QoS in SIP-based NGN – state of the art and new requirements

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Abstract

Both, surveillance of the market and studies of ongoing research and standardisation work show that the evolution from traditional telecommunication networks (such as ISDN) towards NGN (Next Generation Networks) currently takes place. SIP (Session Initiation Protocol) as an IP-based signalling protocol plays a major role in future NGN-based telecommunication networks. Quality of Service (QoS) is one of the most important key features of NGN. This paper presents new requirements to the QoS management in SIP-based NGN. Also the new concept of virtual data pipes is introduced to improve the QoS management mechanism.

Keywords

NGN, QoS, SIP, Resource Reservation, Virtual Data Pipe

1. Introduction

The concept of NGN as defined by ITU-T and ETSI TISPAN (Telecoms & Internet converged Services & Protocols for Advanced Network) can be outlined by the following main key features (Trick and Weber, 2007).

1. Packet-based (core) network for all services
2. Quality of Service
3. Utilisability for new services
4. Separation of call/service control and user data transport
5. Integration of any existing, important telecommunication network, especially access networks
6. Application Servers
7. Multimedia services
8. High bit rate
9. Overall unified network management
10. Mobility
11. Integrated security functions
12. Service-appropriate billing
13. Scalability
14. Unrestricted access by users to different networks and service providers
15. Consideration of applicable regulatory requirements

The IMS (IP Multimedia Subsystem) (3GPP TS 23.228, 2006), which is defined by 3GPP (Third Generation Partnership Project) as the SIP-based IP multimedia session control system in UMTS (Universal Mobile Telecommunication System) Release 5 and for higher releases, has been chosen by ETSI (ETSI TR 180 001, 2006) to be introduced to the NGN framework for call/session control.

Traditional ways to provide QoS (Quality of Service) in IP transport networks are usually based on mechanisms such as DiffServ (Differentiated Services), IntServ/RSVP (Integrated Services / Resource Reservation Protocol), or MPLS (Multi-Protocol Label Switching). These mechanisms are (by definition) not aware of communication sessions (e.g., a Voice over IP session) established by higher layer protocols such as SIP. (Camarillo *et al.* 2002) show a standardised approach to combine SIP session signalling and IntServ-based network resource reservation. This approach is applied in UMTS IMS standardisation by 3GPP (3GPP TS 24.228, 2006) and in NGN Release 1 standardisation by ETSI TISPAN (ETSI TR 180 001, 2006) as a basis for the respective overall QoS concepts of both, IMS and NGN.

However, the standardised NGN QoS concept comes along with a high volume of additional traffic for the allocation and reservation, and – after call termination – the release of network resources for each call. The resource management traffic is not efficiently controllable by the respective NGN's provider because it does not only depend on the number of end users but also on their session behaviour (e.g., the number of session requests per time per user, and the average duration of each session). Thus today's standardised NGN approaches of per-session QoS control lead to inefficient resource management traffic.

This paper gives an overview of the standardised NGN QoS concept and shows its vulnerability. Also, a summary of past and current research activities concerning the QoS aspects of SIP-based NGN is given.

New requirements concerning the provision of QoS control in NGN are elaborated on and a new general approach for QoS in SIP-based NGN is introduced.

2. NGN QoS standardisation

In the following chapters the standardised general NGN architecture according to ETSI TISPAN is briefly described. Its resource control approach, essential for the provision of QoS in SIP-based NGN, is introduced and its deficiencies are outlined.

2.1 General NGN architecture

(ETSI ES 282 001, 2005) describes the standardised general NGN Release 1 architecture (see figure 1). It can generally be divided into two layers, the service layer and the transport layer.

All logical functional components shown in figure 1 are simplified in the way that necessary sub-functions contained within these components are hidden. The shown component's interfaces are simplified in the way that they may or may not consist of divers interfaces grouped together.

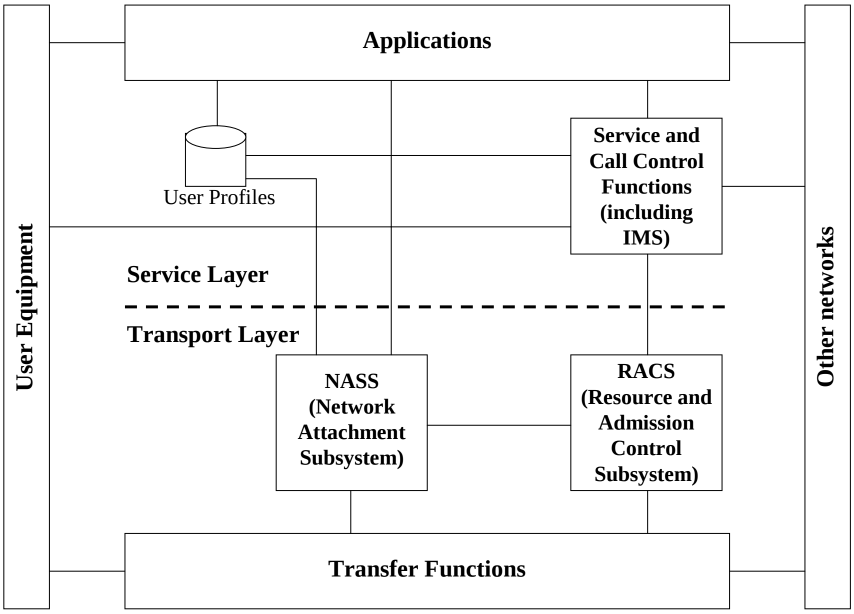

Figure 1: Overview of the general NGN Release 1 architecture (ETSI ES 282 001, 2005)

The NGN service layer consists of the following logical functional components.

- Service and Call Control Functions: These functions include a subset of the 3GPP IMS as the NGN's SIP-based session control architecture.
- User Profiles: Collection of data required for network access authorisation, and access network configuration on a per-user basis.
- Applications: Containing e.g. SIP application servers, this component is essential for the provision of value added services to the respective NGN.

The following logical functional components are contained within the NGN transport layer.

- NASS (Network Attachment Subsystem): This subsystem provides IP addresses and other terminal and access network configuration parameters to the respective entities. Also authorisation and, at the IP layer, authentication functionality is performed by the NASS, based on the user profiles.
- RACS (Resource and Admission Control Subsystem): This subsystem is responsible for the admission and gate control in the NGN transport system. This also includes the IP transport priority marking and NAPT control (Network Address and Port Translation). Operator specific policy rules, available and desired network resources (such as bandwidth) and the user profiles are taken into account by this logical component. The RACS is the most important logical network element for the interaction between the service layer and the transfer functions for resource control and QoS support within the respective NGN.
- Transfer functions: Transfer functions in terms of a standardised NGN Release 1 cover those functions of the underlying transport network that are visible and accessable by other components of the respective NGN. Simplified spoken, IP routers or L2 switches that can be manipulated by RACS for the reason of QoS

control within the IP transport network are part of the respective NGN’s transfer functions.
The IP transport network components contained within the transfer functions support IP QoS mechanisms such as IntServ/RSVP and DiffServ.
Also, for the interconnection with other telecommunication networks (both, NGN or non-NGN), gateways and session border controllers belong to the NGN transfer functions.

Both, user equipments (shown leftmost within figure 1) and other networks (shown rightmost) can be connected to certain interfaces of an NGN. The user equipment (e.g., a SIP endsystem) is connected to an interface (e.g., a DSL-based access network (Digital Subscriber Line)) of the respective NGN’s transfer functions. Sending IP packets over this interface, the user equipment uses SIP to communicate with the NGN’s Service and Call Control Functions (e.g., to setup media sessions to other user’s end systems). Performing certain actions (e.g., sending a SIP request to a specific SIP URI or sending a SIP instant message with a specific content), a subscriber can use applications (e.g., a value added service) provided within the respective NGN.

Other networks, e.g., another provider’s NGN or any other telecommunication network such as an ISDN (Integrated Services Digital Network) also have to be connected to the transfer functions, the service and call control functions and the applications to enable full interconnection functionality. If applicable, gateways must be applied (e.g., IP/PSTN gateways for both, media and signalling interconnection) to allow the connection of non-NGN networks.

2.2 NGN QoS and resource control functionality

In general, three different NGN QoS control scenarios can be distinguished (ETSI TS 185 001, 2005). The application of a specific scenario, amongst others, depends on the QoS signalling capabilities of the respective user equipment that initialises a session requiring certain QoS conditions within the respective NGN’s transport network.

For clarity, no protocol details, message responses or acknowledgements are displayed in the respective figures. Only the primary QoS signalling message ways are described. The necessary signalling for the release of resources after a session termination is not accounted. Furthermore, the interworking with other networks and the resulting inter-domain QoS signalling ways have not been considered within this paper for the purpose of simplification.

Both, the reservation and the release of resources within the IP transport network come along with a certain volume of signalling traffic, which has to be counted on a per-session basis. I.e., both, the reservation and the release of network resources have to be signalled for every session that is going to be established within the NGN.

In real-life NGN, the reservation and the release of resources have to be signalled by the RACS not just to one network element within the transfer functions’ block but to all network elements of the IP transport network that are part of the respective resource path and, at the same time, have to be kept informed about QoS conditions for the respective call.

2.2.1 Senario 1

This scenario can be applied if the user equipment initialising the respective session has no QoS capabilities at all. Figure 2 shows the principal of this scenario.

A user equipment without specific QoS signalling capabilities requests a service (e.g., the initiation of a voice session) by sending a SIP service request (step 1.) to the service and control functions of the NGN it is connected to. The service and control functions identify the required resource conditions (e.g., a certain minimum bandwidth provided) for the respective service and, in step 2., send a resource request to the RACS. The RACS might authorise the subscriber to use a specific amount of resources (depending on the subscriber's user policy) and check whether the requested resources are available within the NGN's transport network. If the resource request can be fulfilled, the RACS triggers the resource reservation (step 3.) in the transfer functions of the respective NGN's IP transport network.

This scenario is also called the push model because the resource allocation is pushed from the top (service and call control functions) via the RACS down to the transfer functions.

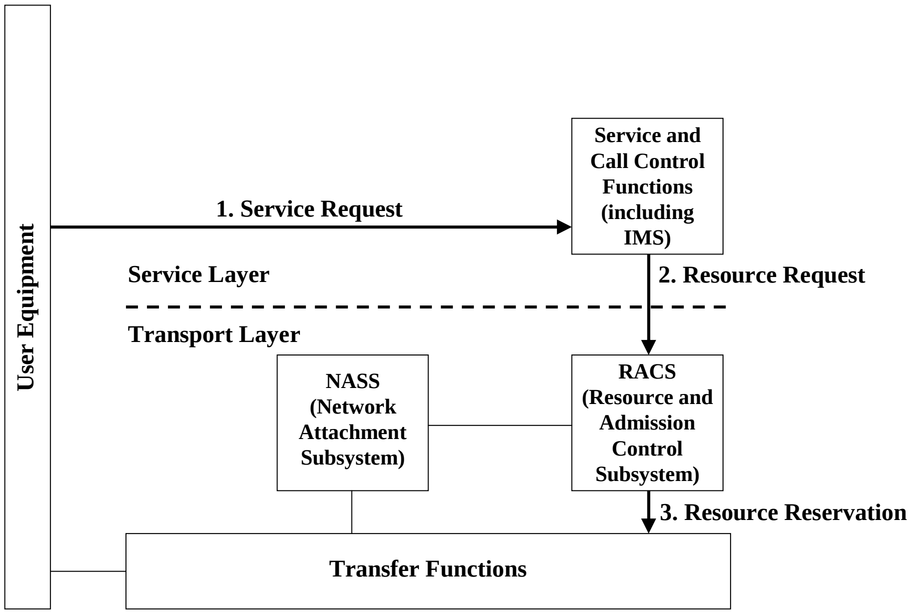

Figure 2: NGN QoS and resource control scenario 1 (ETSI TS 185 001, 2005)

2.2.2 Scenario 2

The application of scenario 2 assumes that the respective user equipment has certain QoS signalling and managing capabilities (i.e., the user equipment can make use of IntServ/RSVP). It is also assumed that the resources demanded by the user equipment have to be authorised by the service and call control functions before the allocation of resources in the IP transport network can be applied. Figure 3 shows the principal of this scenario.

A user equipment supporting layer 3 QoS signalling capabilities (such as RSVP) requests a service by sending a SIP service request (step 1.) to the service and control functions of the NGN it is connected to. The service and control functions identify the required resource conditions for the respective service and may relay an associated authorisation token to the user equipment. Also, the service and call control functions initiate the policy enforcement within the RACS (step 2.).

The user equipment starts layer 3 QoS signalling (e.g., by sending RSVP messages, step 3.) and, within the signalling, turns the before given authorisation token to the NGN's transfer functions. The responsible subsystem of the transfer functions requests QoS authorisation at the RACS (step 4.) based on the authorisation token information. If the resource request can be granted, the RACS triggers the resource reservation (step 5.) in the transfer functions of the respective NGN's IP transport network.

This scenario can be referred to as the push-pull model, because the resource allocation is first pushed from the top (service and call control functions) down to the RACS and, from there, is pulled down by the respective NGN's transfer functions after the authorisation token has been sent by the user equipment within QoS signalling.

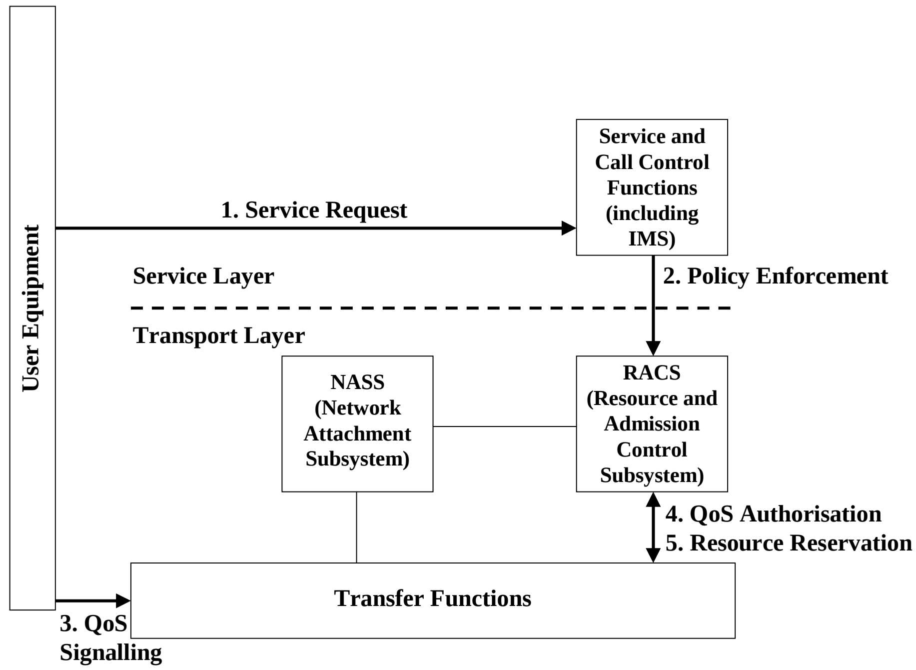

Figure 3: NGN QoS and resource control scenario 2 (ETSI TS 185 001, 2005)

2.2.3 Scenario 3

The application of this scenario assumes that the respective user equipment has QoS signalling and managing capabilities (i.e., the user equipment can make use of IntServ/RSVP).

It is also assumed that the resources demanded by the user equipment do not have to be authorised by the service and call control functions before the allocation of resources in the IP transport network can be applied. Figure 4 shows the principal of this scenario.

The user equipment starts layer 3 QoS signalling (e.g., by sending RSVP messages, step 1.). The responsible subsystem of the transfer functions requests QoS authorisation at the RACS (step 2.) based on information given within the QoS signalling. If the resource request can be granted, the RACS triggers the resource reservation in the transfer functions of the respective NGN's IP transport network (step 3.).

This scenario is also referred to as the pull model, because the permission to allocate the resources requested by the user equipment is pulled down by the respective NGN's transfer functions from the RACS.

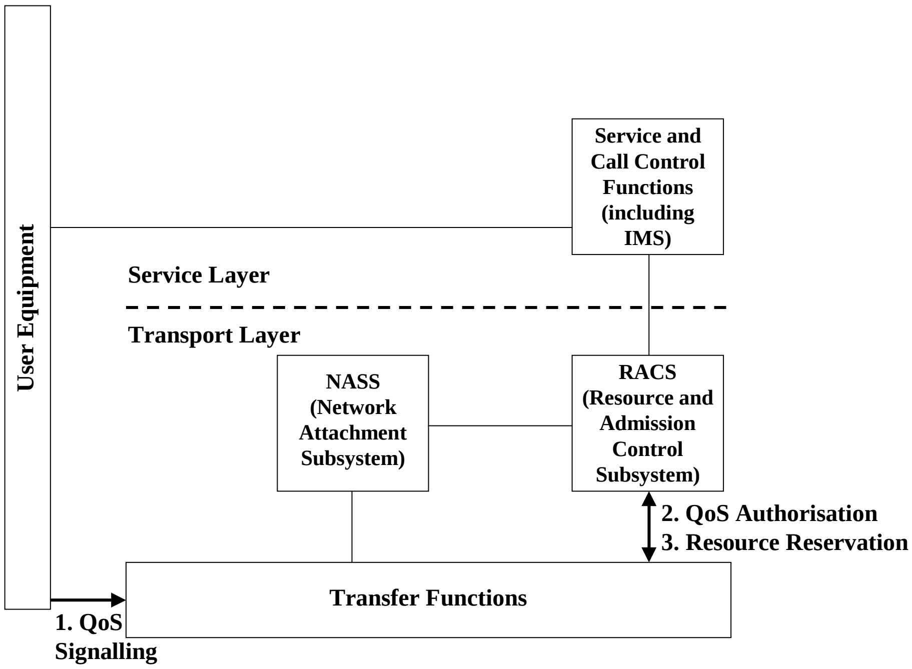

Figure 4: NGN QoS and resource control scenario 3 (ETSI TS 185 001, 2005)

2.3 Deficiencies of the standardised NGN QoS approach

The standardised solutions for resource and QoS control in NGN explained in Chapter 2.2 show significant deficiencies. They all come along with a high volume of additional traffic for the authorisation, allocation and reservation, and – after call termination – the release of network resources for each call. Assuming a large carrier NGN, these approaches to provide per-session QoS lead to a huge amount of resource management traffic that comes along with session signalling and user data traffic.

The more media sessions have to be established simultaneously, the less resources are available (because new resources have to be reserved for each media session in order to fulfil its respective QoS requirement). I.e., resources should be saved, especially in the busy hour. But this situation leads to even more traffic which is produced by the resource control mechanism, reserving and releasing resources.

The shorter the average duration of a media session is, the more sessions could be served by the IP transport network within a certain period of time. I.e., from a workload point of view, the network could be used more efficiently because resources are occupied for a shorter period of time (and, therefore, are sooner available for the next session). But this situation

also leads to even more traffic which is produced by the resource control mechanism, reserving and releasing resources.
The resource management traffic is not efficiently controllable by the respective NGN's provider because it does not only depend on the number of end users and the number of network elements involved in the resource reservation process but also on the subscribers' session behaviour (e.g., the number of session requests per time per user, and the average duration of each session). The NGN resource and QoS management concept standardised in (ETSI TS 185 001, 2005) does not scale and does not work efficiently.

Furthermore, inter-domain QoS negotiation is not sufficiently considered.

3. Related research work

Past and current international research activities with a main focus on the provision and management of QoS in IP networks show different approaches. However, none of these approaches covers all significant aspects of end-to-end QoS provision in NGN-based telecommunication networks, especially relating to efficient QoS management and control in both, IP core and access networks.

The following chapters give an overview of the most related research work.

3.1 Related research projects

The EuQoS research project (EuQoS Project Web Site, 2006) currently designs a complex, multi protocol-based end-to-end QoS concept for heterogeneous networks. Amongst others, this concept assumes that user end systems need specific QoS signalling capabilities (Rao, 2005) which might not be applicable for all NGN scenarios. Furthermore EuQoS aims on a concept for self-adaptive inter-domain edge routing to provide QoS for inter-domain sessions (Yannuzzi, 2004) but does not explicitly deal with QoS provisioning in IP core networks of the respective domains.

The NETQOS project (NETQOS Project Web Site, 2007), amongst others, focuses on policy-based network management, and discrete and transparent policy adaption to service providers, services, users, and applications. Network monitoring as a way to trigger QoS adaption is taken into account, but relevant protocols (such as SIP), communication models (such as client-server-based communication), and network infrastructures (such as NGN) are not explicitly considered. This project's approach aims on the public Internet, and, therefore, does not consider standardised NGN. Inter-domain policy and QoS negotiation are not explicitly taken into account (Avallone, 2006).

The MUSE project (MUSE Project Web Site, 2006) explicitly aims on the ETSI TISPAN NGN Release 1 standards with IMS integration. Although the standardised NGN QoS and resource control management architecture is taken into account, QoS provision is only considered for those transfer functions located between access and home IP transport network. The core network of the respective NGN is not considered (Vidal *et al.* 2006) (Vidal *et al.* 2007).

In the ENTHRONE project (ENTHRONE Project Web Site, 2004) the main focus is on the provision of QoS for multimedia streams on basis of the MPEG-21 multimedia framework

(Moving Picture Experts Group-21) (ENTHRONE Deliverable D23i, 2004) (ENTHRONE Deliverable D24i, 2004). Hence the ENTHRONE approach does not cover well-established multimedia session negotiation mechanisms such as SIP/SDP call signalling and media description (Session Description Protocol) (IETF Liaison Statement Web Site, 2005).

Also the KING research project's QoS approach (KING Project Web Site at Fraunhofer, 2004) deals with an intelligent QoS management for edge networks but, at the same time, assumes that IP core networks do not support any reliable QoS mechanism (Schrodi, 2002) (Hoogendoorn, 2005).

The MESCAL research project (MESCAL Project Web Site, 2005) explicitly deals with inter-domain QoS provision for the internet (Morand *et al.* 2005) and so does not consider QoS-relating NGN-specific architectures and hierarchies (e.g., the use of service control entities such as call servers).

3.2 Other related research work

(Cho *et al.* 2006) introduce an architecture for SIP-based QoS support and session management. The architecture combines both, DiffServ and IntServ as a hybrid approach which leads to a scalable infrastructure. Although the architecture generally works with standard SIP end systems, full functionality is only given if end systems are used that are aware of a special, not standardised SIP extension (Q-SIP; Salsano and Veltri, 2002). Also the SIP server infrastructure must support Q-SIP.

(Mani and Crespi, 2005) define a new mechanism for QoS control within heterogenous wireless/wireline networks, based on UMTS core networks. Therefore, additional SIP-aware network elements have to be integrated into the respective network to allow the access networks' capacity to be taken into account in SIP session initiation. SIP User Agents are enabled to express more detailed QoS requirements that can be easily mapped to UMTS QoS classes. NGN standards are not explicitly taken into account and Q-SIP has to be supported.

4. New requirements

As a result of the state of the art overview given in chapters 2 und 3, the following requirements can be named.

- The reservation of media resource paths within SIP-based NGN on a per-session basis to provide QoS to the subscriber is not efficient in terms of scalability and saving of resources. Therefore, functions and mechanisms have to be found that lead to a trustworthy QoS for each built-up session and, at the same time, do not occupy resources on a per-session basis themselves.
- For the optimisation of QoS control and management in SIP-based NGN, efficient and adaptive functions should be applied to the whole IP transport network, i.e., not only to access and edge networks but also to the core network. Also, inter-domain QoS negotiation should be considered.
- Simple and resource saving resource control and resource management approaches should be preferred over complex approaches that lead to increased volume of QoS signalling and resource management traffic. If possible, approaches should

rely on standardised protocols (such as SIP (Rosenberg *et al.* 2002)) and architectures (such as NGN (ETSI ES 282 001, 2005)).
- Both, session-based multimedia services and non-session-based services (such as email and internet access) should be accessible within the same network. I.e., the respective NGN's resource control has to be aware of a certain amount of traffic that is not session-based, and therefore, can not be rated by observing the respective network's session control functions.

One approach for the optimisation of the QoS management in SIP-based NGN could be based on the use of virtual data pipes ("virtual resource trunks") with defined bandwidths and defined QoS parameter values. These pipes can be virtually spanned upon each specific IP communication path (e.g., on an IP path between two or more routers within a NGN IP core network or between edge routers of different NGN to provide interconnect sessions (see figure 5)).

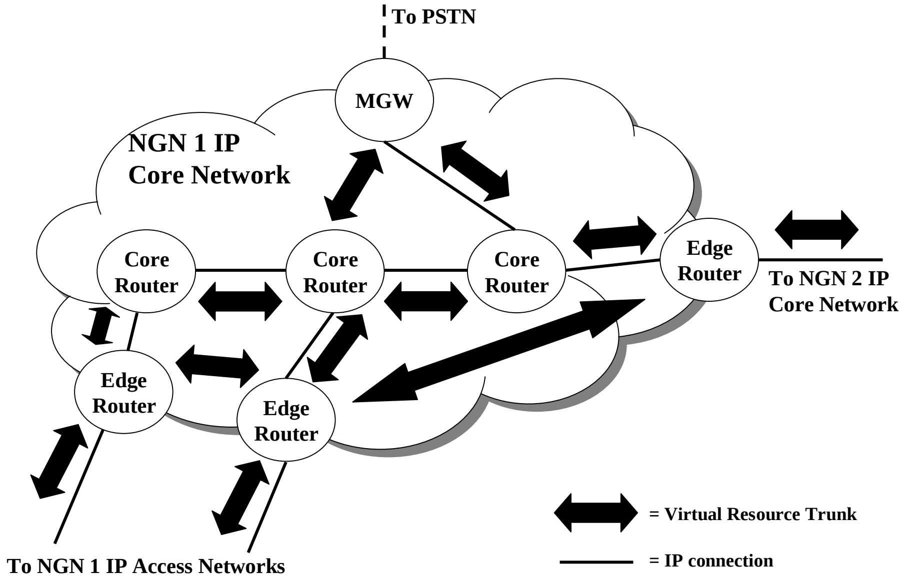

Figure 5: Reliable data pipes within an NGN IP transport network

The management of data pipes does not necessarily lead to any resource management traffic at all because these data pipes even might only exist virtually. Network elements that build the borders of a virtual data pipe do not even necessarily be aware of this function.

The total bandwidth provided by a data pipe is to be shared among all media sessions that use resources of this path. If a new session requires resources on a specific IP communication path, it shares the resources provided by the data pipe which is already set up on this path. Hence, no signalling for the allocation, reservation, and release of network resources is necessary in a per-session manner since resources required by several upcoming sessions using a communication path are already virtually reserved for one data pipe.

A virtual data pipe is not necessarily limited to one direct IP connection between two IP network elements (such as two connected IP routers) but may be spanned upon a combination of several IP communication paths that include more than two routing elements (see figure 5).

The utilisation of reliable data pipes has to be observed and controlled by a suitable resource management function. This function has to observe and/or calculate the remaining bandwidth on every virtual data pipe and perhaps, in effect, has to repartition the total amount of available bandwidth between different data pipes that share the same IP communication paths.

Media session signalling data available within the service and call control functions of the respective NGN should also be taken into account for the calculation.

The dimensioning of reliable data pipes should be established by the use of predictable values such as traffic profiles and formerly observed end user behaviour. The respective NGN infrastructure's QoS and resource control plane should be responsible for the arrangement and assignment of the data pipes in the IP transport network and for the administration of the data pipes' resource capacities. The same approach should also be applied for the inter-connection of different provider's NGN (inter-domain QoS control).

The appliance of this approach would lead to significant enhancement of network efficiency since no per-session signalling for the allocation, reservation, and release of network resources was necessary.

The research and development of mechanisms and algorithms for the appliance of virtual data pipes, and the work-out and adoption of the data pipe concept within IP networks are for further study.

5. Conclusion and outlook

This paper presents new requirements to the QoS management in SIP-based NGN. These requirements are derived from the state of the art reflexion of both, standardisation and research work collected within this paper. Especially the principle of resource reservation within NGN transport networks in a per-session manner is concerned by these requirements. The new concept of the application of virtual data pipes is introduced and outlined. The ongoing research work is focussed on the definition and development of mechanisms and algorithms for the appliance of virtual data pipes, and the work-out and adoption of the data pipe concept within SIP-based NGN.

6. References

3GPP TS 23.228 V5.15.0 (2006), Technical Specification, "IP Multimedia Subsystem (IMS); Stage 2 (Release 5)", 3GPP

3GPP TS 24.228 V5.15.0 (2006), Technical Specification, "Signalling flows for the IP multimedia call control based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 (Release 5)", 3GPP

Avallone, S., Di Gennaro, P., Miloucheva, I., Rao, S., and Roth, M. (2006), "NETQOS: Policy Based Management of Heterogeneous Networks for Guaranteed QoS", IFIP Networking, Coimbra, Portugal

Camarillo, G., Marshall, W. and Rosenberg, J. (2002), RFC 3312, "Integration of Resource Management and SIP", IETF

Cho, E., Shin, K. and Yoo, S. (2006), "SIP-based Qos support architecture and session management in a combined IntServ and DiffServ networks", *Internet Communications Security, 2006*, Vol. 29, No. 15, pp. 2996-3009

ENTHRONE Deliverable D23i (2004), "End-to-end QoS Signalling & Policy-based Management Architectures", ENTHRONE consortium

ENTHRONE Deliverable D24i (2004), "Specification of protocols, algorithm, and components, the architecture, and design of SLS Management", ENTHRONE consortium

ENTHRONE Project Web Site (2004), "Enthrone Web Site", http://www.ist-enthrone.org, (Accessed 16 April 2007)

ETSI ES 282 001 V1.1.1 (2005), ETSI Standard, “NGN Functional Architecture Release 1”, ETSI TISPAN

ETSI TR 180 001 V1.1.1 (2006), Technical Report, “NGN Release 1; Release definition”, ETSI TISPAN

ETSI TS 185 001 V1.1.1 (2005), Technical Specification, “Next Generation Network (NGN); Quality of Service (QoS) Framework and Requirements”, ETSI TISPAN

EuQoS Project Web Site (2006), “Home - EuQoS - End-to-end Quality of Service support over heterogeneous networks”, http://www.euqos.eu, (Accessed 16 April 2007)

Hoogendoorn, C. (2005), “The KING Research Project – Overview”, 5. Würzburger Workshop IP-Netzmanagement, Netzplanung und Optimierung

IETF Liaison Statement Web Site (2005), “Liaison Statement Detail”, *Response to Liaison Statement SC 29 N 6689*, https://datatracker.ietf.org/public/liaison_detail.cgi?detail_id=149, (Accessed 16 April 2007)

KING Project Web Site at Fraunhofer (2004), “KING”, http://www.fokus.fraunhofer.de/bereichsseiten/projekte/KING_MOBIS/index.php?lang=en, (Accessed 16 April 2007)

Mani, M. and Crespi, N. (2005), “New QoS Control Mechanism Based on Extension to SIP for Access to UMTS Core Network over Hybrid Access Networks”, *IEEE Wireless and Mobile Computing, Networking and Communications*, WiMob 2005, Vol. 2, pp. 150-157, Montreal Canada

MESCAL Project Web Site (2005), “IST MESCAL project: Interdomain QoS for the Internet”, http://www.ist-mescal.org, (Accessed 16 April 2007)

Morand, P., Boucadair, M., Coadic, T., Levis, P., Egan, R., Asgari, H., Griffin, D., Griem, J., Spencer, J., Howarth, M., Wang, N., Georgoulas, S., Ho, K. H., Flegkas, P., Trimintzios, P., Pavlou, G., Georgatsos, P., Mykoniati, E., Liabotis, I. and Damilatis, T. (2005), “D1.3 – Final specification of protocols and algorithms for inter-domain SLS management and traffic engineering for QoS-based IP service delivery”, MESCAL consortium

MUSE Project Web Site (2006), “Multi Service Access Everywhere (MUSE)”, http://www.ist-muse.org, (Accessed 16 April 2007)

NETQOS Project Web Site (2007), “Netqos”, http://www.netqos.eu, (Accessed 16 April 2007)

Rao, S. (2005), “QoS in the access networks: present status and current research activities”, OBAN workshop Dresden

Rosenberg, J., Schulzrinne, H., Camarillo, G., Johnston, A., Peterson, J., Sparks, R., Handley, M. and Schooler, E. (2002), RFC 3261, “SIP: Session Initiation Protocol”, IETF

Salsano, S., Veltri, L. (2002), “QoS Control by Means of COPS to Support SIP-Based Applications”, IEEE Network, 2002

Schrodi, K. J. (2002), “High Speed Networks for Carriers”, *Lecture Notes in Computer Science (LNCS)*, Vol. 2334, pp229-242

Trick, U. and Weber, F. (2007), *SIP, TCP/IP und Telekommunikationsnetze*, Oldenbourg, Munich, Germany

Vidal, I., García, J., Valera, F., Soto, I. and Azcorra, A. (2006), “Adaptive Quality of Service Management for Next Generation Residential Gateways”, 9th IFIP/IEEE International Conference on Management of Multimedia and Mobile Networks and Services (MMNS 2006), Dublin, Ireland

Vidal, I., García, J., Valera, F., Soto, I. and Azcorra, A. (2007), “Integration of a QoS aware end user network within the TISPAN NGN solutions”, IEEE 4th European Conference on Universal Multiservice Networks (ECUMN'2007), Toulouse, France

Yannuzzi, M. (2004), “Towards Self-Adaptive Inter-Domain Edge Routing”, Proceedings IEEE Infocom Student Workshop

Proc. of SEIN 2007, Uni Plymouth, p 201-214, June 2007