Towards 'Quality of Service aware' services for the Virtual Home Environment

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***Abstract*-**This paper presents the needed enhancements to the open service architecture and the Parlay application programming interfaces in order to allow dynamic Quality of Service management for enhanced services in the Virtual Home Environment.

I. INTRODUCTION

The Virtual Home Environment (VHE) is a concept introduced by the 3rd Generation Partnership Project (3GPP) for UMTS which enables its users' personal service environment to be portable across network boundaries and between terminals. The VHE ensures that users are consistently presented with the same personalised features, user interface customisation, and services in whatever network and whatever terminal wherever the user may be located.

In order for VHE service providers to be able to develop services in a non-restrictive manner, access to certain network and terminal capabilities and features should be provided in a transparent manner. 3GPP proposes four methods by which service providers are able to provide VHE services and applications to their users: through the use of the Customised Applications for Mobile network Enhanced Logic feature (CAMEL), the Mobile Station Execution Environment (MExE), the UMTS SIM Application Toolkit (USAT), or the Open Service Architecture (OSA)[1,2,3,4]. CAMEL provides the mechanism to support intelligent network (IN) type of services in the mobile network environment consistently and independently of the serving network within the 3GPP system. The MExE concept allows service providers to develop applications that suit different types of terminals according to their capabilities and characteristics, regardless of the terminal's platform. These applications that reside on the terminal can then interact with a MExE server to provide services in the VHE. This approach is particularly suitable for terminal-centric services and applications but requires the terminal to be MExE compliant. The SAT approach provides a VHE by allowing applications residing in the SIM card to interact with applications or services located on a SAT server. OSA was developed for server-centric applications and services, and exposes network features and capabilities (e.g. call control) through a set of standardised interfaces.

An important implication in the VHE is that the Quality of Service (QoS) provided by the network affects the service provision of 'QoS aware' services to the user. Users may choose to map VHE services to different QoS requirements from the network, thus creating a mapped ‘services to network QoS’ user profile. For example, the user may prefer to receive video streaming content at a lower resolution if the allocated bandwidth is low. However, considering that the guaranteed QoS provided by the network may vary dynamically during a service (e.g. when a handover is performed in a mobile environment), VHE services should be able to adapt service provision according to the network conditions through some sort of dynamic QoS management. For example, the service should be able to request higher QoS from the network provider when the network becomes less congested. 3GPP has realised that these requirements are extremely important and has proposed the use of a MExE QoS manager component residing in a MExE compliant terminal to satisfy them[5]. However, this approach only satisfies the VHE requirements of 3rd Generation (3G) mobile systems as only MExE compliant terminals will have this component. Furthermore, the MExE QoS manager achieves QoS management through an interface that is compatible with 3G core network protocols only.

If the VHE concept is viewed from a non-3G mobile network point of view then providing interfaces to expose the network capabilities (i.e. the OSA approach) would seem to be the most advantageous means of providing VHE services. This would allow non-MExE terminals, such as current laptops, to access these services through non-3G mobile networks (e.g. fixed IP networks). 3GPP acknowledges that VHE should be applicable to all types of future networks, as well as providing a framework for the evolution of existing networks. As such, other consortia such as the Parlay group have been working closely to 3GPP and have defined similar interfaces to that of OSA for fixed networks in the view of providing VHE to non-3G mobile users[6]. In view of these developments, issues on QoS provisioning through standardised network interfaces such as OSA/Parlay should be extremely important in the future. These issues include the specification of a suitable bi-directional model to expose a sufficient degree of network performance information to the service application, as well as allowing it to dynamically modify its QoS requirements. On the one hand, the information passed to the application needs to be rich enough to ease the realisation of services and applications that, being network-aware, can exhibit a sufficient level of adaptation with respect to the underlying network layer. On the other hand, applications and services need to gain a sufficient level of access of the underlying networks to be able to dynamically negotiate the effective use of network resources.

Neither OSA nor Parlay currently provides such dynamic QoS management features, and therefore there is a need to study extensions and modifications to those interfaces. This paper elaborates on the hurdles related to the provisioning of advanced 'QoS aware' VHE services in the context of future integrated fixed and mobile networks.

II. The VHE Concept

There are many definitions of the term VHE from various sources, each describing its interpretation of VHE enabling features. This section examines the similarities and differences in the expected VHE enabled features. Some definitions of the VHE are presented in table 1 below. (Note that the last two definitions are from European projects researching the VHE concept)

TABLE 1
VHE DEFINITIONS

	Definitions
3GPP	"The VHE ensures that users are consistently presented with the same personalised features, User Interface customisation and services in whatever network and whatever terminal (within the capabilities of the terminal and network), where ever the user may be located" [7]
GSM MoU	"Virtual Home Environment (VHE) is a system concept for service portability in the Third Generation across network borders" [8]
ITU / IMT2000	"VHE is a capability whereby a User is offered the same service experience in a visited network as in his Home system." [9]
UMTS Forum	"VHE means that the user will have the same interface and service environment regardless of location (personalised user interface independent from the current serving network)."[10]
Eurescom P920-GI	"The Virtual Home Environment is an environment, which presents the user with a common look and feel interface and service experience regardless of location, network and terminal type. The VHE is based on standardised service capabilities and personalised features that are consistently presented so that the user always "feels" that he is on his home network even when roaming across network boundaries" [11]
IST VESPER	"VHE main feature is that the customised environment will be following the user while he/she is roaming within different networks and using different terminals" [12]

The common denominator among those definitions is provisioning of customisable and personalised services, portable across heterogeneous environments. However, there are some issues with regards to other aspects of the VHE, as discussed below.

A. Home Environment

3GPP defines the 'Home Environment' (HE) as the environment that is responsible for the overall provision of services to users. In ITU's VHE definition, the term 'Home system' is used in comparison with the term 'visited network'. Through this comparison, it appears that the HE is within the domain of the user's home network provider. Although this may be true, 3GPP have never explicitly stated that the provider of user's HE must be the user's home network provider. Therefore, it is possible that the two are separate business entities i.e. the HE provider, and the home network provider.

B. Networks and Terminals

As all of the definitions in table 1 state that the user's service experience should be similar regardless of the network used, the primary understanding of the VHE concept seems to be that of service interoperability and portability between networks. However, it is important to note that 3GPP have added the condition of terminal-independent service functionality to its definition of the VHE (although the service provision itself is limited to within the capabilities of the terminal and network).

This presents another consideration for service providers when developing services or applications. Service providers must therefore ensure that they can adapt their applications and services both to terminal and networks. These two factors are not mutually exclusive as the terminal's capabilities also determine the maximum QoS supported (e.g. bit rate) to run the application or service. The QoS required from the network to support the service should therefore not exceed the maximum QoS supported on the terminal for reasons of costs and efficiency. In the case of a video-on-demand service, the bandwidth reserved in the network should complement the maximum receivable bit rate of the terminal. For example, a 56 kb/s modem user using a dialup Internet connection shouldn't reserve 2 Mb/s bandwidth from the network.

III. Parlay and the Open Service Architecture

As the Parlay APIs and the OSA will probably be the technologies to hide network heterogeneity to the VHE, it is important to understand their differences in architecture and implementation. This section presents a short introduction on the two technologies.

The OSA was developed by 3GPP to allow service providers to develop server-centric services requiring UMTS network capabilities in an unrestrictive manner. Figure 1 illustrates a high level view of the open service architecture while figure 2 shows the Parlay architecture. The key component of both Parlay and the OSA is the framework server and its Application Programming Interface (API). These allow applications to discover the network functionalities that are exposed by the network provider. The network provider is not obligated to expose the entire functionality of the network through the framework API, and therefore service discovery is a key feature of using both Parlay and the OSA.

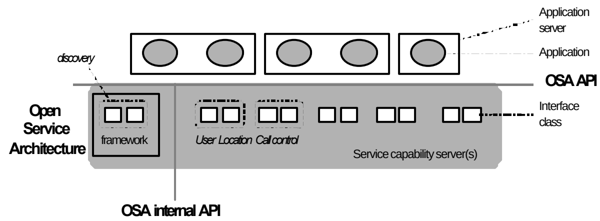

Fig. 1. The Open Service Architecture

The APIs also exposes the service capabilities, such as call control and messaging, of the network. For the case of the OSA, the API calls are handled by different service capability servers (SCS). Parlay uses a different approach whereby the different categories of service capabilities are separated into different respective APIs.

A limitation in the OSA API is that there are no methods for QoS control and management that can be used by external applications. QoS management has been partly addressed by the Parlay APIs through the introduction of the connectivity manager interface, i.e. interface 6 in figure 2 [13]. This interface allows an enterprise to enquire about and configure aspects of QoS provisioning in its virtual private network provided by the network provider. However, the connectivity manager interface was designed with the intention of providing QoS management on an enterprise scale and not for individual users. The intended user of the connectivity manager interface is shown to be the enterprise operator administration tool in figure 2. Therefore, Parlay does not provide any APIs for a server-centric service application to perform QoS management on behalf of its individual users. Another difference is that Parlay allows for some enhancements by third party vendors through the use of interfaces 3 and 5 in figure 2 whereas OSA does not. This makes Parlay a more ideal platform than OSA to implement additional network service functionality.

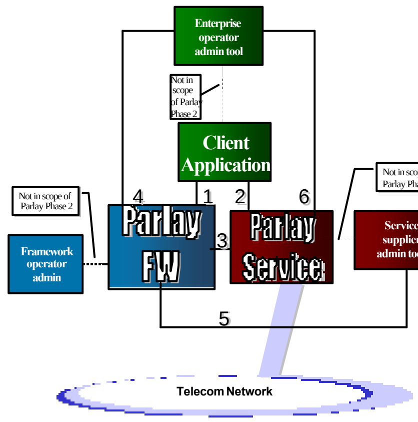

Fig. 2. The Parlay Architecture [13]

IV. PROVIDING QOS IN NEXT GENERATION NETWORKS

In order to provide 'QoS aware' services in the VHE, there should be a unified way of allowing service providers to discover and utilise the QoS provisioning capabilities of the underlying network, regardless of its type and complexity. This section describes how QoS is provided in UMTS and IP networks. PSTN and ISDN networks are not discussed in this section, as they do not offer QoS customisation to their users.

A. UMTS

The two important bearer service domains within UMTS are the Radio Access Bearer (RAB), and the Core Network (CN) bearer domains. The separate QoS provided in each domain combine together to provide the overall QoS in the UMTS bearer service. For example, the guaranteed transmission bit rate depends on the resource allocation in the Universal Terrestrial Radio Access Network (UTRAN) whereas traffic prioritisation is handled in the CN. In order to provide end-to-end QoS for the user or application, inter-working and service level agreements must exist between the UMTS and external networks.

There are four QoS classes defined in UMTS - conversational, streaming, interactive and background. Each of them caters for different types of data traffic generated or/and expected by the user's application. The first two classes are used by 'real-time' applications where data are non-bursty and delay sensitive. The conversational class differs from the streaming class through the requirement of a stricter delay tolerance and is typically used for telephony services (e.g. voice over IP and video conferencing). Applications that would use the streaming class are video, and audio on demand.

The interactive class is used for non-delay sensitive data traffic and is suitable for bursty traffic, such as the transport of human or machine interaction with remote equipment (e.g. web browsing). As such, 3GPP has determined that traffic handling priority in the core network be used as a QoS mechanism in this class. The background class is similar to the interactive class with the exception of being able to tolerate a higher delay as a result of the lack of priority based traffic policy. Applications that are suitable for this class include machine-to-machine messaging. Table 2 summarises the features and attributes of the four QoS classes in UMTS [14].

TABLE 2
UMTS BEARER ATTRIBUTES DEFINED FOR EACH BEARER TRAFFIC CLASS

Traffic class	Conversational class	Streaming class	Interactive class	Background class
Maximum bitrate	X	X	X	X
Delivery order	X	X	X	X
Maximum Service Data Unit (SDU) size	X	X	X	X
SDU format information	X	X		
SDU error ratio	X	X	X	X
Residual bit error ratio	X	X	X	X
Delivery of erroneous SDUs	X	X	X	X
Transfer delay	X	X		
Guaranteed bit rate	X	X		
Traffic handling priority			X	
Allocation / Retention priority	X	X	X	X

B. IP networks

There are two prominent proposals aimed towards providing QoS in next generation IP networks – the Differentiated Services (DiffServ), and the Integrated Services (IntServ) architectures [15,16]. DiffServ involves the marking of IP headers on individual IP packets by ingress nodes in the DiffServ network to classify the QoS class to which they belong. This allows packet classifiers in routers within the network to differentiate the packets in order to apply the appropriate forwarding behaviour on each packet (e.g. delay). The forwarding behaviours of QoS classes in DiffServ are determined by the SLA between the user and the network provider. It is interesting to note that 3GPP has declared that DiffServ will be used as the QoS enabling technology if an IP backbone is used as the UMTS core network. In this case, the four UMTS QoS classes shown in table 2 would be mapped into different DiffServ QoS classes.

The IntServ architecture's main feature to providing QoS in IP networks is to configure the routers along the flow path through a resource reservation protocol (RSVP) to emulate a connection-oriented network for its users[17]. The IntServ connection can be set up on demand by RSVP through querying the admission control of each router along the path. QoS attributes that negotiated with the routers through RSVP are the 'flowspec' parameters given by the user's application.

V. FUNCTIONALITIES NEEDED FOR 'QOS AWARE' SERVICES

This section presents the need for additional functionality in the Parlay/OSA APIs for 'QoS' aware services to function more effectively and efficiently. The proposed additions will also enable providers of such services to develop their applications with the confidence of interoperability in heterogeneous networks, and encourage creativity in the adaptability of the service in dynamic network conditions.

A. 'Change in QoS' notification and monitoring

The service application has to be notified of any changes in the achievable QoS, enabling the application to adapt its service accordingly. For example, this change in the QoS may result from a dynamic change of QoS policy in an IP network, or it may be the result of a handover or bad reception in a mobile network environment. A change of QoS notification must therefore inform the application of the details about the new QoS level provided, which in turn may cause the application to decide whether a change of network is necessary to support the service. For example, in the case of a mobile network environment a different network provider offering better reception in the area may be used. For the case of a content-based service, the notification may serve to trigger an adaptation in the service provisioning (e.g. lowering the video quality etc.). As such, the application should have the option of stating the level of monitoring it requires from the network. Examples are:

1) Not to monitor for changes in quality of service;
2) To receive a notification when the change has occurred.

B. Dynamic setting of QoS preference for service session

The service application should be able to negotiate QoS with the underlying network connectivity provider on behalf of its users before starting a new service session. If the request is rejected, an alternative proposal should be sent from the network back to the service application. It is important to remember that a user may have more than one service session at any one time, therefore the management of various QoS connections from different services is essential for the user's home environment provider. In the case of a UMTS user, the maximum bit rate supported by the user's terminal will be 2 megabits per second. Therefore, if the user accesses a new service while still using another, the total guaranteed bit rate for both services should not be more than 2 megabits per second. This may require the users to state service preference in their user profiles regarding the QoS provided.

C. Dynamic modification of a connection's QoS

It is possible that the QoS provided by the network during the start of a service may be lower than that desired by the user. This can be due to reasons such as bad reception in the case of UMTS, or network congestion for the case of fixed IP networks. Therefore, in the case where a higher level of QoS is made available to the user during the service, the service provider should be able to initiate a sequence of upgrading the QoS on behalf of its users.

D. Providing an independent means of exposing the QoS options available in the network

This functionality arises through the need to incorporate the VHE concept into heterogeneous networks and already exists in Parlay's connectivity manager interface. Parlay allows its users to discover the different classes of QoS provided by the network (e.g. Gold, Silver etc.). Users of the Parlay interface have two options – to select one of the classes with the default QoS attributes, or to modify attributes within the selected class. However, the attributes in the QoS class templates currently defined by Parlay are only specific to fixed networks. These templates should be enhanced to include those attributes shown in table 2 for the UMTS networks. Attributes that are not supported by the network should be indicated in the template accordingly. It would be convenient for service providers if there were standards in place that require all network providers to define customisable classes of QoS that support the four types of applications stated in table 2, i.e. conversational, streaming, interactive, and background type of applications. Service applications could then be presented with an easy and uniform way of discovering the QoS capabilities of the network that are related to the type of service that they are providing.

VI. TOWARDS REALISATION IN PARLAY/OSA

In order to implement and provide the functionalities discussed in the previous section, enhancements to Parlay and OSA will need to be made. It is possible that these two technologies will provide these functionalities in their respective APIs in the future. Should this not be the case, it is still possible to include these functionalities as an add-on feature. By referring back to figure 2 showing the Parlay architecture, we are reminded that interfaces 3 and 5 allow third party vendors to access the Parlay architecture by announcing their services in the Parlay framework. It is therefore possible to implement the discussed functionalities and make them accessible through these interfaces without modifying the existing Parlay APIs. This gives the added convenience of allowing services to access the interfaces directly, instead of relying on the Parlay connectivity manager interface (i.e. interface 6). This convenience is particularly important as it allows dynamic nature of the network to be made known immediately to the services, thus enabling them to respond dynamically as well. This could not have been possible through the current architecture as there are no interfaces between the client application (i.e. the server-centric service application) and the enterprise administration tool (see figure 2). The following sub-sections discuss the potential implementations issues regarding the functionalities proposed in the previous section.

A. 'Change of QoS' notification

The 'Change of QoS' notification functionality has recently been proposed by 3GPP for UMTS through the CAMEL service environment[1]. However, this has functionality to yet to appear in the Parlay and OSA APIs and an addition to the APIs should not be a problem in terms of implementation for UMTS networks as CAMEL will be able to support this feature. For IP networks that can guarantee a QoS (e.g. differentiated services), a change of QoS provided to the user would most likely occur as a result of a fault, a congestion in the network, or a change in QoS policy. For the former two cases, the network management system would learn of these situations through SNMP events and notify the service provider's application accordingly. As for the latter, a change in QoS policy is a network provider initiated event and therefore notification to the service provider's application should be initiated by the network operator.

B. Dynamic setting of QoS preference for service session

An interesting proposal by 3GPP regarding QoS preference in UMTS connection set-up is that a QoS manager located on a

MExE terminal is responsible for such functionality on behalf of MExE applications. This QoS manager manages this through a network control API that allows access to network specific control. It remains to be seen if 3GPP will look into ways of integrating this network control API with OSA. This could allow service applications to state QoS preferences for their users. For the case of packet switched services in UMTS, this would require the OSA to translate and route the API calls to the Serving General packet radio service Support Node (SSGN) of the user as the SSGN is responsible for admission control in the packet switched domain of UMTS. For the case of fixed IP networks, it is possible to use IntServ compliant routers at the edge of the network complimented by DiffServ compliant routers inside the network to achieve this aim. This allows the use of RSVP to create a connection with the preferred QoS requirements on the fly. For the case of DiffServ networks where RSVP is not supported, there is research towards the provision of a bandwidth broker that can be utilised to provide the required connection on the fly [18].

C. Dynamic modification of a connection's QoS

The network API used by MExE terminals in UMTS to perform QoS related functions also allows dynamic modification of provided QoS. As was mentioned in the previous sub-section, a way to implement this functionality through OSA or Parlay is to make this network API available to server-centric applications. For the case of IntServ networks, dynamic modification of the provided QoS can be done through using RSVP to perform admission control functionalities in the network again. For the DiffServ networks, research on a bandwidth broker that handles dynamic QoS modification is being done to provide this functionality in the future [18].

VII. CASE STUDY

The case study described here serves as an illustration of the concepts introduced in this paper. Consider a case study of a roaming user who relies on a VHE provider and requires a service involving the access of video content available in a remote server. We assume an IP-Based network with support for QoS as provided by the Differentiated Services approach (supporting e.g. conversational, streaming, interactive, and background classes of QoS). Initially, the user will access the HE provider and request the particular service from a list of available services. The user is also presented with the option of modifying service preferences from those stated in his profile. In these preferences the user has also the option to set a number of parameters related to the presentation of the service that are usually depended on network conditions. The user initialises its service and the appropriate service parameters set are translated to network requirements. This process maps a user view of what is expected from the service to a network view of required configuration and control parameters. Let us assume that the user sets a presentation parameter representing the quality of video received to low (other options are: normal and high). This could be mapped into a network view as an initiation of the 'interactive class with low priority required' connection with intense end-to-end performance monitoring and threshold checking to ensure that there is quick notification to potential changes in network conditions. After the connection has been established for the user, the video stream starts flowing from the server to the user's terminal.

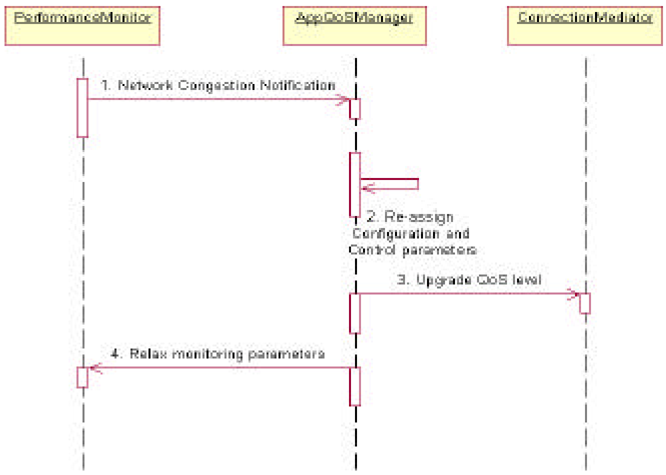

Fig. 3. UML sequence diagram showing events triggered by a Network Congestion Notification

Soon after the initiation of the service the performance monitoring system sends a threshold event notification alerting on heavy congestion in the network. This will cause the service controlling logic of the HE provider to decide that the service cannot be provided anymore using the current set-up but the QoS configuration and control parameters should be upgraded one level higher. This may reflect on an upgrade to an 'interactive' QoS class with an increased preferential treatment of packets compared to that of low priority as well as a requirement for a more relaxed performance monitoring of the connection. This last sequence of events is also depicted in the UML sequence of figure 3. The importance of this case study is that it reflects on typical issues arising within a VHE environment showing its dynamic nature that also requires dynamic management of network QoS.

This case study illustrates the need for a QoS manager to exist on the server to handle dynamic QoS management on behalf of the user. In contrast to 3GPP's proposal for such functionality to be provided on MExE terminals, this approach would allow HE providers to provide the same functionality on the server side, alleviating the need for users to own MExE terminals. Furthermore, it also allows the extension of the QoS aspects in the VHE concept to non-UMTS networks. It would be ideal if the user's QoS manager is under the control of the user's HE provider. The other option is to for service providers to implement a QoS manager for each of their users. The advantage of having the QoS manager under the HE provider's domain is to facilitate the ease of monitoring, managing, and coordinating various QoS demands from multiple active service sessions that the user may have.

VIII. CONCLUSION

This paper has explored the possibilities of introducing dynamic QoS management in the VHE for enhanced 'QoS aware' services. The VHE concept was introduced by 3GPP for 3G mobile networks and several technologies were developed to allow its implementation, e.g. MExE, USAT, and OSA. If the VHE was to work in non-3G mobile networks, e.g. IP networks, then such 3G dependent technologies cannot be used for its provision. This was the research motivation for the Parlay APIs, which allow the exposure of non-3G network capabilities to server applications. However both 3GPP's OSA and the Parlay APIs lack the functionality to allow the control and management of QoS for individual users. 3GPP has already realised the importance of dynamic QoS management as they have proposed the use of a QoS manager in MExE terminals. In our view, the functions of the MExE QoS manager should ideally be located on a server, controlling and coordinating the users' QoS demands through the manipulation of the OSA and Parlay APIs. Therefore there is a great need for the current OSA and Parlay specifications to include such dynamic QoS control and management functionalities. A list of the needed enhancements and a thorough examination of the difficulties in making such enhancements were presented, the latter focusing on the feasibility of each enhancement. Finally, the case study presented at the end of the paper proves that such enhancements to the OSA/Parlay APIs are needed if the VHE concept of non-varying service experience is to be introduced in non-3G networks.

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