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A Strategy for Harmonised QoS Manipulation in Heterogeneous IMS Networks

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Abstract Heterogeneous networks are collections of communication platforms utilising different protocols. Heterogeneity was born by the need of operators to offer within short time many different services on the market. As a result, nowadays users communicate through collections of networks utilising different protocols, rendering service mapping from one network to another a complex issue. With the emergence of IMS and the introduction of IP and SIP protocols as a means for achieving network homogeneity, service interoperability has become even more important. With regard to this problem, the paper proposes a method for homogenising IMS networks with regard to the utilised QoS settings and charging policy. The paper explains how the method can be applied on real IMS networks for the preservation of QoS and charging records across the whole communication path and carries out a comparative analysis with performance figures obtained in real networks.

Keywords IMS · QoS management · WLAN · UMTS · Converged communications · SIP · SDP

1 Introduction

The need for lending QoS a higher granularity was first obviated in mobile communications networks, where services consisting of multimedia components (voice, video, etc.) rather

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than simple voice, were put into play. Before that, QoS was solely used for setting up links of much lower quality, suitable for voice communications. With the proliferation of multimedia communications and the introduction of the converged communication concept, with the Internet Protocol having the role of the link homogenisation protocol, the need for having higher granularity QoS was also born for the fixed networks. Nevertheless, applying QoS on fixed networks is not an easy issue as specificities exist in the underlying networks. Signalling protocols and the bandwidth capacity of the data path are the most usual discriminating factors that cause discrepancies in QoS values. Rounding of QoS in such cases is inevitable. With regard to this problem our paper proposes a restoration mechanism of the original QoS values requested by the user, in case they undergo rounding as they propagate across a heterogeneous communication path towards the other end. In particular, the cumulative effect of such rounding on the communication quality, in the absence of a certain restoration mechanism, could be highly disruptive for the communication path and in many cases may cause communication breakdowns.

As IMS is by definition a single point of convergence for broadband services realisation that allows both traditional telecommunications and IP networks to be involved, it offers the frame for the realisation of multimedia calls practically in any network and on any terminal type. In IMS, homogenisation in communications over heterogeneous networks is achieved with the use of the SIP protocol for user operations management and the SDP protocol [1] for session description. By employing these protocols, IMS becomes decoupled from the protocols under IP [2] and offers mechanisms for user sessions mapping between networks supporting different QoS capabilities.

Due to this advantage, it is expected that in the near future, IMS will be become the main technology for delivering rich-content multimedia communications through ubiquitous networking usage scenarios, also exhibiting seamless mobility and single sign-on service experience. However, before it is commercially launched, a number of hindering issues should be resolved.

The most stringent of them relate to the uniform exploitation of the requested service across multi-operator networks. For example, when a mobile user makes a call towards a fixed or wireless user, the network is forced to create a communication path traversing various heterogeneous technology networks. In IMS, set up of traverse paths is handled be the Proxy Call Service Control Function (P-CSCF), a component responsible for mapping the QoS classes of one network type to another. Taking into account the different QoS classes supported by mobile and wireless networks, it can be easily obviated the mismatch in mapping user calls from one network type onto the other with obvious consequence on communication quality. Since nowadays UMTS is the network technology with the most granular and well defined QoS classes, the tendency of concerned groups working on IMS standardisation is clearly towards matching the communication capability of fixed networks with the QoS classes of UMTS networks [3].

TISPAN [4], a technical body of ETSI, the ADSL forum [5] and the FGNGN group of ITU [6] work on the definition of QoS classes for fixed networks. Among them, the TISPAN NGN architecture aims at specifying a standardized set of QoS for service capabilities ranging from real time streaming to conversational services, while the ADSL forum has given focus on a "service" architecture for QoS enabled applications in DSL access networks. On top of these efforts, the ITU's Focus Group on Next Generation Networks (FGNGN) works on TISPAN's Resource and Admission Control Subsystem (RACS) with recommendations covering aspects of quality of service implementation in all fixed network types.

Yet, despite QoS harmonization efforts, still open is the issue of interfacing QoS parameters to the underlying network. According to the so-called "single sign-on" concept [7], users registered once on one access network should be allowed to freely roam into foreign cellular and wireless networks without suffering service interruptions. But, QoS mismatches attributed to the different link characteristics of underlying networks can cause rounding of original QoS values and service degradation. In addition, service charging should be made at flat basis and in accord with the charging scheme of the user. For example, UMTS implements charging schemes, spanning from prepaid to specific Service Logic Agreement (SLA) contracts, most of which are not applicable in fixed networks. It is therefore important to have mechanisms for calculating the utilization time of the networks involved in the call by specific user services and relate it to the utilization time of the user service. To implement service charging, IMS uses a Charging Collection Function (CCF), which gets Call Duration Records (CDR) from the CSCFs and records service utilization per network domain, across the whole path. However, implementation of charging on a per call basis is not possible as the IMS network has no means for associating the session type with the collected records of the CCF [8].

In this paper we attempt to give solutions to both problems of mapping QoS on heterogeneous networks and implementing service level charging independently of the underlying network. Particularly with regard to the first problem, our method proposes a restoration mechanism which can be deployed in heterogeneous networks to preserve the original QoS values of the user session and thus eliminate the cumulative effect of QoS rounding across the entire communication path.

The reminder of the paper is organized as follows. Initially we give a brief overview of the IMS architecture and its building elements. Next, we introduce the experimental platform on which we implemented the method for QoS and charging profile interworking, then we confirm the validity of our method with experimental results and finally we conclude our analysis by drawing up a methodology for applying this method in real IMS networks.

2 The IMS Architecture and its Major Components

For the standardisation bodies working on network convergence, IMS is deemed as the main technology for delivering broadband, rich-content applications to moving and fixed users, having as key characteristic the ability of hosting calls, involving terminals of diverged technology. In technical terms, this innovation will be realised in an all-IP environment, where transportation of user data is done uniformly for all packet networks, using the IP protocol.

In order to be able of servicing users of different access networks uniformly, IMS must have generic mechanisms for handling user requests (Fig. 1). IETF and 3GPP have solved this problem by concluding to a common SIP version that has been adopted for the implementation of signalling communication between the IMS components and the underlying networks. In IMS nomenclature, SIP servers and their proxies appear as CSCF entities with three basic variations; Proxy (P-CSCF), Servicing (S-CSCF) and Interrogating (I-CSCF). IMS networks can communicate with each other through the I-CSCF, service a call using the S-CSCF and perform resources allocation and Authentication, Authorization and Accounting (AAA) between access networks involved in user calls, using the P-CSCF.

Within SIP, IMS uses SDP to describe user sessions in terms of user-requested QoS and call type (e.g. multiparty, user/server, etc.). During call setup, the INVITE message being sent from the user towards the network is intercepted by the P-CSCF attached to the border gateway (e.g. the GGSN for 3G UMTS network) of the access network, which further routes it) and is sent to the S-CSCF. The S-CSCF uses the encapsulated SDP protocol to determine the QoS values and the call type the user has requested [9].

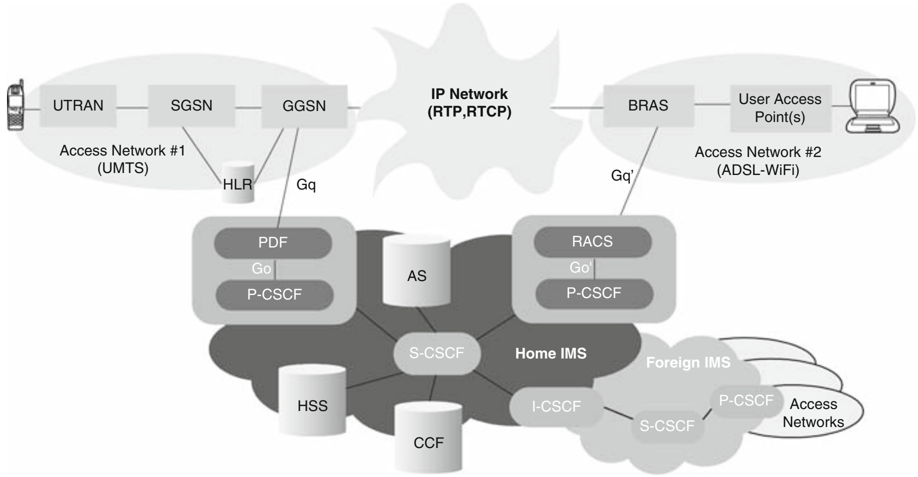

Fig. 1 General IMS architecture

Apart from the bandwidth requirement, SDP conveys important media information, such as, media type (video, audio, text, etc.), transport protocol type (RTP/UDP, etc) and media format type (MPEG-2, H.323, etc.). To represent those values [1] defines the following parameters:

v = *(protocol version)
o = *(owner/creator and session identifier).
s = *(session name)
i = * (session information)
c = * (connection information—not required if included in all media)
b = * (bandwidth information)
k = * (encryption key)
t = *(time the session is active)
a = * (zero or more media attribute lines)

The "a" parameter provides the means for extending the use of SDP in describing particular applications or media types with the amendment of extra session information.

Despite its name, SDP itself is a syntax for describing user sessions rather than a protocol. It is therefore conveyed in other protocols such as Session Announcement Protocol [10], Session Initiation Protocol, Real-Time Streaming Protocol [11], electronic mail using the MIME extensions, and the Hypertext Transport Protocol to communicate descriptions of user sessions between the network and the user.

In IMS networks, SDP is be used by SIP to convey the QoS class and timing parameters (time of request and grant) of the user session. As it is illustrated in the simplified network model of Fig. 2, during call setup, the user requested QoS class is applied on the border gateways, connecting the access networks and the backbone transport IP network by the S-CSCF, via dedicated mechanisms administered by the P-CSCF. The function of these mechanisms and their compatibility with the QoS capabilities of the underlying network dictate to much extend communication quality. As we point out in the following sections, our method captures the QoS and timing parameters conveyed in the SDP protocol to preserve their values, across the whole communication path and to allow restoration of original values whenever they undergone "rounding".

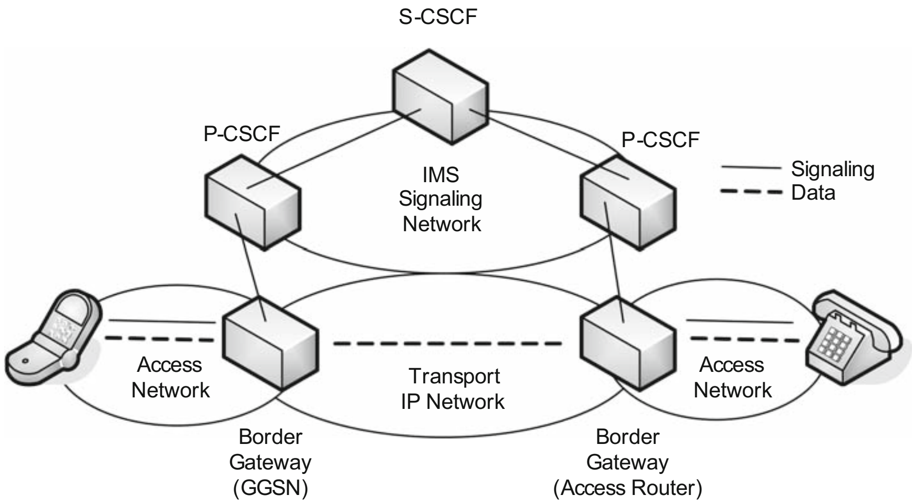

Fig. 2 Traffic flow in IMS networks

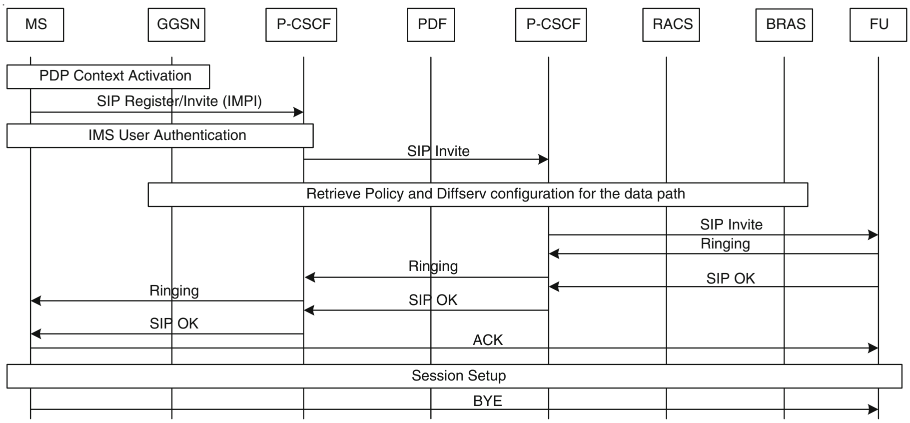

Fig. 3 Message flow for call setup between a fixed and a mobile user

The detailed process of establishing a call in IMS networks is analysed in the following paragraphs, taking as a representative example two different user types; a mobile and a fixed one. Since, as of this writing, the content of the SIP messages being used can be different in different implementations [12], in our description we focus on the procedures rather than on the content of particular messages (Fig. 3).

Before any SIP message can be sent in the network, the user must establish a bearer between him and the access network. This bearer is established across the access network as a physical channel for the transportation of IP packets. In UMTS, this bearer setup procedure involves the so called Packet Data Protocol (PDP) context activation procedure, where the characteristics of the bearer are sent to the network as a PDP table, containing the link characteristics such as bandwidth, quality of service and upper protocol support.

After the PDP context activation procedure is accomplished, the path for sending messages towards the IMS network is established via the P-CSCF. To register in the IMS network, the Mobile Subscriber (MS) sends a SIP REGISTER message, containing his IP Multimedia Personal Identity (IMPI). If the user is already registered and his session has been interrupted as a result of his movement (e.g. a handover case) then the PDP activation can be followed by a SIP INVITE message. On reception of the SIP REGISTER message, the P-CSCF authenticates the user in the network, while when it receives a SIP INVITE message, P-CSCF performs resources reservation in the data path. During the later procedure, the calling P-CSCF forwards the SIP message towards the called P-CSCF. At this point the called P-CSCF uses the values contained in the INVITE message to establish the resources of the data path and then alerts the Fixed User (FU). As a final step towards data path establishment, all P-CSCF involved across the path must enforce the QoS values on link.

Reservation of the QoS values requested by the user means that the PDF and RACS have established a data path, which can cope with the delay and the jitter requirements of the requested service. As a result, the FU is informed by the called P-CSCF that is being called with a SIP INVITE message, whereas his terminal responds with a SIP RINGING message propagated back to the calling user, indicating that the path with the called party is established. When the called party answers the phone, a SIP OK message is sent to the calling MS, triggering a SIP ACK response that signals successful setup of the data connection. Finally, call ends up when either party hangs up the phone, causing the terminal to send a SIP BYE message to other party.

Although in the 7th release of UMTS, 3GPP defines adequate mechanisms on the PDF for resource admission control, the same does apply for RACS. Though in UMTS networks, the GGSN is responsible for UMTS-to-IP QoS mapping, not all of the six UMTS classes can be mapped on IP ones, and the inevitable rounding of QoS values causes distortion in the quality of communication. Furthermore, recent studies [13] have shown that many multimedia applications can be better serviced in IP networks if their audio and data components are routed on more than one bearers.

In particular, packet losses caused by increased handoff delay can be mitigated through the implementation of soft handoff techniques where data packets are routed through more than one network routes, while at the receiving side, duplicated packets are filtered out. In [13] it is shown that such technique is capable of eliminating the problem of increased handover delay at the expense of high end-to-end delay jitter, which, on the other hand, can be tolerated by multimedia applications.

If such considerations are to be taken into account in real communication platforms, where high network heterogeneity requires frequent traffic mapping from one QoS type to another, the necessity of establishing a mechanism for original QoS values retrieval along the whole communication path can be obviated. With such a mechanism rounding of QoS values will be limited only to those parts of the communication path where QoS rounding cannot be avoided, whereas applications requesting splitting of traffic will be performed without the risk of losing track of the original characteristics of the session.

Also, associated with the function of PDF and RACS, is the need for uniform charging. Currently, IMS performs charging in a completely decoupled way, having its own mechanisms for collecting users' CDRs and performing Authentication and billing. Particularly, in the IMS version of 3GPP, the CCF interacts with the S-CSCF and P-CSCF to charge the user at application and network level, getting the charging data from both the session description contained in SDP and the CDRs collected on GGSN. Though the mechanism works in UMTS networks, it proves inadequate to service mixed calls involving fixed or wireless networks. Because of the different charging schemes applied on the different access networks, in a mixed call the IMS network would have failed to retrieve the charging parameters of the fuser when, for example, the later was calling from a fixed network. In addition, tariffing

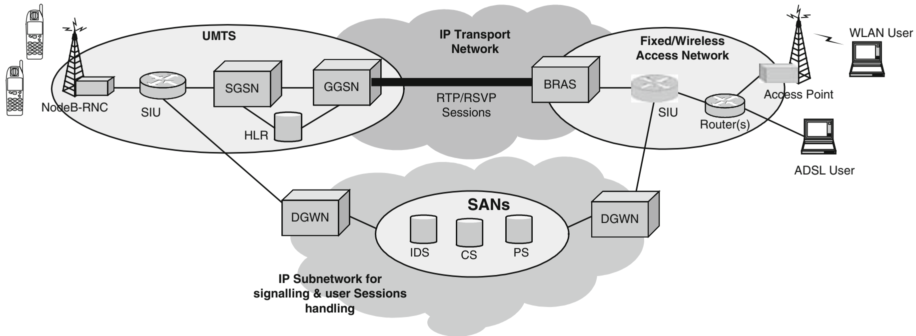

Fig. 4 Experimental platform; The proposed solution for QoS values interworking

of roaming users would have been also impossible. The network architecture we present in the following sections aims at offering solutions to both problems of QoS restoration and accurate charging.

3 The Experimental Platform

In order to experiment on ways of mapping user QoS values across heterogeneous networks, we setup the platform configuration depicted in Fig. 4 [14]. The platform is composed of two access networks, a UMTS and a broadband IP, encompassing wireless and wired (ADSL) access interfaces, which are connected together via the public packet network (Internet).

In our example the two access networks are complemented by a sub-network comprising an interworking unit (Data GateWay Node-DGWN) and a collection of databases (IDentity Server-IDS, CDR Server-CS and Profile Server-PS) placed behind a Storage Area Network (SAN) infrastructure.

Interworking of the sub-network with the two access networks was implemented via a Signalling Interworking Unit (SIU). We connected the SIU on the interface (IuPS) connecting the UTRAN and the SGSN nodes of the UMTS network and on the interface of the local routers with the access gateway (BRAS) in the broadband IP network.

Under this configuration the main task of the SIU was to intercept the signalling traffic exchanged between the user and the network, such as, mobility management (handover, location and routing updates, etc.), authentication and service (de)-activation messages. In the event of such messages, SIU extracts the enclosed parameters, estimates whether the concerned procedure the message belongs to needs handling from the sub-network and if yes proceeds with sending the corresponding parameters, along with the user identity (i.e. the IMSI in the case of a UMTS user) and a management operation code, to the databases via the DGWN.

The three databases are designed to handle associations of the user identity (user ID) with active user sessions and the corresponding CDRs generated by the access network. These user ID-CDR associations can be one-to-one or one-to-many in cases of multi-party calls (e.g. videoconferencing).

Therefore the SIU can intercept and store in the sub-network, QoS and CDR values assigned to user sessions by the access network, so that they are available for other SIUs involved along the communication path. On the other communication end or at intermediate points, corresponding SIUs may retrieve this information, using as an index the identity of the calling user.

This way the original values of user data sessions can be maintained across the whole communication path, so as to be retrieved at points where data traffic undergoes QoS “rounding”. Since such operations mostly concern multi-operator communication environments, where the need of gaining access to private user data is protected by exclusive peer agreements between operators and service providers and therefore is strictly forbidden to the wider public, we selected SANs as the preferred technology for building the database infrastructure. SAN technology [15] ensures best performance in large-scale data aggregation applications, combined with data privacy and infrastructure scalability.

In its basic configuration, our platform was tested under the following reference communication scenario: A UMTS user was initially attached in the network. During message exchange with the SGSN, the attach message was intercepted by the SIU and a record was opened in the IDS database. When the attached user activates an application, a PDP context activation is sent towards the SGSN. This message conveys the QoS parameters (service ID, traffic rate and QoS class) and other characteristics (e.g. multiparty, client/server, etc.) of the user session to be applied on the data path. When the SGSN returns a PDP context activation response, the SIU creates an association between the IMSI of the user and the service ID of the service the user has activated in the PS, and initialises a corresponding CDR in the CS to use for keeping service utilisation time. At the other communication side, the corresponding SIU intercepts all arriving SIP messages and processes those that are marked by the called P-CSCF with the IP address of the called user. On reception of the corresponding INVITE message the SIU creates an end-to-end association between the called user ID, the original QoS values of the call, and those assigned by the local access network. The SIU maintains this association locally for the whole lifecycle of the call in order to retrieve session’s original characteristics, when the called user performs handover or roaming. Similarly, ID-local QoS values associations can be created, and maintained by every network involved in the call, in order to be used for retrieving the original QoS values, every time QoS undergoes “rounding” due to QoS mismatches among the networks involved in the call.

When the path is successfully established, the SIUs involved along the communication path initialise the corresponding CDRs, using the tariffing policy of the local network, thus enabling implementation of accurate charging.

To confirm validity of this method, in the following section we give some performance figures obtained on our platform, which, later on, we compare with the response times of a standard UMTS and fixed networks.

4 Numerical Results

The results we present in this section were obtained using custom-made measurement acquisition functions on the SIUs. These, were mainly recordings of time intervals, representing the response time of the sub-network to requests submitted by the SIU. In calculations, the delay introduced by the SIU, the DGWN and the Databases involved, was also taken into account. Thus, the following procedures were studied: Attach/Detach Procedures, PDP Context (De-)Activation Procedures, Network Roaming, User authentication.

4.1 Attach/Detach Procedures

During the Attach procedure a mobile terminal sends an Attach request to the UMTS network. Before sending a response, the network examines the user ID and performs authentication of the user and identity check.

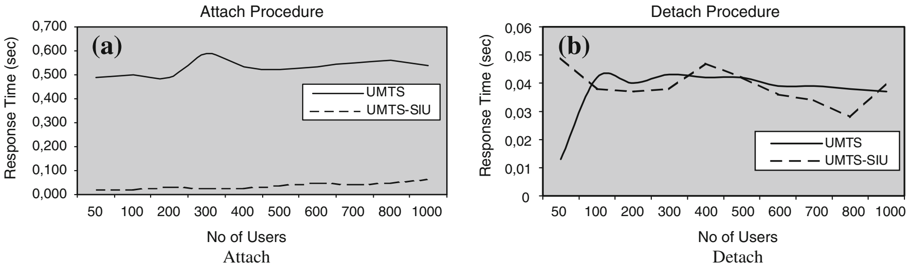

Fig. 5 Attach (**a**) and detach (**b**) procedures; Response times for UMTS and UMTS-SIU configurations

In our experiments, the SIU intercepts Attach requests and sends the contained IMSI to the databases of the sub-network in order to be used as an index to the sessions that will be created through subsequent PDP activation requests. It must be noted here that SIU does not interfere in the normal evolution of the UMTS procedures, meaning that the signalling messages are exchanged between the user and the network without to undergo any content modification. Thus, UMTS operations, such as user authentication, identity check and attach response are implemented according to the standards, leaving the UMTS network unaware of the procedures taking place on the sub-network. The performance results obtained for Attach/Detach operation are given in Fig. 5 for both the standalone UMTS and UMTS-SIU platform configurations.

During the Detach procedure, the MS or the network itself sends a Detach request towards the other end. The SIU intercepts the message, retrieves the IMSI of the given user and deletes all corresponding associations in the databases. If by the time of Detach, there are open data sessions, the SIU deletes their associations with the user IMSI and updates the corresponding CDRs.

4.2 PDP Context (De-)Activation Procedures

During PDP context activation, the SIU intercepts the corresponding request message and associates it with the IMSI of the concerned user, using the Source Local Register (SLR) and the Destination Local Register (DLR) parameters encapsulated in the corresponding DT1 SCCP message [16]. These two parameters are unique identifiers, assigned by the network to the signalling bearers of the user, following the successful completion of the attach procedure. Each mobile user has one signalling bearer established between the RNC and the SGSN to use for the exchange of signalling information, with the network. Therefore, the same bearer is used for all active PDP activations/de-activations. In addition, apart from the SLR and DLR parameters, SIU also interprets the Transaction Identifier (TI), a parameter that serves as an index to the active PDP contexts, their particular QoS settings, and the destination IP address of the called party(-ies).

As in the case of the Attach procedure, also in this process the SIU has a passive role, allowing it to intercept messages being exchanged on the IuPS interface without interfering with the operations of the access network. This way, a successful PDP context response is sent to the user from SGSN, forces the SIU to create an association between the granted by the network QoS parameters and the IMSI of the user in the IDS and PS databases and initialises a corresponding CDR in the CS database, based on the charging policy contained in the profile of the user. Quantitative estimations of the duration of these operations are given in Fig. 6a, for both configurations.

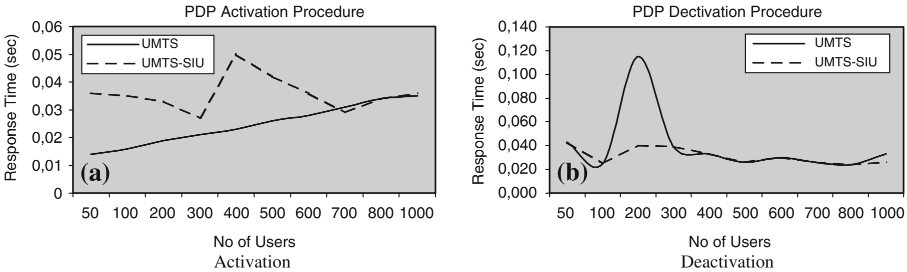

Fig. 6 PDP context activation (**a**) and de-activation (**b**); Response times for UMTS and UMTS-SIU configurations

During the PDP context de-activation, the SIU looks up the open sessions of the user in the IDS, using the SLR/DLR as an index to the signalling bearer of the user and the TI as an index to the session that must be de-activated. Having retrieved the QoS/CDR pair that corresponds to requested session, the SIU waits for the SGSN to answer the request. If the PDP context deactivation response has a successful indication, the SIU deletes the retrieved QoS/CDR pair and its association with the IMSI in the IDS and CS databases and adds the value of CDR to the overall CDR value maintained by the system for the given user. The response times of the PDP activation/de-activation procedure obtained with our solution are depicted in Fig. 6b.

4.3 Network Roaming

Roaming occurs when a mobile/wireless subscriber moves into an area covered by a foreign network. In that case the communication capability is offered by the foreign network operator and call charging is applied based on peer agreements between network operators. In IMS, network roaming is an important procedure because due to the diversity of supported services, roaming may happen on a frequent basis, posing the requirement for seamless traffic interworking and accurate billing. To fulfil such requirement, networks must have adequate mechanisms for getting accurate information about the service the user has originally asked and the charging profile the home network applies for him for the given service.

To experiment on our method, we set up a platform configuration that differed slightly from the network architecture depicted in Fig. 4, in that the radio part of the UMTS access network was split into two different radio areas, which were configured in such as way so as to become identified by the core network as two different network coverage areas.

During the roaming procedure, the SIU of the visited network intercepts an Attach request message being sent to the network from the new location area as a result of user roaming. Before creating an association in the IDS database, the SIU asks the local DGWN to interrogate the attached access network as to whether the IMSI of that user belongs to the local registry or is a foreign one. In the former case it performs the steps described in the previous sections, while in the latter case, it finds out the foreign network's DGWN the user belongs to, by looking up the local DGWN directory. Then, the DGWN submits a request towards the home network of the user to get his profile and the QoS/CDR pairs of his active sessions. The home network is informed about the user's move and changes its charging policy according to the peer agreement that is in force with the given foreign network operator (Fig. 7). On the other hand, the foreign network creates an association in the local IDS and CS databases, following the steps discussed in the attached procedure.

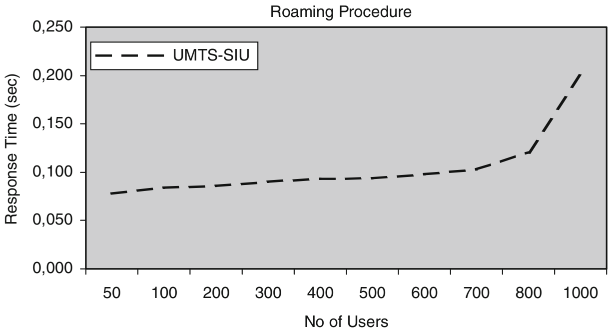

Fig. 7 Response times for user roaming

In a consequent PDP context or service activation request, the foreign network will serve the user by using the authentication policy stored in his profile and will update his QoS/CDR associations stored in the local IDS and ICS databases accordingly, following the steps discussed in previous section.

When the user leaves the foreign network, the foreign network returns the QoS/CDR pair to the home network of the user in order to be considered in the calculation of service charging. As a final action, the foreign network cleans up any records that have been created in the local databases, using as an index the IMSI of the foreign user.

As performance results indicate, the values achieved with the UMTS-SIU configuration (Fig. 7) are by far better from those obtained in commercial networks, where roaming can be accomplished within 4–10 s [14].

In the graphical plots depicted in Figs. 4–7, the response time that appears to be reaching its maximum values as the number of users submitting requests to the network increases, is a known phenomenon which is attributed to the higher utilisation percentage of the ingress and egress buffers of the communication components, as well as the processing capacity of their internal traffic management logic.

4.4 User Authentication

To measure the performance of our method in wireless and fixed networks we consider the case where a fixed or wireless user attempts to get authenticated by the network. Since authentication usually happens during call setup, measuring the time it takes, gives reliable indication of the call setup time.

Concerning available authentication types, in wireless networks two methods are widely used; the SIM based and the login/password based method, whereas in fixed networks only the second method is applicable. Since these methods differ only in the way the user is identified by the network, we evaluate the performance of SIU using the login/password authentication method [9].

The following figure summarises the results obtained in comparison to the normal case, after applying our method in wireless and fixed networks. Since the same mechanism has been applied for both network types, the obtained results represent measurements corresponding to authentication requests issued from both network types.

Results have shown (Fig. 8) that our method is somewhat slower in accomplishing authentication requests. This extra delay is unavoidable as SIU has to service user requests, following the normal procedure with the core network and at the same time create an index for each

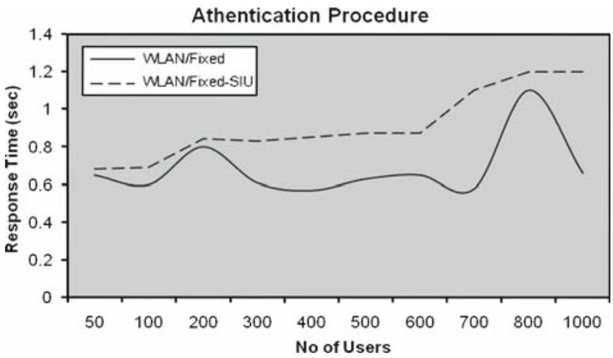

Fig. 8 Completion delay for the authentication

user, in the databases of the sub-network. Nevertheless, the incremental rise of the delay line with the number of users, implies that part of the extra delay is introduced by the processing capability of the input buffers of SIU and therefore can be compensated with buffer capacity optimisation.

5 Discussion

In this section we analyse the obtained results and propose a method for incorporating the sub-network into the IMS architecture. To understand the negligible impact of the sub-network on the overall performance of the access network, we must stress that most of the functions it hosts take place in parallel to those of the access network and therefore do not add delay to the completion time of the normal network procedures. Thus, during user-oriented procedures, such as the attach, detach and authentication, the functions of the sub-network take place in parallel to the procedures of the access network, while in application-oriented operations, such as the PDP context activation/de-activation, roaming and handover, the procedures of the sub-network have an additive, but minimal effect.

Having clarified this we can observe that all procedures are accomplished within very small time intervals, spanning from few milliseconds to less than a quarter of second and therefore are comparable to the delay time of the standard procedures. Therefore, integration of our sub-network with access networks could be done without inducing considerable delay in the overall performance of the network.

Such an assumption is valid as the experimental results have shown that even the procedures of the sub-network with additive effect on the normal network procedures are accomplished in quite short time, namely some tens of milliseconds for PDP context activation and less than 250 ms for roaming, although the latter increases exponentially with the number of roaming users.

Now that we have proven the suitability of the method to be applied on real networks, we elaborate on a scheme for integrating it into the IMS architecture. As we illustrate in Fig. 9, the logic of DGWN can be incorporated in the P-CSCF. Such an assumption is valid as the main task of P-CSCF is to proxy messages exchanged between the core network and the user. Therefore P-CSCF is the most suitable component for hosting DGWN mechanisms for home network tracking.

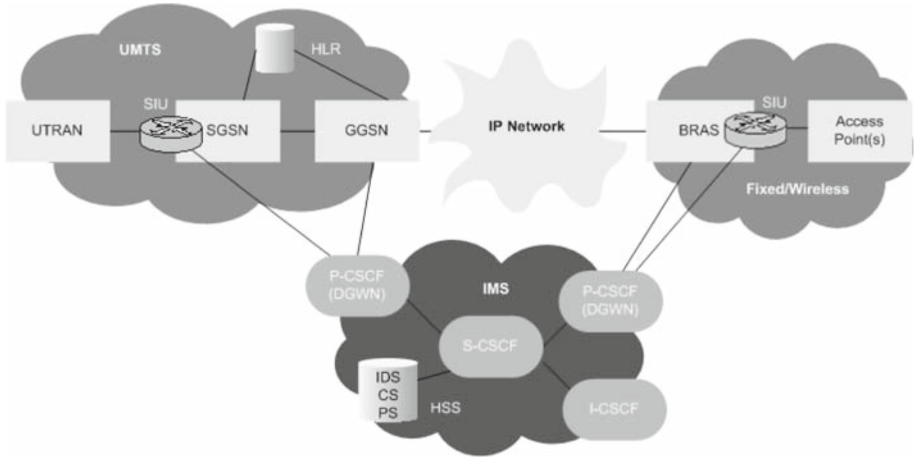

Fig. 9 Integration of SIU-DGWN-IDS-CS-PS network configuration in IMS networks

Furthermore, since P-CSCF makes use of the SIP protocol for its communication with the neighbouring IMS components, it may accommodate an additional SIP based interface for the communication with the SIU. Assuming that such interface exists, the databases we introduced for the storage of the IMSI-QoS/CDR associations can be integrated within the database of the Home Subscriber Server (HSS) of the host IMS network. In IMS networks, HSS is accessible by the P-CSCF, through the S-CSCF, over a SIP-based interface making use of the Diameter protocol [17].

Under this network configuration, SIUs can communicate with the components of the IMS network with SIP messages. Therefore, all queries towards the IDS, CS, PS databases can be sent to the P-CSCF encapsulated in the SDP protocol field of a SIP message or in SIP DIALOG messages. Messages circulated using the first method must use of the protocol fields 'Method' and 'To' to allow the S-CSCF identify the recipient and message type. For the implementation of the second method, IETF specifies the use of "Dialogs", a mechanism, which allows requestors to submit their queries, using own-defined SIP messages and repliers to issue their responses enclosed in OK and ACK messages [16].

6 Conclusions

This paper proposed a method for preserving the QoS values and charging data of users communicating over IMS networks. As IMS is formed of collections of heterogeneous networks, service establishment is very likely to undergo performance deteriorations, due to QoS mismatches that may distort communication quality at the expense of user charging.

The method we described can mitigate the effect of these limitations, which is caused by the inevitable adaptation of the original QoS settings to those of the of intermediate networks. This is done by allowing original descriptions of user sessions and charging records to migrate, along with the data call, across the entire communication path, via a complementary network in order to be used by local networks for the restoration of service quality and billing accuracy.

Furthermore we demonstrated, with the help of an experimental network, that our method has acceptable performance in comparison to normal UMTS, wireless and fixed networks and it is highly flexible concerning deployment in IMS networks.

Nevertheless it must be noticed that in a possible commercial deployment two issues will need to be generically addressed; the interface between the P-CSCF and the SIU, which is currently a proprietary solution and the type of SIP messages that SIU exchanges with the databases.

References

1. Handley, M., & Jacobson, V. (1998). RFC 2327: SDP: Session description protocol. IETF. http://www.ietf.org/rfc/rfc2327.txt, April 1998.
2. Fathi, H., Prasad, R., & Chakraborty, S. (2005). Mobility management for VoIP in 3G systems: Evaluation of low-latency handoff schemes. *IEEE Wireless Communications, 12*(2), 96–104.
3. 3GPP. (2001). 3GTS 23.207: End-to-end QoS concept and architecture (release 6). 3rd Generation Partnership Project, Technical Specification Group Services and System Aspects. http://www.3gpp.org/ftp/specs/archive/23_series/23.207/23207-200.zip, June 2001.
4. ETSI. (2006). TS282-007: Telecommunications and Internet converged services and protocols for advanced networking (TISPAN); IP Multimedia Subsystem (IMS); Functional architecture. ETSI, DES/TISPAN-02029-NGN-R. http://portal.etsi.org/.
5. DSL Forum. (2003). TR-058: Multiservice architecture & framework requirements. DSL Forum Technical Report. http://www.broadband-forum.org/technical/download/TR-058.pdf, September 2003.
6. Carugi, M., Hirschman, B., & Narita, A. (2005). Introduction to the ITU-T NGN focus group release 1: Target environment, services, and capabilities. *IEEE Communications Magazine, 43*(10), 42–48.
7. Cuevas, A., Moreno, J. I., Vidales, P., & Einsiedler, H. (2005). The IMS service platform: A solution for next-generation network operators to be more than bit pipes. *IEEE Communication Magazine, 44*(8), 75–81.
8. Marquez, F. G., Rodriguez, M. G., Valladares, T. R., de Miguel, T., & Galindo, L. A. (2005). Interworking of IP multimedia core networks between 3GPP and WLAN. *IEEE Wireless Communications Magazine, 12*(3), 58–65.
9. Lin, Y., Chang, M., Hsu, M., & Wu, L. (2005). One-pass GPRS and IMS authentication procedure for UMTS. *IEEE Journal on Selected Areas in Communications, 23*(6), 1233–1239.
10. Handley, M., Perkins, C., & Whelan, E. (2000). RFC 2974: SAP—session announcement protocol. IETF. http://www.ietf.org/rfc/rfc2974.txt, October 2000.
11. Schulzrinne, H., Rao, A., & Lanphier, R. (1998). RFC 2326: RTSP—real time streaming protocol. IETF. http://www.ietf.org/rfc/rfc2326.txt, April 1998.
12. Cuevas, M. (2005). Admission control and resource reservation for session-based applications in next generation networks. *Kluwer BT Technology Journal, 23*(2), 130–145.
13. Wu, W., Banerjee, N., Basu, K., & Das, S. K. (2005). SIP-based vertical handoff between WWANS and WLANS. *IEEE Wireless Communications, 12*(3), 66–72.
14. The FlexiNET Consortium. (2006). Deliverable 5.3: System Evaluation Report. http://cordis.europa.eu/fetch?CALLER=FP6_PROJ&ACTION=D&DOC=1&CAT=PROJ&QUERY=011b01c10137:5bf4:4eb1eeb1&RCN=71456, March 2006.
15. Rupp, S., Banet, F., Aladros, R., & Siegmund, G. (2004). Flexible universal networks—a new approach to telecommunication services? *Springer Wireless Personal Communications Journal, 29*(1–2), 47–61.
16. ITU-T. (1996). Q.713: Switching and Signalling Specifications of Signalling System No. 7—Signalling Connection Control Part (SCCP)—Signalling Connection Control Formats and Codes. ITU-T Q-Series Recommendations. http://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-Q.713-199607-S!!PDF-E&type=items, July 1996.
17. Hakala, H., Mattila, L., Koskinen, J.-P., Stura, M., & Loughney, J. (2005). RFC 4006: Diameter credit-control application. IETF. http://www.ietf.org/rfc/rfc4006.txt, August 2005.

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