter-domain links.

Let us remark that such reference MPs can be useful not only for QoS measurements, but also for passive measurements of volume and characteristics of traffic:

- *In $MP^X_t$*: measurements of traffic generated by a given terminal,
- *In $MP^X_a$*: measurements of traffic entering $AS_X$ on a given inter-domain link,
- *In $MP^X_b$*: measurements of traffic entering the intra-domain service in $AS_X$,
- *In $MP^X_c$*: measurements of traffic outgoing from the intra-domain service in $AS_X$,
- *In $MP^X_d$*: measurements of traffic outgoing from $AS_X$ on a given inter-domain link.

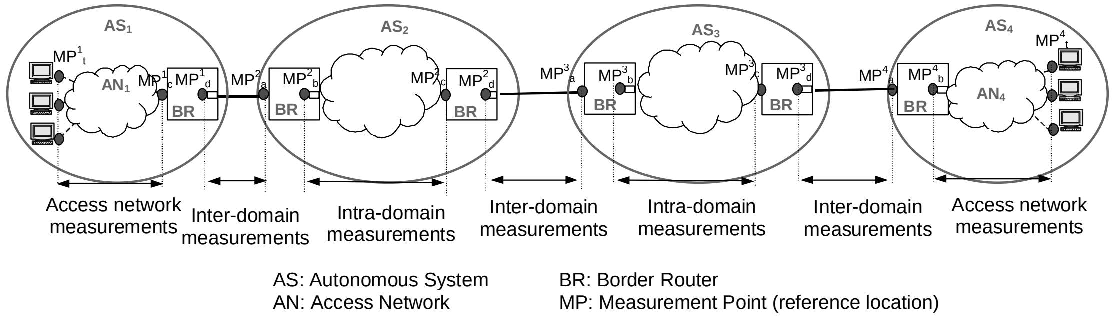



**Figure 3. Recommended reference locations of MPs in the multi-domain network**

### 3 Deployment of measurement equipment

Let us recall, that up till now for setting the reference locations for MPs we did not consider the barriers that may come from implementation. We believe that the most critical issue is limited access to the internal router and terminal entities. As a consequence, we are not able to locate the MPs directly in the routers. To overcome this, we propose to deploy the measurement equipment as an external terminal connected directly to the router.

#### 3.1 Inter-domain scenario

Similarly, as it was done in section 2, we will illustrate the approach by considering the exemplary path passing by multiple domains. Notice, that for this purpose we need to take into account the types of measurements (active or passive) we want to perform.

##### 3.1.1 Active measurements

For the case of active measurements (like e.g. performed with the aid of NetMeter tool [11]), the probes, it means the equipment for generating and receiving measurement traffic, should be directly connected to the border routers. The location points for probes we call as Active Measurement Points (AMP). Table 3 shows the recommendations for AMPs placement. Let us remark that by setting the AMPs we only approximate the reference measurement points (see Figure 4). Anyway, we expect that such solution does not introduce significant error in measurements.

**Table 3. Recommended locations of AMPs**

| *MP* | *Location* |
|---|---|
| **$AMP^X_t$** | On the terminal in the access network |
| **$AMP^X_a$** | Connected to the ingress border router |
| **$AMP^X_b$** | Connected to the ingress border router |
| **$AMP^X_c$** | Connected to the egress border router |
| **$AMP^X_d$** | Connected to the egress border router |

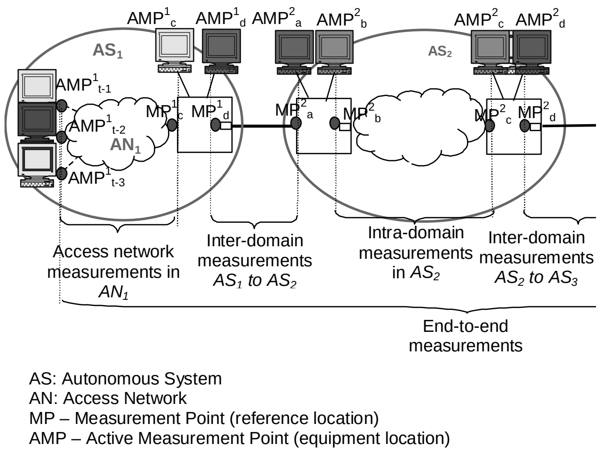



**Figure 4. Illustration of AMP locations**

The MMS performs the following QoS measurements between the proposed AMPs:

- *Between $AMP^X_t$ and $AMP^X_c$*: measurements of QoS offered by the access network (which should be measured between the reference points $MP^X_t$ and $MP^X_c$).
- *Between $AMP^X_b$ and $AMP^X_c$*: measurements of QoS offered by the intra-domain service in $AS_X$ (which should be measured between the reference points $MP^X_b$ and $MP^X_c$).
- *Between $AMP^X_d$ and $AMP^{X+1}_a$*: measurements of QoS offered by the inter-domain service between

$AS_X$ and $AS_{X+1}$ (which should be measured between the reference points $MP^X_d$ and $MP^{X+1}_a$).

- *Between* $AMP^X_t$ *and* $AMP^Y_t$: measurements of end-to-end QoS (which should be measured between the reference points $MP^X_t$ and $MP^Y_t$).
- Additionally, we can measure the QoS experienced on the paths consisting of multiple domains and inter-domain links.

In the assumed scenario, the sending and receiving probes connected to the same border router (e.g. probes $AMP^X_a$ and $AMP^X_b$, or $AMP^X_c$ and $AMP^X_d$) are presented as separate devices. Notice, that in fact these probes can be co-located on the same machine.

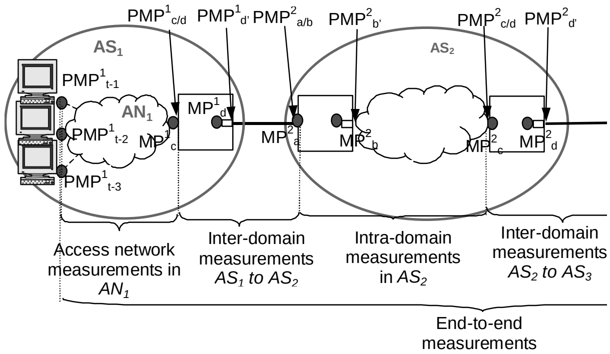
### 3.1.2 Passive measurements

The location points of passive measurement equipment or software we call as Passive Measurement Points (PMP). Remark, that capturing traffic for passive measurements can be done in two ways: (1) by software executed on the open routers, or (2) by attaching external capture devices to the monitored links.

In the case of open routers (e.g. Linux-based) passive monitoring can be performed with the aid of software tools like Tcpdump [7] or Ethereal [8], which capture packets transmitted on the router interfaces. However, the capturing cannot be done exactly in the reference MPs located at the entry to the queue (e.g. in $MP^X_b$ and $MP^X_d$). Therefore, similarly as in the case of active measurements, we propose the locations of PMPs that approximate the reference MPs (see Table 4 and Figure 5).

**Table 4. Recommended locations of PMPs (in the case of software capture tools)**

| *MP* | *Location* |
|---|---|
| $\mathbf{PMP^X_a}$ | Input interface of the ingress border router (exactly at the same point as $MP^X_a$) |
| $\mathbf{PMP^X_b}$ | Input interface of the ingress border router (at the same point as $PMP^X_a$) |
| $\mathbf{PMP^X_{b'}}$ | Output interface of the ingress border router (after the exit from the queue) |
| $\mathbf{PMP^X_c}$ | Input interface of the egress border router (exactly at the same point as $MP^X_c$) |
| $\mathbf{PMP^X_d}$ | Input interface of the egress border router (at the same point as $PMP^X_c$) |
| $\mathbf{PMP^X_{d'}}$ | Output interface of the egress border router (after the exit from the queue) |




AS: Autonomous System
AN: Access Network
MP – Measurement Point (reference location)
PMP – Passive Measurement Point (capture software location)

**Figure 5. Illustration of PMP locations (in the case of software capture tools)**

Let us remark that the commercial routers usually offer only limited possibilities for performing passive traffic measurements (like e.g. simple counters of traffic carried on given interface in CISCO [10] routers). Moreover, it is usually not possible to run the packet capture software tools on such routers. Therefore, for passive measurements we must use external capture devices, like e.g. DAG cards [9]. The capture device is connected to the physical link and it passively monitors the carried traffic. The recommended locations of capture devices for the MMS are presented in Table 5 and on Figure 6.

**Table 5. Recommended locations of PMPs (in the case of hardware capture devices)**

| *MP* | *Location* |
|---|---|
| $\mathbf{PMP^X_a}$ | Attached to the incoming link of the ingress border router, close to its input interface |
| $\mathbf{PMP^X_b}$ | Attached to the incoming link of the ingress border router, close to its input interface (at the same point as $PMP^X_a$) |
| $\mathbf{PMP^X_{b'}}$ | Attached to the outgoing link of the ingress border router, close to its output interface |
| $\mathbf{PMP^X_c}$ | Attached to the incoming link of the egress border router, close to its input interface |
| $\mathbf{PMP^X_d}$ | Attached to the incoming link of the egress border router, close to its input interface (at the same point as $PMP^X_c$) |
| $\mathbf{PMP^X_d}$ | Attached to the outgoing link of the egress border router, close to its output interface |

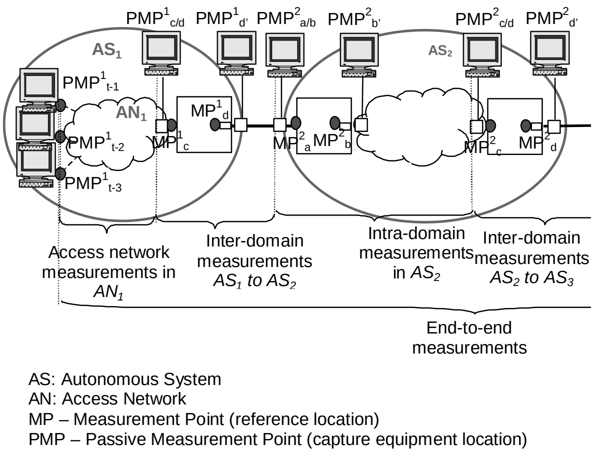



**Figure 6. Illustration of PMP locations (in the case of hardware capture devices)**

The MMS performs the following QoS measurements between the proposed PMPs:

- *Between $PMP^X_t$ and $PMP^X_c$*: measurements of QoS offered by the access network (which should measured between the reference points $MP^X_t$ and $MP^X_c$).
- *Between $PMP^X_b$ and $PMP^X_c$*: measurements of QoS offered by the intra-domain service in $AS_X$ (which should be measured between the reference points $MP^X_b$ and $MP^X_c$).
- *Between $PMP^X_d$ and $PMP^{X+1}_a$*: measurements of QoS offered by the inter-domain service between $AS_X$ and $AS_{X+1}$ (which should be measured between the reference points $MP^X_d$ and $MP^{X+1}_a$).
- *Between $PMP^X_t$ and $PMP^Y_t$*: measurements of the end-to-end QoS.

Notice, that the proposed PMPs (both in the case of capture software and hardware devices) can be additionally used for performing passive measurements of volume and characteristics of carried traffic:

- *In $PMP^X_a$*: the traffic entering the domain $AS_X$ form $AS_{X-1}$ (which should be measured in the reference point $MP^X_a$)
- *In $PMP^X_{b'}$*: the traffic entering the intra-domain service in domain $AS_X$ (which should be measured in the reference point $MP^X_b$).
- *In $PMP^X_c$*: the traffic outgoing from the intra-domain service in $AS_X$ (which should be measured in the reference point $MP^X_c$).
- *In $PMP^X_{d'}$*: the traffic outgoing from the domain $AS_X$ (which should be measured in the reference point $MP^X_d$).

Let us remark, that the proposed architecture assumes attaching two separate capture devices to each link connected to the border router. Obviously, limiting the number of deployed PMPs can affect the functionality of the MMS. For example, if we put the capture equipment only in $PMP^X_{d'}$, and skip the $PMP^X_d$, we can still measure the volume of traffic outgoing from $AS_X$, but we cannot measure the QoS offered by the inter-domain service between $AS_X$ and $AS_{X+1}$.

### 3.2 Access domain scenario

Now, we focus our attention on deployment of measurement equipment in access domains. Taking into account that access networks are usually built based on different technologies, like LAN, WLAN, xDSL, etc. therefore it is difficult to fix common reference locations of the MPs. Anyway, we can point out at least three general recommended locations: (1) as close as possible to the points, where the user terminals are connected to the access network, (2) at the input of the edge/border router and (3) after each of multiplexing stages in the access network.

As an example, let us consider a wireless LAN (WLAN) [12] access network, as depicted on Figure 7.

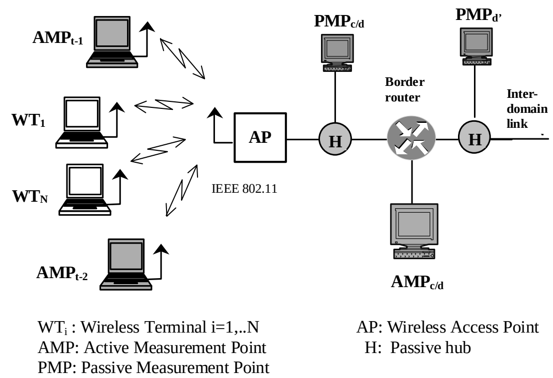



**Figure 7. Illustration of reference MPs for WLAN**

For performing active QoS measurements two AMPs ($AMP_{t-1}$, $AMP_{t-2}$), equipped with wireless network interface cards, should be connected to the wireless access point. Moreover, a single wired AMP ($AMP_{c/d}$) should be connected to the border router. These terminals should be equipped with appropriate measurement software that emulates behaviour of a user and allows for measuring the QoS parameters related with specific traffic profiles e.g. VoIP. For obtaining credible results it is important that all wireless terminals should be subject to similar propagation conditions, equipped with similar radio devices, etc. Moreover, they should be configured with the same physical and MAC layer parameters.

For performing passive measurements, two PMPs are needed in the discussed configuration. One on them, $PMP_d$, should be connected to the inter-domain link just behind the border router, while the second one, $PMP_{c/d}$, should be connected between access point and the border router. Note that in case of open software equipment, both PMPs may be implemented on the access point and border router, respectively.

## 4 Management of measurements

In this section we focus on solutions for management of measurements preformed in the multi-domain network. The considered management tasks are: configuring the MPs, planning and executing tests between particular MPs, collecting measured results, storing them in a database and pre-processing to the form understandable by a user.

The management of measurements may be performed in three different ways that are:

- with a central controller, where all measurements, both intra- and inter-domain are managed by a single, central controlling entity.
- with domain controllers communicating with measurement control protocol. In this approach each domain has its own measurement controller responsible only for performing intra-domain measurements. The results of inter-domain measurements, including end-to-end measurements, are calculated based on the results of intra-domain measurements. For that purpose a protocol for inter-controller communication is required.
- with domain controllers, but without measurement control protocol. In this scenario each domain has its own measurement controller that manages intra-domain measurements, as well as the inter-domain measurements originating in its domain.

Below we shortly discuss the main features of the above approaches. For the clarity of presentation, we consider only the scenario with AMPs performing measurements on the exemplary path crossing three domains: $AS_1$, $AS_2$ and $AS_3$. Notice, that all the approaches can be easily extended to the scenario with more complex inter-domain topologies, with both active and passive measurement points.

### 4.1 Central Measurement Controller

This approach assumes, that a single Central Measurement Controller (CMC) is responsible for managing all measurements preformed inside particular domains as well as between domains (see Figure 8).

Note that the role of central controller can be shifted to particular controllers located in different domains. However, at a given time only one CMC can be active.

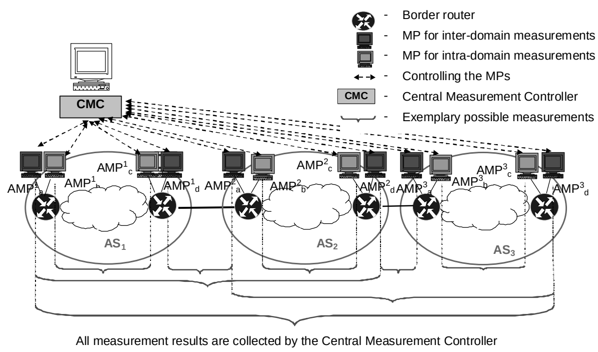



**Figure 8. Managing measurements by the Central Measurement Controller**

The main advantage of this approach is simplicity, and straightforward implementation. However, it is not scalable, because it assumes a single point of control. Moreover, this approach is difficult to deploy in a network consisting of domains under different administration (as in the case of the Internet). Summarising, this approach may be applied for networks of limited size under a common administration, like e.g. in case of trial networks.

### 4.2 Domain Measurement Controllers

In this solution, each domain needs its own Domain Measurement Controller (DMC) that is responsible for performing intra-domain measurements. The results of measurements on inter-domain paths (including end-to-end) are estimated on the basis of intra-domain measurements (see Figure 9). Therefore, this solution requires implementation of measurement control protocol for exchanging measurement data between neighbouring DMCs. In addition, appropriate methods for estimating inter-domain result from measurements preformed in particular domains should be defined.

Notice, that in this scenario in order to perform measurements of the inter-domain service on particular inter-domain link, the DMC in each domain has control a probe located in the next domain on the inter-domain path. The main advantage of this method is independency of measurements performed in particular domains.

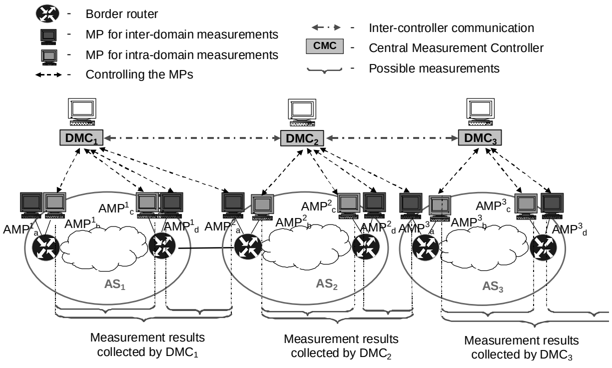



**Figure 9. Managing measurements by the Domain Measurement Controllers**

### 4.3 Domain Measurement Controllers without inter-controller protocol

According to this approach each domain has its own DMC (see Figure 10). Any DMC can control the measurements from its origin domain to any reachable MP. For instance, the $DMC_1$ of domain $AS_1$ can request the measurements to the MP located in domain $AS_3$. Then, we can collect the results of measurements between the MPs located in domain $AS_1$ and in domain $AS_3$, as well as between the MPs located in domain $AS_1$ and in domain $AS_2$. But, in this approach it is not possible to collect measurements between the MPs located in domain $AS_2$ and domain $AS_3$.

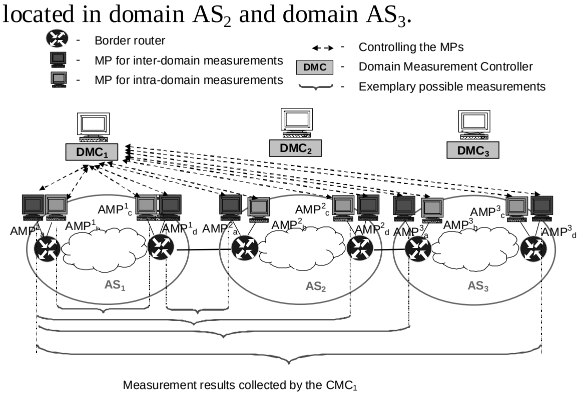



**Figure 10. Managing measurements by Domain Measurement Controllers, without inter-controller protocol**

## 5 Summary

The paper discussed the issues related with performing QoS measurements in multi-domain, heterogeneous network. For such network, the reference locations of measurement points needed for performing both active and passive measurements were proposed. These reference points allow us to measure values of QoS metrics on end-to-end paths, as well as experienced on particular parts of the path. In addition, three approaches for performing management of measurement were also discussed.

The approach for overcoming constraints related with limited access to the routers was discussed in details, in the exemplary deployment scenario of MMS in the EuQoS network.

### Acknowledgements

This work was supported by the European Union 6th Framework Programme under contract IST FP6 IP 004503, EuQoS.

### References

[1] The IST-EuQoS (End-to-end Quality of Service support over heterogeneous networks) project, *www.euqos.org*
[2] F.Strohmeier, H.Doerken, B.Hechenleiter, *"AQUILA Distributed QoS measurements"*, proceedings of COMCON8 conference, June 2001, Crete, Greece
[3] M. Dąbrowski, G. Eichler, M. Fudała, D. Katzengruber, T, Kilkanen, N. Miettinen, H. Tarasiuk, M. Titze, *"Evaluation of the AQUILA Architecture: Trial Results for Signalling Performance, Network Services and User Acceptance"*, ArtQoS'2003, LNCS 2698, Springer 2003
[4] I. Miloucheva, P.A. Gutierrez, D. Hetzer, A. Nassri, M. Beoni, *"Intermon architecture for complex QoS analysis in inter-domain environment based on discovery of topology and traffic impact"*, IPS2004, Budapest, March 2004
[5] R.Roth, M.Campanella, R.Sabatino, N.Simar, M.Przybylski, S.Trocha, A.Liakopoulos, A.Sevasti, *"IP QoS Across Multiple Management Domains, Practical Experiences from Pan-European Experiments"*, IEEE Communications Magazine, January 2003
[6] GEANT performance monitoring architecture, draft 0.1 (work in progress), *http://archive.dante.net/tf-ngn/perfmonit/#documents*, 2003
[7] Tcpdump web site, *http://www.tcpdump.org/*
[8] Ethereal web site, *http://www.ethereal.com/*
[9] J. Cleary, S. Donnelly, I. Graham, A. McGregor, M. Pearson, *"Design principles for accurate passive measurement"*, Passive and Active Measurements (PAM), Hamilton, New Zealand, April 2000
[10] CISCO web site, *http://www.cisco.com/*

[11] R. Serral-Gracià, R. Borgione, *NetMeter, a NETwork performance METER, http://www.ccaba.upc.edu/ netmeter*

[12] IEEE 802.11 WG, *"IEEE Std 802.11-1999, Part 11: Wireless LAN MAC and physical layer specifications"*, 1999