Access to IP Multimedia Subsystem of UMTS via PacketCable Network

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Abstract- **Creating a background to let access to IP Multimedia Subsystem (IMS) of UMTS domain over different kind of access networks (like WLAN, PacketCable and DSL), which we name *multi-access to IMS,* can provide many benefits according to the capabilities of IMS in offering different kind of IP-based multi-media services. As a part of *multi-access* idea, we have worked on the access to IMS via PacketCable. PacketCable architecture seeks to enable a wide variety of Internet-Protocol-based multimedia services over two-way hybrid fiber-coax (HFC) cable access systems. We have proposed some solution for different phase of this inter-connection between PacketCable network and IMS of UMTS: from attaching to UMTS core network (UMTS-CN) and making a secure connection, until accessing to services and session establishment. We suggest some modification and development in PacketCable entities to be capable of establishing such an inter-connection.**

I- INTRODUCTION

The popularity and variety of IP Multimedia services has attracted 3GPP; UMTS (3G network) has adopted IP with QoS as the core network protocol in its data subsystem. In addition, IMS was standardized to provide session control and setup for IP based multimedia services like voice, video and multi-media application in 3GPP release 5 and moreover, OSA (Open Service Architecture) was specified to let third party service generators propose a variety of IP-base services [1]; SIP, which is an IETF (Internet Engineering Task Force) protocol, is selected as Multimedia session signaling protocol because of its positive points such as its support of mobility and security beside of the fact that SIP is an text-base protocol and easy to be deployed. SIP is seen today as the glue protocol for Telephony over IP that is open to multimedia services: it allows offering a wide range of applications merging voice, video, gaming, internet, and new enablers such as Presence and Messaging.

Besides, during recent years other network technologies like WLAN, xDSL and PacketCable (PCb) have been developed to provide better access possibilities in bandwidth consuming applications of Internet for subscribers. Having the picture of IP ubiquitous heterogeneous network in mind, it is clear that the investors of these access networks are interested in creating all-IP interconnection with IP core and IMS in UMTS because IMS provides IP services and mobility.

We call the access to IMS via different access networks, such as xDSL, WLAN and PCb, *multi-access to IMS*. (In this paper by IMS we mean IMS of UMTS).

The *multi-access* idea creates the capability to make many benefits in two main categories. First, allowing a user of IMS to access in IMS via different kinds of Access and benefits the positive points of these access networks (such as better bandwidth, lower cost). Second, multi-access idea can let the users of different kind of networks like PacketCable, xDSL or WLAN privilege the capability of accessing to IMS and enjoy its various kinds of service facilities. This paper introduces new scenario for the interconnection and interoperability between PCb and UMTS. Currently, there is an ongoing work at 3GPP for the WLAN access to 3GPP [6]. However, there is no ongoing work in standardization bodies for packet cable – 3GPP inter-working and there is no available mechanisms proposed by manufacturers. Moreover, there are no published papers addressing this issue. Though this area is very attractive because it will lead to converged services and shared infrastructure, the work proposed in this paper is entirely new.

To create this inter-connection, many problems should be solved. Generally speaking, every UE should follow these five steps to access to IMS of UMTS: 1) attaching to UMTS network and authentication. 2) IP connectivity 3) Getting setup for IMS services. 4) Application level registration. 5) Session setup and resource reservation.

Moreover this interconnection have to be established in such a manner that at least the equal end-to-end QoS and secure condition existing in the pure UMTS connections (access to UMTS-CN from UTRAN) can be reachable.

The first two phases are not IMS-specific and are just for providing connectivity with UMTS-CN.

In this paper, we first review the architecture of PacketCable networks and try to exploit the shortage and lacks in protocol and architecture for this interconnection. Then we will declare the possible inter-connection architecture and propose two scenarios of interconnection. Then in continue each phase of this interconnection for both proposed scenarios will be discussed. Finally the most important points will be summarized.
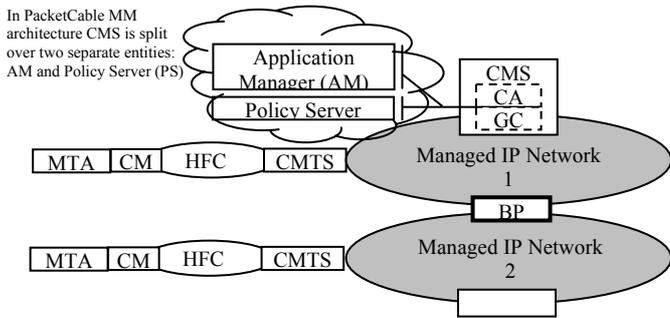
In PacketCable MM architecture CMS is split over two separate entities: AM and Policy Server (PS)

Fig. 1: PacketCable Architecture

Fig. 2: A Big Picture of Inter-Connection between PCb and IMS

II- PACKETCABLE ARCHITECTURE OVERVIEW

PacketCable is a project conducted by Cable Television Laboratories Inc (CableLabs) and its cable operator members with the goal of enabling a wide variety of Internet-Protocol-based multimedia services over two-way hybrid fiber-coax (HFC) cable access systems [13]. PCb specifications have been organized and released in the five project phases: PacketCable 1.0, PacketCable 1.1, PacketCable 1.2, PacketCable 1.3 and PacketCable Multimedia (MM).

But architecture developments have happened only in PacketCable 1.0, PacketCable 1.2 and PacketCable Multimedia (MM). Up to now, a complete solution for delivering VoIP services is realized but not for all kinds of multi-media services; the work for defining the architecture of PacketCable MM is unfinished.

In all of these phases, the architecture utilizes the services of three underlying networks: the HFC access network, the managed IP network, and the PSTN [3]. PacketCable 1.0 defines the subscriber environment and its interfaces to other network components including Multimedia Terminal Adapter (MTA), Cable Modem Termination System (CMTS), and Call Management Server (CMS). MTA is a PacketCable client device provides codecs and all signaling and encapsulation functions required for media transport and call signaling.

The CMTS provides data connectivity and complimentary functionality to cable modems over the HFC access network (DOCSIS). The CMTS is located at the cable television system head-end or distribution hub on the side of operator.

The Call Management Server provides call control and signaling related services for the MTA and CMTS. The CMS is a trusted network element that resides on the managed IP portion of the PacketCable network. Call Agent (CA) refers to the control component of the CMS that is responsible for providing signaling services. To control the call NCS (Network Call Signaling) protocol is used between CMS the MTA and SIP is used between different CMSes and border prox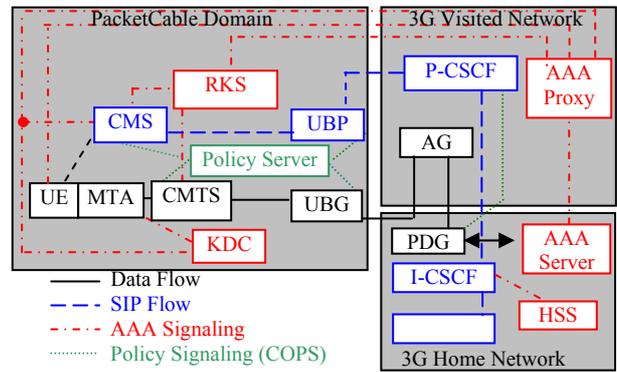ies [4]. The Gate Controller (GC) is a logical QoS management component within the CMS that coordinates all quality of service authorization and control.

PacketCable 1.2 extends the definition of two concepts introduced in the PacketCable 1.0 architecture: the Zone and the Domain [3]. A PacketCable Zone is defined as a single CMS and the endpoints (MTAs) it manages. A PacketCable Domain is the set of security realms managed by a single administrative and/or legal entity. The PacketCable architecture supports single-zone, intra-domain and inter-domain sessions. And then in this release the inter-connection of different operator zones is introduced.

A Border Proxy (BP) is a signaling component that exchanges call signaling information between PacketCable Domains or zones. There may be more than one Border Proxy in each domain.

In the current release of PackeCable Multimedia, the architecture is settled only for one single domain [5]. Moreover, CMS is divided into two separate parts: Application Manager (AM) and Policy Server (PS). It can be said that Application Manager is the advanced version of CA and Policy server is the advanced version of Gate Controller. Hence, policy based session establishment can be supported in this version.
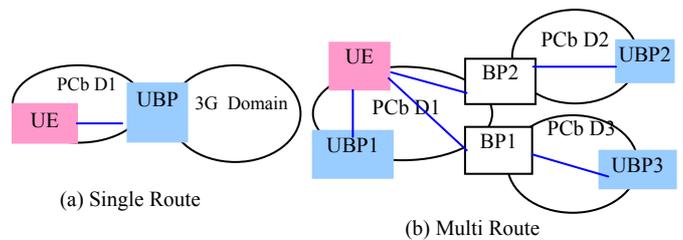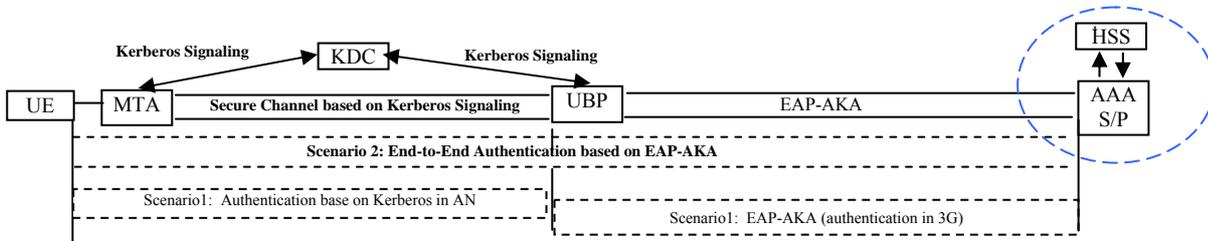

Fig. 3 :Different Inter-connection Architecture

Fig. 4: Proposed Authentication Procedure

In this work we will discuss for the cases that CMS elements in PacetCable networks supports at least the capabilities defined in PacketCable 1.2 architecture specially SIP signaling and because until this version only VoIP is considered in PacketCable we will also consider PacketCable Multimedia architecture to complete our discussion, specially in the session setup phase, for resource reservation and QoS control.

III- INTERCONNECTION SCENARIOS BETWEEN UMTS-CN AND PACKETCABLE

As explained above, in this work we are interested in access to IMS services over PacketCable (PCb) access network as a part of *multi-access* idea. But before accessing to the services, a user should be attached to UMTS-CN. In [6], 3GPP has introduced 6 scenarios of interconnection between WLAN and UMTS-CN [12]. Each scenario has added some new features to its previous scenario. The most interesting scenario for us is the scenario 3 proposed in their work. Scenario 3 has introduced the capability of access to UMTS services via WLAN.

For PCb access, because it is a wired access network, we propose two scenarios suitable to this fact for accessing IMS services:

Scenario 1: in this scenario we consider access of a PCb subscriber to IMS services. The PCb subscriber starts a call and the SIP proxy in PCb domain determines that the call destination is located in 3G domain or the requested service resides in IMS of UMTS. In this scenario PCb operator will charge the subscribers and this interconnection is transparent to user.

Scenario 2: in this scenario we consider providing access to IMS services over PacketCable access network for UMTS subscribers. This scenario can be considered analogous to scenario 3 of WLAN and UMTS-CN interconnection in [12]. In this scenario we can consider that the user will be charged by UMTS operator, and then the end-point device should have the capability of providing USIM (Universal SIM) information to be authenticated and attached to UMTS-CN.

In this paper we will consider only these two scenarios but two other scenarios for service continuity could be considered too. Furthermore, in scenario 1, for accessing to IMS, we can consider two features for UE: 1) it supports SIP. 2) It doesn't support SIP.

But for scenario 2, because some developments in user endpoint for supporting UICC are mandatory, we also consider the development of UE for supporting SIP and therefore only SIP-based UEs will be considered in this scenario. Currently in all of proposed architecture of PacketCable, user end-points doesn't support SIP as but the CableLab team is aimed to add this feature to benefit positive aspects of SIP such as mobility and security in addition to its simplicity.

A big picture of interconnection between PCb and IMS is declared in Fig. 2. UBP is the special SIP Border proxy for making trustable signaling between PCb domain and IMS of UMTS. AG (Access Gateway) in UMTS-CN is counterpart of WAG defined in [6] beside of PDG (Packet Data Gateway). The functionality of these entities will be defined in their related section in the following.

Moreover, different architectures of interconnection between PCb and IMS in UMTS can be considered. Fig. 3 shows possible architectures. In architecture (a) there is only one route possibility for user to access to IMS but in architecture (b) there are several routes.

IV- FIRST PHASE FOR ACCESS TO IMS: ATTACHING TO UMTS-CN

To attach to UMTS-CN a subscriber should be authenticated and authorized by the 3G network as well as access network. But for scenario 1 and 2 the condition is completely different. In scenario 1 the user is the subscriber of the PCb network therefore for authentication in 3G domain the reliable entities in Pcb should translate the ID of user to an ID that can be authenticated and authorized in 3G Domain. On the other hand, in scenario 2 the PCb as the access network should gain some new possibilities to authenticate and authorize the user with 3G ID of the user (USIM value). In this section first we will discuss the general requirements for authentication and authorization from non-3G access networks to 3G domain and then we will propose our solutions for scenario 2 and 1 respectively.

When the access to UMTS-CN is over another kind of access network like PacketCable, certainly the attachment process

should not threaten the existing acceptable security in UMTS. Furthermore, the profile of user should be more complete and the access network information should be added. 3GPP has specified AAA (Authentication, Authorization and Accounting) server and Proxy to perform authentication and authorization process for WLAN access [6]. But it is very likely that these entities be reused for other kinds of accesses too.

3GPP has defined Wa reference point between access network and AAA server/proxy for carrying AAA protocols. Security requirements are defined in [7]; authentication should be based on challenge response protocol and in addition, mutual authentication should be supported. This is why EAP-SIM and EAP-AKA is selected for authentication [7] and both of these protocols should be supported by both UE and AAA server. For USIM based authentication which satisfy security requirements and is defined in [6], EAP-AKA method should be used. In this paper we won't go too much to the detail of the attachment process. We just declare some parts of our work for modification and development in PacketCable entities to be capable of establishing such a secure connection with AAA entities in UMTS-CN.

To perform the authentication from a non-3G access network (for both of the proposed interconnection scenario), the secure information should be transported in three major domains: 1) from UE to the border of the access network. 2) From the border gateway of access network to the AAA server/proxy. 3) Between AAA server and other entities in charge of authentication (like HSS) in the 3GPP domain.

In the access network a secure tunnel should be established between UE and Border Gateway. The selection of protocol depends on operator but it should satisfy the requirements defined in [6]. Fig. 4 shows the end-to-end authentication process for two scenarios. Reference [7] has defined that for WLAN access the user authentication in access network should be based on NAI (Network Access Identifier). NAI is composed of a user part and a realm part and should be extracted from USIM. Using USIM for authentication is a proven method that satisfy security requirement, we will consider that in scenario 2. For sending the AAA protocol information between two networks a secure route should be established between UBP and AAA sever/Proxy in 3G domain. In scenario 2, the authentication of subscriber in the access network should be based on NAI. In PacketCable, one of the responsibilities of KDC (Kerberos Key Distribution Center) is to authenticate the user. So in scenario 2 the NAI information should be sent to KDC via a secure channel by using IPSec protocol. In PCb domain, KDC supports Kerberos which is a third party authentication and authorization protocol. KDC functions as the trusted third party by authenticating Kerberos Principals (users) for a given realm in which the KDC is authoritative.
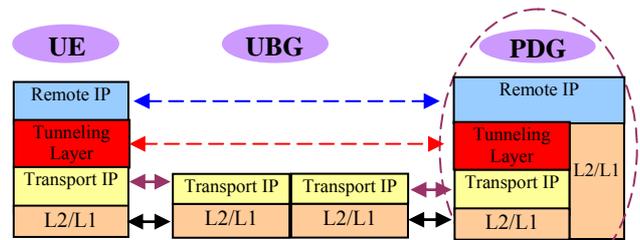

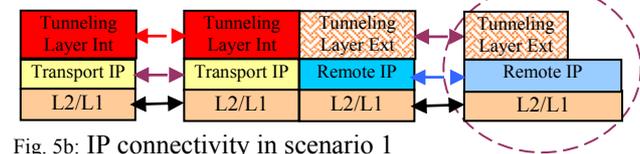Fig. 5a: IP connectivity in scenario 2

Fig. 5b: IP connectivity in scenario 1

Every translation of EAP-AKA and Kerberos signaling should be done by MTA and UBP in a manner that this translation be transparent to the UE.

For authentication in scenario 2, UE sends an EAP request/identity. MTA translates it to Kerbos Signaling and forward the request to KDC. KDC should authenticate the subscriber with his NAI. The realm part of NAI indicates the 3G home network (Home Public Land Mobile Network or HPLMN) of the user. If the NAI was valid, the user will be authenticated by KDC in the PCb domain. According to the HPLMN of the user, KDC should contact to the proper UBP and exchange the keys between UBP and MTA to establish an IPSec tunnel. KDC may contact a DNS and ask for proper UBP. UBP will receive the authentication request of user and translate it to EAP/AKA and send it for AAA Server/Proxy and then AAA Server ask HSS for the user profile and authenticate the user (Fig. 4).After authentication if the user was authorized for accessing to UMTS-CN a secure IP tunnel between UE and the access point in 3G domain should be established. Surely, routing enforcement is required. It means that at least the IP address of the access gateways in access network (UBG) and 3G domain (AG) should be negotiated and be forced for a secure connection.

In scenario 1, the user is a subscriber of PacketCable network; so logically he can't have USIM value. Hence, authentication will be done in PCb network as usual with Cable Modem (CM) code number.

Afterwards, the entity in charge of authentication in PCb network (KDC) should make a secure tunnel between itself and AAA server in UMTS on behalf of the user and authenticate him in UMTS domain.

As depicted in Fig. 4, the user will be authenticated by using Kerberos Signaling. But UBP will allocate a USIM value to the subscriber according to the contract between PCb operator and 3G operator and bind that to the local identification of the user and send a EAP-AKA authentication request to AAA server on behalf of the user. The rest is similar to scenario 2.
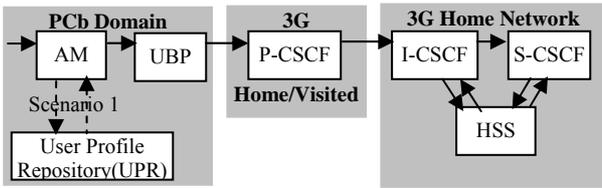
Fig. 6: Registration Signaling Flow

V- SECOND PHASE: IP CONNECTIVITY

The IP protocol stack defined by [6] between UE and PDG is depicted in Fig. 5-a.

In the remote IP layer, the UE will be addressed by a valid address in the domain of 3G network dedicated by a DHCP server there. The tunneling layer, encapsulate the remote IP packet in a secure tunnel between UE and PDG. And finally the transport IP address will be used locally between UE and UGB. This is a multi-stack architecture that eliminates the use of NAT. This architecture can be used for scenario 2. But for scenario 1, where the user is the subscriber of access network and will be charged by PC operator, the user can't negotiate directly with UMTS-CN to obtain a Remote IP address routable in UMTS domain. And this is UBG that should change the Transport IP of UE to a Remote IP. Then we have proposed the model in Fig. 5-b. In this method, UBG acts as a NAT. But NAT forces some problems for SIP signaling. Because NAT only change the IP address of destination in IP layer and not the IP address inserted in "To" header of SIP messages. Hence, for SIP signaling this problem should be considered and solved.

VI- THIRD AND FORTH PHASE: GETTING SETUP FOR AN IMS SERVICE AND SERVICE REGISTRATION

After attachment to UMTS-CN and providing the connectivity, the procedures of access to IMS will begin. The first step is to find the P-CSCF as the first contact point in the IMS. Several methods for discovering P-CSCF are possible including the use of DNS or DHCP. But the question is that in our case that we are accessing the IMS via another kind of access network how the process of P-CSCF discovery should be triggered.

We recall that in PacketCable 1.2 architecture, SIP is considered as session signaling between CMSes (AMs) or between CMSes and Border Proxies. Border Proxies (BPs) are defined as SIP proxies between two different domains. We have developed the functionality of BPs and have defined UBP as the SIP border proxy for accessing in IMS. As such, it is logical to consider UBP the responsible of P-CSCF discovery. Hence, two ways may be considered: The first way is that sending a SIP registration request by user, trigger this discovery procedure. The second way is that UBP start this procedure offline before receiving any SIP registration request from a user. We have considered a mixture of these two

methods. It means that at first UBP will discover available P-CSCFs, but because maybe the topology changes, it is necessary that the process of discovery can be triggered by SIP registration request too. In addition in the scenario 1 because the user is the subscriber of access network (PacketCable network) so the discovery of P-CSCF should be transparent to user and user shouldn't be aware about the IP address of P-CSCF.

After discovery of P-CSCF, the user should register for the service. The aim of the service registration is to assign dynamically an S-CSCF that will perform session control and keep the P-CSCF information during the registration lifetime. The S-CSCF can be only in the 3G home network [1].

In the current signaling procedure of PacketCable there is no registration mechanism. So we have added this mechanism for access to IMS services; but for scenario 2 and scenario 1 the mechanism is different.

In scenario 1, the case is that the user should sense no difference between services residing in PacketCable network and the services residing in IMS. Services, some may reside in PacketCable zone and/or in IMS and this is the AM (CMS) that should consider this fact and not user directly. In our proposed solution, the AM should extract the user profile to see in which services of IMS he has right of access. In the current version of PacketCable MM specification there is no user information database (like HSS). But because in this release the CableLab team has defined different services, such an entity should be required. For our work, we have introduced a new functional entity in the architecture: the *User Profile Repository* in the architecture.

Then AM queries the *User Profile Repository* to determine the service keys to which the user has right of access in IMS, the access network domain name and in addition the address of Border Gateway (UBG). Afterwards AM inserts this information in the SIP REGISTER request and send the message to the UBP. The rest is similar to scenario 2 that will be explained in next sentences. But it should pay attention that the 200 OK responses sent by the S-CSCF will be destined to AM not UE.

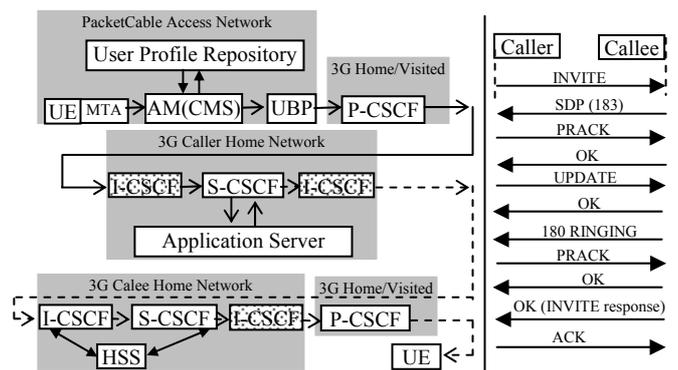In scenario 2, for service registration, we have proposed the

Fig. 7 : Session establishment Signaling flow

following scenario: The UE sends the SIP registration request. We have extended this request to contain some more information in addition to the 3G home domain name of the user, including access network technology and its domain name. The AM detects that the home domain name belongs to 3G network. Then according to the home domain name of the message, the AM should decide to which UBP (If there will be more than one UBP in that PCb domain) should forward this message. A UBP may be connected to more than one P-CSCF. Again, according to the home domain name, UBP selects the P-CSCF and forward the message to this appropriate entity. From this point the procedure is similar to the existing procedure for service registration in IMS via 3G accesses [2]. The P-CSCF examines the home domain name to discover the entry point to home network and forward it to the proper I-CSCF. I-CSCF asks HSS for the capabilities of the S-CSCF. Then with consideration of the access network information in the SIP message and the returned information from HSS, I-CSCF allocates an S-CSCF to this registration request and then forwards the message to the selected S-CSCF. The S-CSCF will ask HSS for the user profile and then respond 200 OK via I-CSCF and P-CSCF.

VII- FIFTH PHASE: MULTIMEDIA SESSION ESTABLISHMENT

After allocation of the S-CSCF in the 3G domain for the user in PacketCable domain, the user can initiate a call session and benefits the services residing in IMS. In this section we have declared the proposed entities that should participate in session signaling exchange and the signaling route for both scenarios 1 and 2. But before explaining that, we first present a general overview about the SIP signaling for session establishment in IMS.

In general, signaling exchange can be divided in three main phases [8] (signaling exchange is shown in Fig. 7): 1. Session Initiation: negotiation of the media components between calling and called party. The caller sends an INVITE message containing its supported multimedia capabilities for the session. The called party responds with a 183 (SDP) and indicates its acceptable multimedia parameters. The caller will acknowledge the receipt of 183 (SDP) with a PRACK.

2. Resource reservation: After the two end-users have agreed at session level on the media characteristics to be used for the session, the resources for the media flows can be reserved at bearer level according to the policy of the network domain. On the UMTS access network, resource reservation means PDP context activation. But for the cases that the access network is another IP based network, resource reservation in local access network (WLAN or PacketCable...) can be based on the IP resource reservation protocol like RSVP or DiffServ. In addition we believe that between AG and PDG (equivalent to the route between SGSN and GGSN) the resource reservation should not be based on PDP anymore

otherwise there will be a lot of useless QoS signaling translation process.

3. Session completion: First the calling party notifies the called party that resources are reserved (with UPDATE message). The called party is alerted and the calling party is informed. When the called party hooks off, the session is established and required bearers are dedicated to call.

Now, to have these three main phases done in the case that the user access is via PacketCable network, we suggest the signaling route depicted in Fig. 7.

In scenario 1, if the user doesn't support SIP, he will send a NCS (Network Call signaling) request and describe the details of his requested media in SDP inside of NCS request. We recall that in the current specification of the PacketCable the signaling protocol is NCS. (The detail of this protocol can be found in [13].) The CMS (AM) receives this request and checks if the user has the right of these requested media according to its profile residing in "user profile repository". If user is eligible for the requested service in IMS, CMS (AM) will act as the User Agent (UA) on behalf of the user and send an SIP INVITE message to the proper UBP. The selection of the proper UBP will be like the explained process in "Service Registration". In Scenario 2 and in scenario 1 when user supports SIP he himself sends an SIP Invite message to start the session. But in these cases too, we will push this constraint that this INVITE should pass through CMS (AM). This is because before forwarding this INVITE to IMS in 3G domain, CMS should check the requested media parameters in the message to be sure that there is no confliction with local policies in access network. This method is very useful in reducing media negotiation signaling. To explain why, consider the situation that a user, sends an SIP INVITE request and asks for a certain media which conflicts the local policies in access network (PacketCable Network). If the CMS (AM) doesn't check the inside of this INVITE and lets it pass to IMS in 3G domain, the termination point may accept these media parameters and respond with an SDP-183 message. Later, when the caller, after receiving SDP-183 answer, starts resource reservation and sends its IP-QoS resource reservation signal, according to the polices of the access network this request will be failed and the caller should send another INVITE and change the parameters of the requested media. But if the CMS checks the INVITE message as we have proposed, it will deny to accept the requested media parameters without involving the other party and in addition before starting resource reservation process. Hence, the amount of signaling exchange will be reduced considerably.

If the INVITE request passes the examinations in CMS (AM), it will be forwarded to UBP. As explained before, UBP is responsible for signaling translation and providing a condition for reliable signaling exchange. According to the fact that SIP is used as the session signaling in both IMS and PacketCable, there is no need of signaling translation. But UBP is necessary

to negotiate a public key for the session signaling outside of the PacketCable domain. So the first INVITE is necessary to pass through UBP. But after dedicating the public key for IMS domain the AM can forward the other session messages directly to the P-CSCF. (Of course the fact that UBP remains in the signaling flow or not depends on the PacketCable and 3G operators policies)

P-CSCF is the first contact point in the IMS domain and it can reside in the Home network or Visited network. Note that in scenario 1, the home network is the 3G network to which the PacketCable operator has the contract of interconnection.

However P-CSCF will forward the message to the S-CSCF to which the user has registered before. Use of I-CSCF for internal topology hiding is optional. But we consider that because topology hiding lead to more reliable inter-connection. If the session is established for just accessing to a service located in IMS of 3G Home network, it will be terminated in the proper Application Server connected to the S-CSCF. But in the most general case, the session can be destined to another user in a visited network. The dotted arrows in Fig. 7 show the signaling flow of the later case. It is important to note that the use of I-CSCF to find the proper S-CSCF in the called party is necessary.

X- CONCLUSION AND SUMMARY

In this paper we have evaluated the access of PacketCable to IMS of UMTS. We defined two scenarios of inter-connection and for each scenario we clarified new elements. Some development to the existing elements and new functionalities, especially in the PacketCable domain, required for that inter-connection is discussed. We proposed two scenarios of inter-connection. Proper solution for the five main phases of interconnection from attaching to UMTS-CN and user authentication until session establishment was explained. We specially focused on session layer signaling and access to the services of IMS. We proposed the monitoring of session media parameters inside of INVITE message in the access network. This helps to verify that media parameters do not conflict with local polices before forwarding them to IMS in 3G domain and then the amount of signaling exchange will be decreased considerably.

ACKNOWLEDGEMENT

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