Paper

Concept for a Measurement Management System for Access Service to the Internet

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Abstract—This paper describes the problems associated with the provision of quality of service over an access connection to the Internet, i.e. the Internet Access Service (IAS). The paper has something of an overview character. Following a comprehensive introduction to the subject of "Changing Network Technologies" the paper focuses on the topic "Quality of IAS" in the light of regulatory directives of the European Parliament and the latest recommendations of ITU-T and ETSI. The focus will then shift to "Measurement Points and Measurement Scenarios for Determining QoS". This topic will be described in detail and illustrated with several graphics. The final chapter has a pronounced scientific character and contains, among other things, a suggestion for a so-called Measurement Management System (MMS) to aid the design, execution and evaluation of efficient, automatic QoS measurements in networks.

Keywords—Internet, Measurement Management Systems, Quality of Service.

1. Introduction

There is no denying that the store and forward technique has become tremendously popular throughout the telecommunications market since the turn of the century. Little by little, it has managed to oust older switching technologies. So it is not surprising that many network providers have announced their intention to pull out of ISDN [1] and ATM [2] in the near future. The success of the new technology is no doubt due to the flexibility of its redesign of packet switching. It allows for a high degree of flexibility in modern digital network architecture and management. The World Wide Web also uses this switching technique in the form of its datagram concept. The Internet Protocol (IP) [3] used in the network layer supports packet switching splendidly, and modern mobile wireless networks use packet switching as well. At the heart of these networks are transport platforms that also operate according to the TCP/IP [4] protocol stack. It is impossible to imagine modern digital networks without store and forward technology.

Internet works according to the "best effort" principle. Although it is very flexible, it does have a number of drawbacks. The packets are transported through the network along the best routes available at any given time (according to whichever metric is used). There are no confirmation mechanisms on this level, which means that lost packets will not be resent. Nor is there any content control (apart from the information in the header). Any errors that occur will be propagated and will accumulate towards the receiver's end. This can have a substantial effect on quality of service (QoS). It is often the case in IP-based networks that bottlenecks occur in various places. This means that in overloaded areas individual packets must be stored for a considerable time to be handled at a later time, and this causes significant end-to-end delays. An overload situation also means that the interarrival times of individual packets that belong to a single communication (in a word: jitter) can vary enormously. Jitter, too, can have a negative influence on QoS. If, during real-time communication, large jitter values cannot be redressed in the jitter buffers, additional packet losses will occur, and QoS will deteriorate even more. So it is evident that IP-based networks are flawed by multiple impairment parameters that can influence QoS.

A major aim in modern networks is to keep the customer happy. As the guru of American management, William Deming, once so aptly put it: "Quality is what satisfies, or even excites, the end user". To achieve this aim, the quality of service provided by the network must be constantly monitored, and corrective measures must be taken the instant it shows signs of decreasing significantly. It would be best if the continuous measurement of QoS values that this assumes could be done discretely and automatically. That is by no means an easy task for either network providers or national regulatory authorities.

The issue of QoS has received much attention in Brussels in recent years with negotiations leading to the enactment of the Communications Package in November 2009. It contains two eminently important directives: Directive 2009/136/EC [5] and Directive 2009/140/EC [6], that have been designed to ensure network neutrality and transparency throughout the telecommunications market of the European Union. With the publication of these Directives the Member States of the EU committed themselves to implementing them, as it turns out, however, with widely differing quantities of vigour from one country to the next. In November 2012, Poland's regulatory authority

UKE [7] launched an initiative called “QoS Memorandum”. In April 2013 Germany’s regulatory authority BNetzA [8] created a forum for the “Promotion of Transparency in End-Customer Markets and Measurement Methods”. These two steps aimed to stake out boundary conditions for ensuring transparency and network neutrality on the telecommunications market within the respective country.

These two initiatives have been put into practice in both countries: in 2014 the UKE in Poland and the BnetzA in Germany both published official calls for tenders to establish Monitoring and Measuring Systems for evaluating QoS at IAPs. The calls for tender closed at the end of 2014 and contracts have been awarded to selected firms. In Poland the first measurement system (with the features outlined above) already went into operation in the summer of 2015 and its performance is now undergoing tests, of course under the supervision of the contractor UKE. The same is due to happen in Germany in the second half of 2015.

There are a number of companies on the telecommunications market offering systems that measure QoS in networks. Here are some examples: Nextragen [9], Opticom [10], Empirix [11], Ixia [12], NetIQ [13], Ip-Label [14], Telchemy [15], Shenick [16], VoIP Future [17] and Systemics [18]. Surfing the Internet will reveal a number of open systems and/or software solutions with which the actual transmission rate in last-mile downlinks and uplinks can be measured. Here are a few examples: Measurement Lab (M-Lab) [19], Broadband Speedchecker [20], Wireshark [21]. Any appraisal of an open measuring system or a software solution will focus on its reliability, specifically: on its credibility. At the time of writing there are hardly any systems which allow the user to configure, implement and audit measurements of QoS. In a nutshell: there are no MMSs. Any such MMS should have to be designed to measure impairment parameters in networks and yield service-specific QoS values yet all the while remain unobtrusive, operating discretely somewhere in the network. It is of utmost importance that such measuring systems should be compatible primarily with existing standardised, service-specific QoS measurement methods. For only then are objective and comparable measurements possible. Furthermore, any statistical analysis of measurement results must take the rules defined in ITU-T and ETSI Recommendations into account. So it is patently clear that any MMS will be an extremely complex structure which takes many factors and circumstances into account. The authors, given their experience in all matters concerning the subject of QoS, will endeavour to develop and appraise in the course of this paper a concept for a universally applicable MMS. The latest initiatives of EU research projects (e.g. Leone [22] and mPlane [23]) also have this aim, as does the organisation IETF, which is at present working on a framework for the Large-scale Measurement of Broadband Performance (LMBP) [24].

The study will begin with a presentation of the Access Service to the Internet within the context of the regulatory framework in Europe (Section 2). Following that there will be a brief presentation of the existing measurement points and measurement scenarios that are typical of networks; special attention will be paid to ITU-T- and ETSI Recommendations (Section 3). A further Section 4 will be devoted to the main topic of this paper, namely the development of an MMS with the focus on a workable layout design of the system. The paper will conclude with a summary and an outlook on areas of future work in Section 5.

2. Access Service to the Internet

The Body of European Regulators for Electronic Communications (BEREC) has prepared on behalf of the European Commission a consultation process (finished on 28th April 2014) and launched the report “Monitoring the quality of Internet Access Services in the context of net neutrality” [25]–[26] and the report “Guidelines for quality of service in the scope of net neutrality” [27]. These documents will grant National Regulatory Authorities (NRAs) improved capacity to perform regulatory assessments of potential degradation of service. Furthermore, transparency enables end users to compare Internet Access Service (IAS) offers and hence strengthen the demand side of the market. It is therefore essential to have appropriate quality monitoring tools to implement the recommendations drawn from earlier studies in this area. The main goal of this report is to establish a basis for the creation of Internet access service quality monitoring systems covering two main use cases (see Fig. 1):

- Case A – providing transparency on the quality of the Internet access service for end users,
- Case B – regulatory supervision through monitoring the quality of the Internet access service with regard to potential degradation of service.

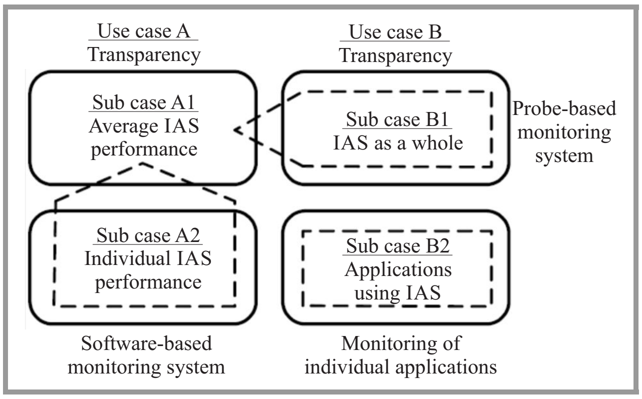

Fig. 1. Measurement systems vs. use cases.

When considering Case A there are two options:

- Sub Case A1 – average IAS performance,
- Sub Case A2 – individual IAS performance.

BEREC recommends implementing end user transparency measurements in a user-friendly manner. A software-based measurement agent download to end user equipment can be sufficient, provided that measurement results are validated by collecting additional end user information. Regarding aggregated results, BEREC recommends – for reasons of cost-effectiveness and user-friendliness – that averaging (based on data gathered from all participating users) should be performed based on crowd-sourcing.

When considering Case B there are two options:

- Sub Case B1 – degradation of IAS as a whole,
- Sub Case B2 – applications using IAS.

Measurements for monitoring the quality of IAS as a whole will typically be conducted in one of two ways. The NRA could either use a controlled system, e.g. with hardware probes that measure the systems of a preselected panel of specialists, or a less controlled system with software agents and a crowd-sourced user base. When evaluating potential degradation of IAS as a whole, BEREC recommends that such measurements are conducted over time to allow trend analysis to be performed. Measurement results need to be assessed in the light of technical progress and market evolution, with the goal of evaluating potential effects such as the provision of specialised services at the expense of IAS.

When it comes to monitoring applications using IAS, BEREC recommends the use of appropriate tools to measure the performance of individual applications (can also be used for transparency; use Case A) and also exploring the use of passive measurements. Leveraging applied to information from the measurement systems of content and applications providers (CAPs) and other complementary methods could also be considered. Measurement results obtained by these methods will need to be assessed by experts with regard to reasonable and unreasonable traffic management, in order to detect degradation of individual applications that are using IAS.

In CEPT's ECC report 195 [28], the following quality metrics have been selected: upload and download speeds, delay, delay variation, packet loss ratio, and packet error ratio. The criteria CEPT used to choose the relevant standard were primarily based on ETSI Guide EG 202 057 [29], ITU-T Recommendations Y.1541 [30] and G.1010 [31].

Quality assurance of measurement results and regulatory assessment of the results require deep understanding of the underlying complexities of Internet communications, and of monitoring methodologies. It is expected that this understanding will need to develop over time, and the exchange of experience among NRAs to foster convergence of practices, and participation in and contribution to standardization activities are good strategies for harmonization in this area. Especially when it comes to gaining experience in assessing degradation of service, BEREC recommends that NRAs collaborate to develop a common regulatory practice. Harmonization of evaluation of potential degradation of IAS as a whole, typically at the expense of specialized service, and assessment of degradation of individual applications, are both of utmost importance.

It is recommended that BEREC conduct a feasibility study for a potential future opt-in monitoring system before it contemplates pursuing the implementation of a full-blown measurement system. This would draw upon the proposed quality monitoring approach described above, containing as it does recommended measurement parameters and methods. The system should be designed in a way that allows additional measurement scenarios to be integrated smoothly into existing national systems. Such a study should also consider the effect of the dissemination of knowledge among NRAs and further development of best practices. This should accelerate harmonization of measurement methodologies and increase competence in the field of quality monitoring in the context of net neutrality.

There are three different types of regulatory approaches to implementing a quality monitoring system:

Traditional regulation – the quality monitoring system may be implemented and managed by the NRA itself or by an independent measurement provider commissioned by a public procurer. Given a sufficient legal basis, the NRA may also impose a system of quality monitoring on the ISPs.

Co-regulation – under certain circumstances, NRAs may find it appropriate to establish joint regulator-stakeholder organs rather than simply imposing implementation on ISPs. Under such a scheme, cooperation with stakeholders may be useful for meeting specific needs or regulatory objectives, or both. Examples would be: (i) system development by independent research institutions; (ii) conducting measurement campaigns with the help of consumer organizations; (iii) publishing results on third-party comparison websites.

Self-regulation – finally, under certain circumstances, NRAs may decide to leave deployment of measurement systems to market forces, and promote self-regulatory initiatives for the implementation of relevant measurement methods, and the publication of monitoring results, through moral suasion. For instance, NRAs may launch education and information campaigns to increase consumers' awareness of the availability and use of measurement tools, while inviting ISPs to make user-friendly tools available to their customers. Here, the NRA may have some influence, but does not control the methodology of the quality monitoring system, supervise its implementation or manage the generated data.

For the purpose of harmonization, BEREC recommends that an evolutionary strategy is pursued in which harmonization itself is viewed as a multi-stage process that encompasses the following:

Stage 1 – convergence of metrics and methods,

Stage 2 – sharing and comparison of measurement results,

Stage 3 – harmonization of cross-border measurements.

3. Measurement Points and Measurement Scenarios in a Focus of ITU-T and ETSI Recommendations

An enormous number of difficulties are connected with the quality of services provided to end users via IP networks. One of them is the issue of Internet access. Physically, it is a combination of different connections and services needed to establish a functioning Internet access. Each of them can be treated as a separate service described by its own quality parameters. On the other hand, inexperienced users do not usually understand the term "Internet access" as an access in the true sense of the word, i.e. the provision of a physical connection to the network [29]. Users normally understand Internet access to mean access to the end-to-end services available on the Internet. To them, a purely physical access to the Internet has no practical meaning beyond the provision of the possibility of using the various services, e.g. e-mail and Web browsing, and applications available in the network. So Internet access is generally understood as a platform that provides access to Internet services. From the technical point of view, however, the primary meaning of term Internet access should be understood as the physical and logical access to the core of the network, including all functionalities needed to enable the user to establish a connection to further entities in the Internet and to run the advanced services [29].

This section presents the main issues connected with specifying the measurement scenarios, locating the points at which the measurements can be performed, and identifying the parameters that affect quality of service. Simply put, this section says "what, how and where" measurements should be made to provide operators, Internet Service Providers and users with a thorough knowledge of quality of service.

Specifying the proper measuring points is quite a serious issue because Internet access is no longer provided by a single network or service provider as was once the case with traditional voice communication in public switched telephone networks (PSTNs). Normally, a user gains indirect access to the public Internet via an Internet Access Point (IAP). There is a transit network between user terminal and IAP. This is usually the public telecommunications network (PTN) but it might also be a wired or wireless local area network (LAN/WLAN). Therefore, the overall quality of services (or, in general, Internet access) is a combination of the performance of all elements involved in the connection.

The measurements can be divided into two groups: so-called "in-net" and "over-the-top" (OTT) measurements. The first case covers the Internet service provider's area - the area on which it acts. OTT measurements are more closely related to the user's perspective, i.e. the way he perceives the quality of service. In the context of net neutrality, performance of individual applications is also important because it can be used to detect potential degradation of the quality of the Internet access service.

ECC Report [28] specifies a list of technical quality parameters that could be used to make a technical evaluation of IAS. Many NRAs or other national institutions agree that the list is too long and consider it to be too complicated and incomprehensible to the average user. Thus, they propose the selection of a subset of parameters to the same ends. There is no consensus on which set of parameters would be best. So, after consulting an abundance of documents [28]–[30] and points of view, the EEC has proposed a list of minimum technical parameters that take their influence on the most popular Internet applications into account.

The following quality metrics have been selected: data transmission rate, delay, delay variation, packet loss ratio, and packet error ratio. Table 1, based on ECC Report 195 [28], illustrates popular services, and the relevance of the network performance parameters to the performance or quality of those services, or both. In the following table, the relevance ranges from "–" (irrelevant) to "+++" (very relevant).

Table 1
Relevance of network impairment parameters to various applications

Service	Data transmission speed		Delay	Delay variation	Packet loss	Packet error
	Down-stream	Up-stream				
Browse (text)	++	–	++	–	+++	+++
Browse (media)	+++	–	++	+	+++	+++
Download file	+++	–	+	–	+++	+++
Transactions	–	–	++	–	+++	+++
Streaming media	+++	–	+	–	+	+
VoIP	+	+	+++	+++	+	+
Gaming	+	+	+++	++	+++	+++

The first parameter presented in Table 1 is data transmission rate (or shorter: transmission rate). It was selected because it is probably the most relevant parameter; it is self-evident, and mentioned in virtually every Internet Service Provider's offer. Moreover, it can be measured on the network layer (in-net measurements) and can be compared with values obtained on the application level (OTT measurements). It is defined as the data transmission rate that is achieved separately for downloading and uploading specified test files between a remote Web site and a user's terminal equipment [29]. The next parameter is delay, defined as half the time (in ms) that is needed for an ICMP packet to reach a valid IP address. This parameter is also easy to understand and has an influence on many applications available over the Internet. It is already being used by many NRAs, operators and web-based speed meters.

For some applications the delay variation is relevant. It is therefore the third parameter selected for measurements. The exact definition of this parameter can be found in [30], [32]. Losing information is another parameter that can be relevant to some applications. IP packets can sometimes be dropped due to a small buffer size or poor radio connection although values for the transmission rate, delay, and delay variation remain good enough. UDP-based applications such as Voice over IP could not work properly in such conditions if it were not for compensation techniques operating on the application level. This phenomenon can be quantified and described by packet loss ratio, which is the ratio of total lost IP packets occurrences to the total number of packets in the population under examination [32]. This parameter can also be measured on the network layer and compared with results obtained on the application level.

The last, but not least, parameter that has been selected as relevant to many applications is the IP packet error ratio, sometimes called packet error ratio. It is defined as the ratio of total faulty IP packet occurrences to the total of successful IP packet deliveries plus faulty IP packet occurrences within a population of interest.

In conclusion, it should be noted that the transmission rate of IAS is the most popular parameter, being the one that end users understand best. It is also used by the operators as a basis for evaluating of the Internet Access Service. Each of the other four equally important parameters addresses a particular quality feature. Thus, IAS can only be comprehensively described by using all of them, including the transmission rate.

Usually, the values of the parameters being measured vary considerably throughout the course of a measurement procedure. So, questions arise as to how the final values can be calculated (the average, minimum, maximum, or perhaps another) and which of them are really important. It seems that the average value is very important for all the parameters: it gives general information. But in the case of transmission rate the minimum value can be very relevant, especially for the end user. Most Internet applications require certain transmission rates, i.e. certain minimum values. Figure 2 presents a generic overview of the elements, network sections and interfaces of the IAS according to ETSI and CEPT documents [28]. Users can be connected to the various Internet Service Providers via access/aggregation networks, using wired or wireless connections. Communication over the Internet requires data interchange over different National and International eXchange Points (NXPs and IXPs). QoS management is therefore a very demanding issue. Moreover, mapping the quality of service of particular network sections according to the Quality of Experience (QoE), i.e. quality as perceived by the user, is quite complicated and requires clear specification of interfaces between these networks. Specification of the interfaces, as presented in Fig. 2, allows so-called "in-net" measurements to be made with which operators and service providers could then examine their own networks to verify their conformity with specifications and minimal service requirements.

Three "in-net" evaluation methods seem to be relevant to measurements connected with IAS quality assessment. The methods all revolve around examination of the access network, the ISP network and sometimes the network connections to national or international exchange points (NXP or IXP). The names of these methods (also see Fig. 3) are listed below:

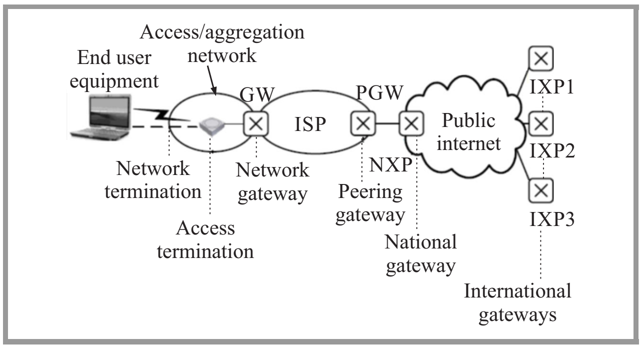

Fig. 2. Generic overview of elements and network sections of private end user IAS.

- QoS evaluation within the ISP leg,
- QoS evaluation between Network Termination Point (NTP) and NXP(s),
- QoS evaluation between NTP and IXP(s).

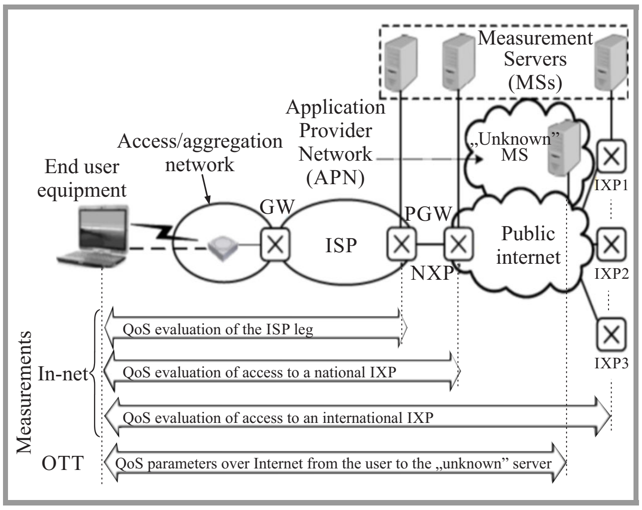

Fig. 3. Internet Access Service QoS evaluation.

According to ETSI [29], the access network is the most essential for the assessment of the ISP leg. To assess the access network only, the test server should be located as near as possible to the gateway (GW) between the access network and the ISP network. If the quality of the entire ISP leg is to be evaluated, the test server should be placed inside the ISP network, near the public Internet interface (PGW in Fig. 3). For a QoS evaluation of the section up to a national Internet Exchange Point, the test server should be located at the NXP. This set-up should make it possible to compare the QoS of access to the NXP of different ISPs within a specific country. Any such evaluation must be done in the light of the set of QoS parameters specified by the NRA of that country. To compare Internet Access Services using different ISPs, a central test server is necessary to establish comparable measurement results.

The bottleneck of the ISP's network, besides the Access leg, lies within the interconnection points, where capacity is usually insufficient. Therefore, the comparability of measurements of the different Internet Access Services can only be achieved if all ISPs being examined are connected to the central measuring point in the same way. To guarantee objectivity it is recommended that such measurements should be performed by a third-party measuring organization (NRA itself or other relevant national institution or independent organization) using suitable hardware tools, software clients or web-based applications. This scenario reflects far more accurately the performance of the IAS as it is perceived by the user than does the "ISP leg scenario" described above. So the results obtained for the QoS of the IAS will come far closer to its QoE values. If QoS evaluation is to be performed on the access to an international Internet eXchange Point, it should be noted that such IXPs might not be a single physical entity. Nevertheless, the results of the measurements should be collected using one – and only one – analysis system capable of encompassing all points.

Finally, the measurement scenarios should also specify the times at which the measurements are made. In general, measurements should be schedules so as not to fall in periods of low or high traffic, let alone peak hours. To obtain representative values within a short time, measurements should be performed continuously, but due to extraneous circumstances (primarily money and pressure of time) the observations might quite reasonably be limited to specific times depending on user behavior.

When accessing the services or applications available in the global network users perceive the quality of access provided by the IAS as a whole. Therefore, the second approach to evaluation, called "over the top" evaluation, has been proposed. It reflects most faithfully users' perception of service quality. It can be performed using a third-party server located in the Application Provider Network, which allows users to conduct end-to-end measurements between their own terminal equipment and a so-called "unknown" application-specific server (see Fig. 3).

4. Concept for a Measurement Management System

The Measuring Management System (MMS) designed for quantifying Quality of Service (QoS) in modern digital networks encompasses four elements:

- organization,
- information,
- communication,
- function.

The element Organization describes the components of the Measuring Management System, such as a manager, agent, etc., and their inter-relationship. The arrangement of these components leads to different types of architecture; this will be discussed at a later stage. The element Information is concerned with the structure and storage of measuring management information. The information is stored in a database called Management Information Base (MIB). The ISO standardized the Structure of Management Information (SMI) to define the syntax and semantics of management information stored in the MIB. The element Communication deals with the process of communicating management data between agent and manager. It is concerned with the transport protocol, with the application protocol and with commands and responses issued and transported between peers. The last element, Function, addresses the measuring management applications that reside in the node management station (NMS). The following function areas are possible:

- configuration – e.g. address of agents, number of measurement sessions, address of sessions, measurement duration, number of repetitions, type of measurement techniques, location of stored measurement information,
- performance – e.g. establishing connections, synchronizing measurement clients, QoS measurement, building of records,
- fault indication – checking availability, route tracing, and generating test functions.

The architecture of the intended MMS is shown in Fig. 4.

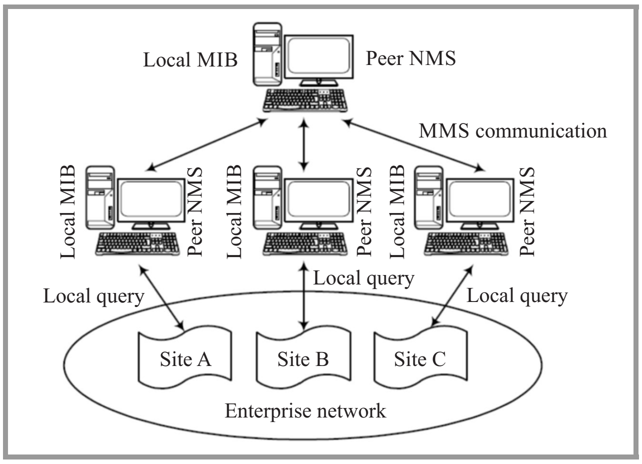

Fig. 4. Architecture of the Measuring Management System.

In a distributed network, a decentralized architecture is more appropriate, with a local NMS at each site. These distributed NMSs can act in a client-server architecture in which one NMS (Manager) acts as master server and the others as clients (Agents). The clients send their data to the master server for centralized storage. An alternative is to have all distributed NMSs bear equal responsibility, each with its own manager databases, so that management information is distributed over the peer NMSs.

Communication between the components in the MMS is done by way of an application layer protocol Simple Network Management Protocol (SNMP). Three versions of this protocol are currently available: V.1 (RFC 1155-7, 1988), V.2 (RFC 1351-3, 1993) and V.3 (RFC 3410-18, 2002). This protocol is well known; it is commonly implemented in such network components as routers and gateways and is thus routable. This proves to be a huge advantage in practice especially when MMS is used in hybrid network structures (with multiple gateways). SNMP utilises the User Datagram Protocol (UDP) and communicates via ports 161 and 162. It is based on an exchange of messages. There are three common types of message:

- GET – enables the management station to retrieve the value of MIB objects from the agent,
- SET – enables the management station to set the value of MIB objects at the agent,
- TRAP – enables the agent to notify the management station of significant events.

A MIB is used to store the structured information representing measuring elements and their attributes. The structure itself is defined in a standard called Structure of Management Information (SMI) which defines the types of data that can be used to store objects, the names of these objects and how they are encoded for transmission via a network. Each object assumes a unique identifier, the so-called Object Identifier (OID). Assignment of OIDs is organized strictly hierarchically. As the above example shows, it is possible, using such a type of OID, to define private objects that can be used in a MIB. They must be requested from Internet Assigned Numbers Authority (IANA) from the standards groups or from the producers of QoS measurement systems.

The MMS manager is usually a standalone workstation, but it might also be implemented under several operating systems. It includes a collection of software called Measuring Management Application (MMA). The MMA includes a user interface to allow authorized MMS agents to manage the measuring system. It responds to user commands issued throughout the network. The agents are measuring management software modules. They respond to requests for information and requests for action from the MMS manager, such as polling, and can provide the manager with important but unsolicited information, such as traps. All management information about a particular agent is stored in the management information base at that agent. An agent might keep track of the following:

- number of measurement sessions,
- address of measurement session,
- type of service,
- kind of measurement method,

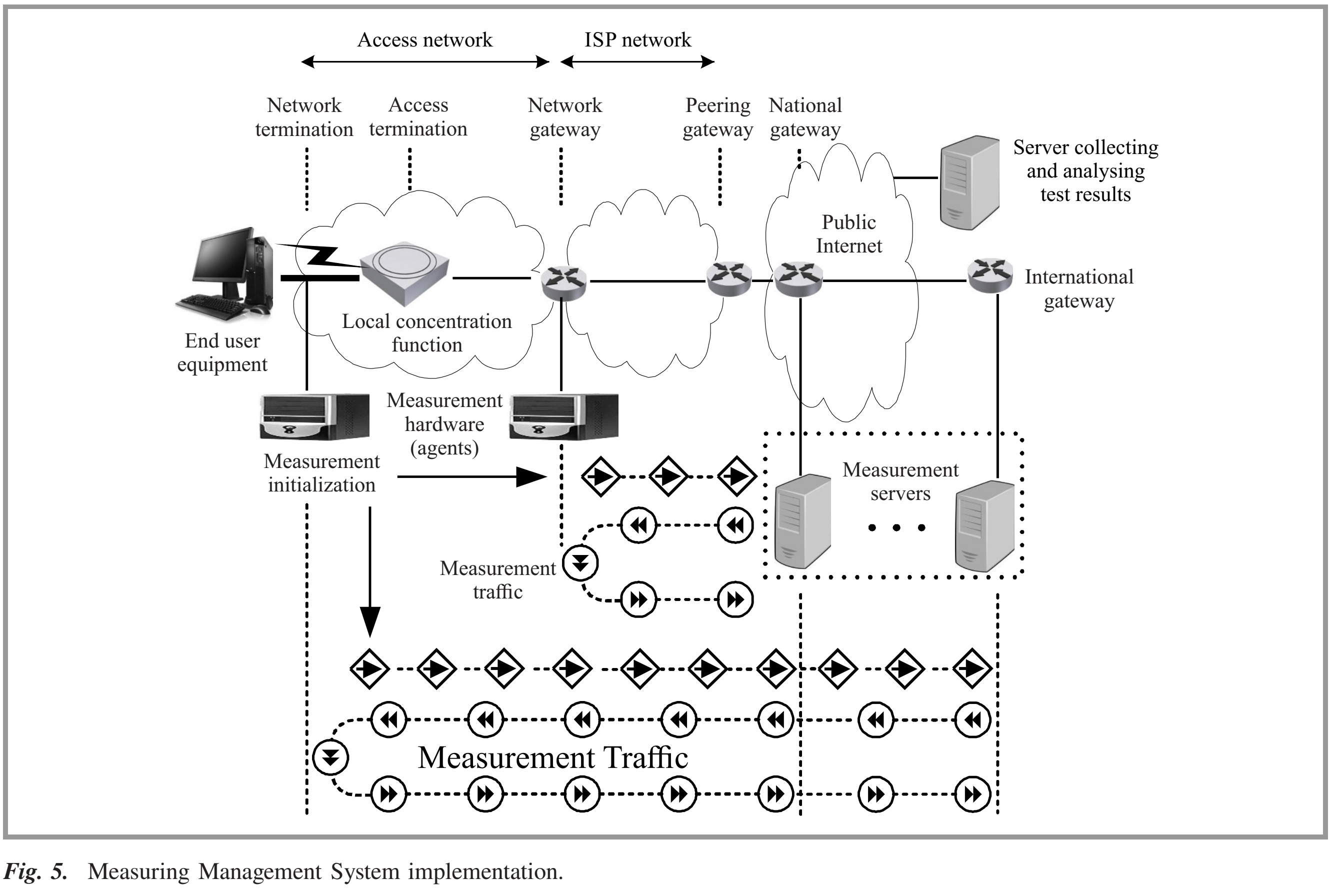

Fig. 5. Measuring Management System implementation.

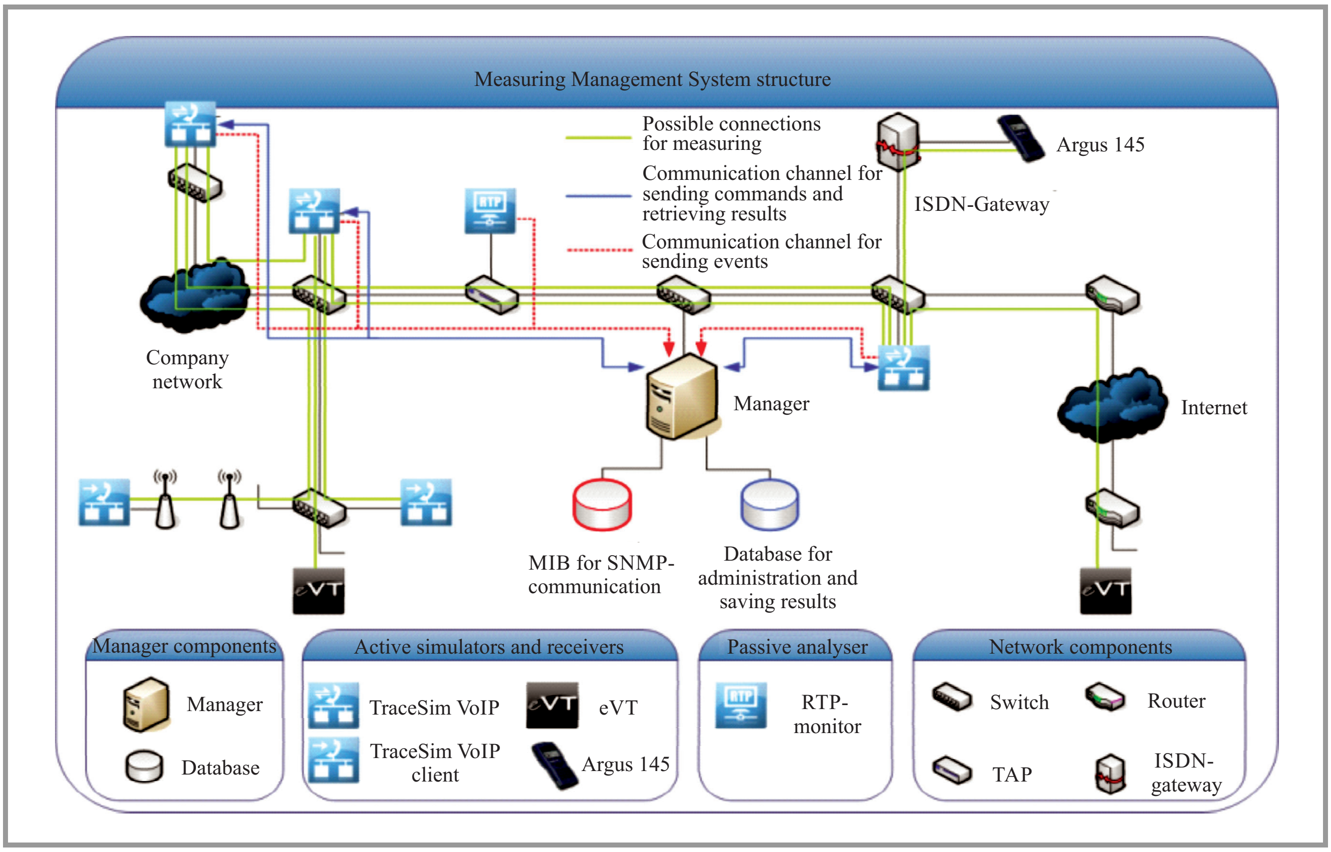

Fig. 6. Architecture of the implemented MMS for QoS in VoIP.

- data and duration of measurement session,
- QoS value for measurement session,
- error indication.

The management entity is also referred to as the manager or NMS. It is responsible for soliciting information from the agent. Such solicitations are based on very specific requests. The manager processes the retrieved information in a number of ways. It can be logged for later analysis, displayed using a graphing utility, or compared with preconfigured values to verify whether a particular condition has been met. Figure 5 presents an example of an implementation of MMS in a real network.

It can be seen that the MMS system consists of several measurement hardware units (Agents) located at characteristic termination points (connected at the interfaces between different network portions) or at node management stations (i.e. the measurement servers in Fig. 5) located in the network core and connected to national or international gateways respectively, or to both. Location of the NMS depends on which portion of the network is to be tested. When testing Internet Service Access within the national network (i.e. within one country) the MMS should be connected to the ISP peer gateway or national gateway. The second solution is recommended for testing and comparison of IAS performed by different ISPs. A measurement scenario must be initialized before measurement traffic can be sent. A special hardware unit with dedicated measurement software plays the role of the agent of the MMS, while measurement servers constitute an NMS. Standard messages, like GET, SET and TRAP, allow the retrieval of MIB values from the agents, the setting of values or notification of important events to the management.

Figure 6 shows the first implementation of a Measuring Management System for QoS in VoIP (designed in compliance with the concept presented above), developed at the Flensburg University of Applied Sciences [33]. The system has a centralized architecture. The manager acts as master and the agents as clients. The manager has two databases: MIB for SNMP communication and SQL for administration and saving results.

The agents contain the measurement systems by the company Nextragen Flensburg, i.e. Trace_View_VoIP, Trace_Sim_VoIP and RTP-Monitor [9]. The agents will be configured by the manager automatically. They send the measurement results back to the manager. It saves and evaluates them. An administrator can access the SQL database any time to view the results obtained.

The tests have confirmed the functionality of the MMS in this configuration, and the new MMS has subsequently been included in the company Nextragen's range of products [9] and is available on the telecommunications market as one of the components of the Trace_Sim_VoIP tool. Using the tool's option EMP (Extended Measurement Plan) it is possible to define the distributed node management station (NMS) as an independent measuring node and have it function as one. This provides a platform for identifying bottlenecks and for making reconfigurations accordingly. In the course of time, however, the new MMS has been shown to have two shortcomings: 1) The system's throughput is low and 2) encoding is only done on a pretty primitive level. So the company Nextragen is busy on an even newer, more efficient MMS based on its own high-performance communications protocol coupled with more sophisticated encoding. The latest developments take into account the latest recommendations of both the EU workgroup [23] and the IETF [24].

5. Conclusion and Outlook

This paper has discussed extensively the problems associated with the provision of quality of service of an Internet access connection, i.e. the Internet Access Service. It started with a detailed presentation of the most recent developments in network technologies and emphasised the importance of QoS. It also contained detailed descriptions of the latest activities of the European Parliament and the Council of Europe affecting network neutrality and transparency. It introduced and illustrated with several graphics the measurement points and measurement scenarios that have been based on the recommendations of ITU-T and ETSI and the EU workgroups BEREC and PTTRIS to determine the QoS in networks. The final chapter defined a concept for the so-called MMS and described it in detail. The concept takes account of the recommendations of international standardization organizations and the most important European telecommunications workgroups. The concept is therefore tailor-made for the real world.

One particularly important initiative affecting Internet Access Service QoS evaluation must be mentioned. In 2010 the European Commission contracted the company SamKnows with the identification of the chief impairment parameters in the IP networks of EU member states. So a massive measuring project was called into life that took three years to complete. For the purposes of this study 8,582 households across the European Union were given a specially configured hardware device (SamKnows Whitebox), which runs a series of purpose-built tests to measure every aspect of Internet performance. The final report is available [34] and includes a comprehensive explanation of the project, the purpose, the test methodology and the analysis of performance against key indicators across the EU. The analysis in this report is based on data collected in the month of October 2014. SamKnows continues to look for volunteers to participate in studies throughout Europe. Participants can sign up at www.samknows.eu.

Several member states of the European Union: Poland, Lithuania, Germany, Greece, France and Austria for instance (see Appendix to [26]) have already taken the initiative, implementing MMSs and using them regularly to determine the QoS in IAS. In Poland a new system called NKP (Measurement & Control Tool) [7] went into operation 2015 and it is designed for control of broadband networks built with EU funds. In 2016, it will be built a system for customers as a mechanism monitoring certified to evaluate the service access to the Internet. A similar MMS has been in operation in Germany since early 2016 [35]. This all goes to show that the issue of QoS in Europe's networks is not only being taken seriously, practical steps to assure QoS are also actually being taken.

The examination of QoS in IAS discussed in this paper is to be extended to cover any and all real-time and non-real-time applications available in the modern Internet of Things. Further types of efficient MMSs are needed and will have to be designed and produced. For only through using such MMSs can transparency and network neutrality be achieved throughout the communications market. This will present a major challenge to Internet engineers.

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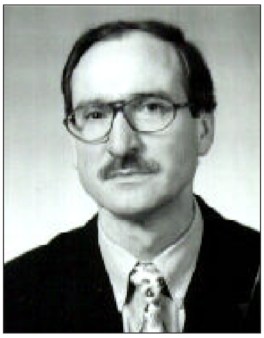

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