Policy-Based Middleware for QoS Management and Signaling in the Evolved Packet System

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Abstract. The 3GPP are currently finalizing their Evolved Packet System (EPS) with the Evolved Packet Core (EPC) central to this framework. The EPC is a simplified, flat, all IP-based architecture that supports mobility between heterogeneous access networks and incorporates an evolved QoS concept based on the 3GPP Policy Control and Charging (PCC) framework. The IP Multimedia Subsystem (IMS) is an IP service element within the EPS, introduced for the rapid provisioning of innovative multimedia services. The evolved PCC framework extends the scope of operation and defines new interactions – in particular the S9 reference point is introduced to facilitate inter-domain PCC communication. This paper proposes an enhancement to the IMS/PCC framework that uses SIP routing information to discover signaling and media paths. This mechanism uses standardized IMS/PCC operations and allows applications to effectively issue resource requests from their home domain enabling QoS-connectivity across multiple domains. Because the mechanism operates at the service control layer it does not require any significant transport layer modifications or the sharing of potentially sensitive internal topology information. The evolved PCC architecture and inter-domain route discovery mechanisms were implemented in an evaluation testbed and performed favorably without adversely effecting end user experience.

Keywords: PCC, IMS, End-to-end, Inter-domain, Testbed.

1 Introduction

As part of the evolution of mobile communications 3GPP has defined a new air interface, known as Long Term Evolution – Radio Access Network (LTE-RAN), which forms part of the LTE work item. This evolved architecture provides higher data rates, increased spectral efficiency and lower infrastructure costs by simplifying the framework. Additionally a flat, all-IP based architecture has been defined, the Evolved Packet Core (EPC), which falls under the Service Architecture Evolution (SAE) work item. The architecture in its entirety is referred to as the Evolved Packet System (EPS).

The EPC is a framework that supports seamless mobility between heterogeneous access networks, and incorporates an evolved Quality of Service (QoS) concept that is aligned with the 3GPP Policy Control and Charging (PCC) framework. The evolved

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PCC architecture maximizes operator control over QoS functions distributed across different network nodes.

The 3GPP IP Multimedia Subsystem (IMS) forms part of the EPS as an IP service element and is the global standard for supporting multimedia services in IP networks. It is essentially a service enabler that integrates services horizontally as apposed to the traditional stovepipe architecture, ensuring the rapid creation of innovative applications [1].

During the lengthy IMS standardization process the phenomenon known as Web 2.0 has advanced. Web 2.0 refers to the new generation of Internet technologies characterized by the harnessing of collective intelligence. This has resulted in exceedingly innovative services, the majority of which are available free of charge with revenues based on the potential for personalized advertizing. This new communications model poses a threat to IMS service deployment – if operators are to charge for services that are available freely on the Internet, they will need to justify this by service differentiation. Increased reliability through efficient management of resources will be critical to this differentiation.

While IMS standardization is largely complete, the architecture responsible for managing resources, the PCC framework, still faces several deployment challenges. Weak specification of interfaces and elements has led to interoperability problems and vendor specific implementations [2]. This is evident in the fact that most preliminary IMS deployments do not support policy controlled resource management, or do so in a very limited and scaled down manner for multiple wireless accesses.

This latest evolution of the PCC architecture extends the scope of operation and introduces new interfaces. In particular an inter-domain interface, the S9 interface, is introduced to facilitate communication between PCC frameworks in neighboring IMS domains to achieve full end-to-end policy provisioning [3]. However the issues of inter-domain route discovery and QoS enforcement across all traversed transport segments of an IMS session still remain open areas, particularly in practical environments.

This paper analyses the current state of the art on linking session based IMS services with transport layer resources, with particular emphasis on the evolved 3GPP PCC architecture. We propose an enhancement to the IMS/PCC framework to discover end-to-end signaling and media routes. This mechanism uses SIP inherent routing information to discover origin, transit and destination IMS domains traversed by the media, and allows an application to effectively issue resource requests from its home domain enabling QoS-connectivity across all traversed transport segments. While this enhancement is limited to IMS services, the fact that it operates at the service control layer and uses SIP routing information to determine the media path means that the end-to-end mediation of resources can occur in a network agnostic fashion without any significant modification to the legacy transport layer. Additionally the sharing of potentially sensitive topology information is not required, removing the need for complex information updating procedures.

2 Evolution of 3GPP Policy Control Framework

When IMS was first introduced as an overlay architecture for 3GPP UMTS it was immediately apparent that QoS provisioning would play an important role in enabling

IP multimedia services. Policy Based Network Management (PBMN) was adopted to ease the management of the network resources through automated and distributed structures using centralized policies.

2.1 R5/R6 Service Based Local Policy Architecture

3GPP R5 introduced the Service Based Local Policy Architecture; R6 further developed this framework by separating logical elements and defining new interfaces. A Policy Decision Function (PDF) and Policy Enforcement Point (PEP) were defined, as well as very basic mechanisms that allowed the service control layer IMS elements to request resources in the transport layer. This initial attempt did not address inter-domain resource reservation and only supported Push mode operation or Service initiated QoS reservation.

2.2 R7 PCC Architecture

3GPP R7 combined the Flow Based Charging and Service Based Local Policy Architectures to form the Policy Control and Charging (PCC) Architecture. The main elements in this architecture were the Policy and Charging Rule Function (PCRF) and the Policy and Charging Enforcement Function (PCRF). This architecture extended the interface between the PCRF and the signaling layer (Rx interface) [4], and the PCRF and PCEF (Gx interface) [5], both based on the Diameter protocol. Both Push and Pull mode operation were supported, but there was still no mechanism for inter-domain resource reservation and the architecture was tailored specifically for UMTS access, though preliminary attempts were made to incorporate PacketCable and WLAN access [6].

2.3 R8 Evolved PCC Architecture

The evolved PCC architecture specified in Release 8, maximizes operator control over QoS functions distributed across different network nodes; the critical components: the Application Function (AF), PCRF and PCEF are extended [7].

In this evolved architecture the IMS is seen as one of several IP service elements, hence the AF is no longer limited to IMS specific elements. The PCRF provides connectivity between the EPC and the IP service elements. This element performs the same role as before but has its functionality split into home domain and visited domain functions. The definition of home and visited PCRFs allows the EPC to offer breakthrough for data in the home and visited domains. This new system introduces service level QoS parameters that are conveyed in the PCC rules; in particular these parameters include a QoS Class Identifier (QCI), an Allocation and Retention Priority

(ARP) and authorized Guaranteed and Maximum Bit Rate values for uplink and downlink [7]. The QCI is a scalar that represents the QoS characteristics that the EPC is expected to provide for each service data flow. This value is used by transport layer devices to access and configure device specific parameters that control packet forwarding treatment.

The interaction between the PCRF and the transport layer has been extended; the PCRF interacts and enforces PCC rules across a greater number of access technologies and QoS models. The PCEF, as the element residing in the transport layer, is separated into the Serving Gateway, the Packet Data Network (PDN) Gateway and the evolved Packet Data Gateway (ePDG). The Serving Gateway is a router that resides in the local network to which the end-user is attached, it performs connectivity provisioning including access control and resource provisioning. The PDN Gateway has similar functionality but is located in the home network of the end-user. The ePDG facilitates untrusted network access by authenticating end-users and monitoring traffic. PCC rules are received by these logical elements and are used to configure the transport layer devices accordingly.

With the PCRF split into home and visited functionality as of Release 8, the S9 interface has been introduced to facilitate inter-domain communication between PCRFs in neighboring domains [3]. This reference point is Diameter based and is in the early stages of development. It facilitates basic roaming scenarios and allows a PCRF to request resources in a neighboring domain. Fig. 1 shows the evolved PCC architecture and how it interacts with the EPC.

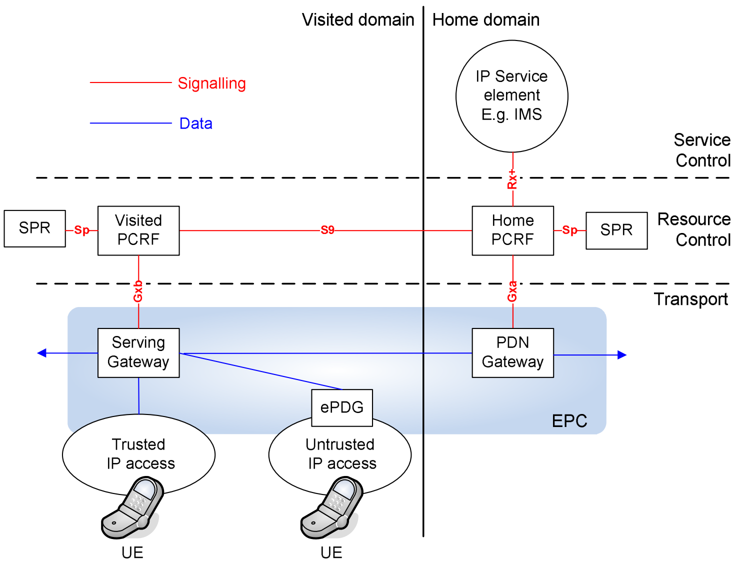

Fig. 1. The 3GPP System Architecture Evolution extends the scope and interactions of the PCC framework

Essentially two end-to-end QoS control scenarios exist. In the first scenario QoS requirements for a given service can be passed over the end-to-end path through the application signaling via the inter-domain reference point. In the second scenario QoS requirements are passed over the end-to-end path through path-coupled QoS signaling, using for example the Next Step In Signaling Layer Protocol (NSLP) or link-layer QoS signaling capabilities. NSLP signaling requires modification to all routing devices in the transport layer, and while this approach may be important for end-to-end service delivery in the future Internet, practical implementation challenges limit the applicability in the short to medium term. In particular network operators heavily invested in legacy networks will be hesitant to commit the necessary capital expenditure for such an overhaul, and link layer QoS signaling, like PDP context activation in UMTS, goes against the principle of separating core procedures from the subtleties of the access network [8]. However the first approach, using currently 3GPP standardized elements and interfaces, does not facilitate end-to-end resource reservation across multiple domains, nor does it link the service control inter-domain routes with the routes followed by the media in the transport layer.

3 Requirements for End-to-End Evolved 3GPP PCC

The general functional requirements of the PCC architecture include admission control, resource reservation and policy enforcement. To ensure end-to-end policy provisioning, the PCC architecture should guarantee resources and perform policy control along all traversed transport segments.

Secondary requirements have been identified that must be fulfilled by this evolved PCC architecture [9].

Minimal affect on Session Setup Delay – This is an important metric for validation as it gives an indication of the effect on end-user experience.

Backwards Compatibility – The Evolved Packet Core should be compatible with R7 and earlier implementations of the PCC architecture to ensure rapid adoption.

Convergence Towards Agnostic Access – The Gx interface provides this network agnostic interaction, but it remains to be seen how this will be implemented.

In no way hinder the Innovative creation of new services – The main purpose of the IMS is provide an environment for rapid service deployment, it should be possible to deploy new services without standardization of QoS support.

3.1 Inter-domain Solutions

To establish end-to-end connectivity, the routes traversed, and hence the domains where resources must be authorized, need to be determined. Having full knowledge of the intra-domain topology is an efficient but practically infeasible approach. A first level of inter-domain routing, where domains are considered as black box nodes and only inter-domain routes are taken into account, is necessary [10].

Topology discovery mechanisms that can be used to map out neighboring QoS elements have been defined [11], but no methods for discovering which domains need resource reservation were proposed. 3GPP propose a Diameter Routing Agent (DRA) to ensure that all Diameter sessions for a certain authorization request reach the same PCRF [12], but this is an intra-domain mechanism.

The AQUILA project proposes an inter-domain resource reservation mechanism that extends the Border Gateway Reservation Protocol (BGRP) [13]. While the proposal exhibits scalability and can be implemented using standard router equipment, inter-domain routing performed at this level requires significant modification to the legacy transport layer and requires the sharing of potentially sensitive topology information with neighboring domains. Additionally the framework is not specific to the IMS/PCC framework and replicates many of the standardized mechanisms.

The End-to-End Quality of Service Support over Heterogeneous networks (EuQoS) is a European research project aimed at building an entire QoS framework, addressing all network layers, protocols and technologies [14]. They propose an inter-domain QoS routing protocol that extends the Border Gateway Protocol (BGP) – EQ-BGP. EQ-BGP takes into account intra- and inter-domain QoS information to create a roadmap of available QoS paths between source and destination networks; these end-to-end QoS paths are advertised to neighboring domains using EQ-BGP. However like AQUILA this approach passes QoS information in path-coupled signaling and requires significant transport layer modifications.

Mechanisms that allow the discovery of end-to-end routes and hence perform inter-domain resource reservation are required. These mechanisms should utilize standardized IMS/PCC mechanisms, and not require transport layer modification by operating at the service control layer.

4 Inter-domain Route Discovery

We propose an extension to the IMS/PCC architecture that extracts SIP routing information during session establishment and uses this to determine the domains traversed by the signaling and hence the media. This proposal is specific to the IMS architecture and makes use of standardized mechanisms and interfaces provided by the PCC framework. Using this mechanism, resources need only be requested in the home domain of the originating end-user as authorization requests sent to the PCRF contain information on all necessary administrative domains and inter-domain requests are sent to the relevant PCC frameworks. Inter-domain routing is performed at the PCRF using signaling information, this means that no significant transport layer modifications are necessary nor is the sharing of potentially sensitive internal topology information.

4.1 Necessary Assumptions

Several assumptions are necessary for the validity of the proposed enhancements.

All Services must be SIP based – The IMS is the global standard for IP multimedia service delivery; hence the most resource hungry applications will most likely be IMS services which are SIP based.

Media and signaling must originate in the same domain, and media must follow a path between origin and destination domains – The media and signaling paths are still decoupled and follow entirely different paths, we do not envisage any IMS scenario that violates this assumption.

PCRFs must know the address of PCRFs in neighboring domains – The addresses of neighboring PCRFs can be manually configured, exchanged through roaming agreements, or discovered automatically using topology discovery mechanisms [6].

Route information in SIP signaling must be visible to traversed proxies – Route information in SIP signaling can be encrypted for security or privacy purposes, e.g. if a Topology Hiding Interworking Gateway is in operation, however the address of the gateway element is always present which is sufficient to determine the traversed domains.

4.2 Signaling Path Discovery

The SIP protocol defines a transaction as a request, any number of provisional responses and a final response, while a dialog is a SIP relationship that exists for some time [15]. All responses must traverse the same proxies as their relevant requests. This route is discovered using the *Via* header – as a request traverses each proxy along its path, the address of the proxy is added to the *Via* header. The subsequent response traverses all proxies listed in the *Via* header and strips each address as the proxy is traversed.

Within the same dialog subsequent requests need not necessarily follow the same path – however if a proxy wants to ensure that it is included on the path for all requests in a dialog it can add its address to the *Record-Route* header of the initial request. An IMS Call Session Control Function (CSCF) is a prime example of this kind of proxy, as it would want to be traversed by all requests in a dialog to enforce charging, resource authorization and service invocation. When subsequent requests are created the proxies listed in the *Record-Route* header of the initial request are added to the *Route* header in the order in which they must be traversed. The *Route* header essentially defines the route a request will take, and each proxy address is stripped from the *Route* header as it is traversed. This means that for any request apart from the initial request, any proxy along the path can map out the entire signaling route from originating user to terminating user by examining the *Route* and *Via* headers.

The calculation of the signaling path occurs at the element in the home domain of the originating end-user requesting resource authorization from the PCC framework; this element could be an Application Server or a Proxy – CSCF (P-CSCF). When an authorization request is created the relevant SIP request is examined and the path from origin to destination domain is mapped out using the *Via* and *Route* headers. Though these headers contain proxy addresses it is possible to determine the domains by taking only the network part of the URI. The addresses are examined and the origin, transit and destination domains are discovered (Duplicate domains are excluded.) This information is encapsulated into the Diameter Authorization Request - we define three new AVPs for the Rx Diameter Application: Origin-Domain, Transit-Domain and Destination-Domain.

4.3 Bearer Path Discovery

Once an Authorization Request is received by the PCRF the media path must be determined. While signaling must traverse IMS proxies as described, the media is decoupled and will usually traverse an optimized route between origin and destination domains. There are three cases to cater for:

Origin and destination domains are the same – This is the simplest case, all transit domains are ignored and resource authorization and reservation is performed only in this domain.

Origin and destination domains are different and there are no transit domains – In this scenario resources need to be authorized and reserved in both origin and destination domains, this is done simultaneously.

Origin and destination domains are different and there are transit domains – In this case it needs to be determined whether the transit domains are traversed by the media or if they can be discarded as unnecessary transit domains along the signaling path. If a PCRF in the home domain of the originating end-user detects this case when performing inter-domain authorization, the authorization request is forwarded as is to the PCRF in the origin domain – the address of this PCRF would be known as it would be exchanged in the roaming agreement that allows the end-user to attach to this network.

We utilize the assumption that all PCRFs know the address of neighboring PCRFs. The PCRF in the origin domain examines the route information in reverse order and when a neighboring domain, whose PCRF address is known, is found all subsequent transit domains are discarded – this new authorization request is forwarded to the neighboring PCRF where the same process is repeated. This operation repeats until the destination domain is reached; in this way the domains traversed by the media are discovered and unnecessary transit domains discarded.

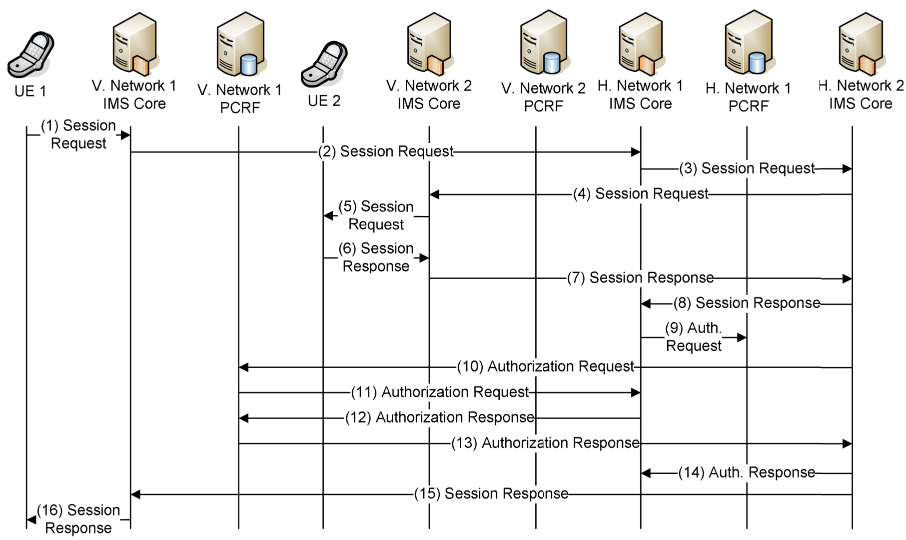

Fig. 2. With the evolved end to end 3GPP PCC framework resources are authorized and reserved only in the domains traversed by the media

The mechanism is demonstrated in Fig. 2. There are 2 end-users, User Equipment (UE) 1 that connects via visited network 1 and is registered with home network 1, and User Equipment (UE) 2 that connects via visited network 2 and is registered with home network 2. UE 1 initiates a session with UE 2 by issuing a SIP Session Request (1), this request traverses visited network 1, home network 1, home network 2 and visited network 2 and is eventually delivery to UE 2 (2-5). UE 2 returns a SIP Session Response with preferred session parameters (6-8). An element in home network 1 (e.g. Application Server, P-CSCF) extracts the service information from both SIP request and response as well as routing information and encapsulates it in a Diameter Authorization Request and sends it to the PCRF in home network 1 (9). Table 1 shows the calculation of the signaling path. The PCRF extracts the information, and upon discovering that both origin and destination domains are different and there are transit domains, forwards the Authorization Request as is to the PCRF in visited network 1 as it is the origin domain (10). The PCRF in visited network 1 examines the route information in reverse and immediately finds that the destination domain, visited network 2, is a neighboring domain. All transit domains are discarded and the new Authorization Request is sent to PCRF in visited network 2 (11). The PCRF in visited network 2 performs policy, subscription and resource checks, enforces the policy decisions in the transport layer and sends a positive Authorization Response to the PCRF in visited network 1 (12). Similar policy, subscription and resource checks are performed here and the policy decisions are enforced in the transport layer of this domain. A positive Authorization Response is conveyed to the PCRF in home network 1 (13), which sends a positive Authorization Response to the control layer element (14). The SIP Session Response is conveyed back to UE 1 (15-16). In this way resources are reserved along all traversed transport segments enabling end-to-end QoS connectivity. Table 1 shows the subsequent calculated media paths.

Table 1. Route Discovery from SIP Update Request

```
UPDATE sip:alice@192.168.125.8:5060 SIP/2.0
Via: SIP/2.0/UDP pcscf.visited1.net; branch=z9hG4bt6
Via: SIP/2.0/UDP 192.168.126.1:5061; branch=z9hG475
Route: <sip:scscf.home1.net; lr>,
Route: <sip:scscf.home2.net; lr>,
Route: <sip:pcscf.visited2.net; lr>
```

Administrative domains traversed by signaling

Origin Domain	Transit Domain	Destination Domain
visited network 1	home network 1; home network 2	visited network 2

Administrative domains traversed by media

Origin Domain	Transit Domain	Destination Domain
visited network 1	-	visited network 2

In the third case, where both origin and destination domains are different and transit domains are present, resource reservation is performed in each domain consecutively, which increases session setup delay. However this is the worst and most unlikely case and for all other scenarios resource reservation is performed simultaneously in each domain.

5 Implementation Experience

As mentioned previously the core IMS specifications are largely finalized, though the PCC architecture still needs to mature and have various challenges addressed before deployment can be realized. The massive success and proliferation of Internet technology has shown that a large number of application developers working on an open infrastructure is needed for the development of successful market driven services. Open IMS testbed initiatives likes the Fokus Open Source IMS Core [16], and the UCT IMS Client [17] have helped expose this complex technology to an open set of developers, bringing academia and industry together.

The Evolved PCC architecture and proposed extensions were implemented in a proof of concept testbed. One of the goals of this implementation was to verify and evaluate the proposed inter-domain route discovery mechanisms and to demonstrate the proposal in a real world scenario. To ensure reproducibility, encourage innovation and provide a convenient point of departure for future research in the field, the testbed used exclusively Free and Open Source software.

A standards based IMS reference framework, the Fokus Open Source IMS Core, was used to implement the core IMS including CSCFs and Home Subscriber Server (HSS) [16]. These elements comprised the service control layer and provided a reliable IMS testing environment. The P-CSCF was extended to extract service and routing information, determine the full signaling path and interact with a PCRF via the Rx+ Diameter interface. The standardized Diameter application for this interface incorporated additional AVPs: OriginDomain, TransitDomain and DestinationDomain as per the inter-domain route discovery mechanism.

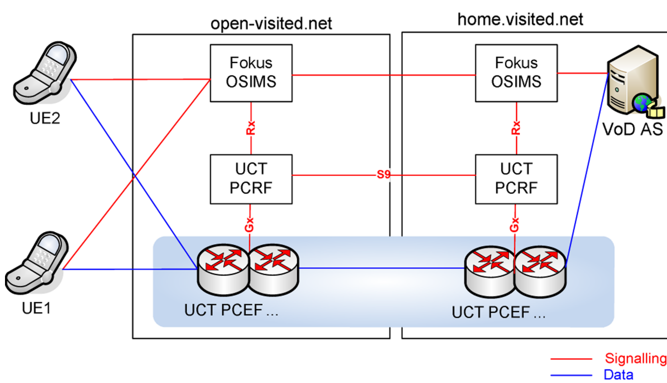

Fig. 3. The testbed architecture is comprised exclusively of Free and Open Source software to expose the technologies to an open set of developers

To provide PCC functionality the UCT Policy Control Framework was developed and released as Free and Open Source [18]. This standards based package contains software implementations of the PCRF and PCEF. The PCRF defines interfaces to the control layer and transport layer; upon receipt of Diameter Authorization requests from the control layer this element performs policy, resource and subscription checks and enforces the policy decisions on the PCEF in the transport layer. The inter-domain route discovery mechanisms were incorporated into the PCRF logical architecture. The PCRF was extended to perform inter-domain resource reservation and interact with neighboring PCRFs via the Diameter S9 interface.

To represent end-user equipment, the UCT IMS Client was used [17]. This standards based client emulation tool implements full IMS signaling, several rich services and a mechanism with which to test other IMS network components. Fig. 3 shows the testbed architecture including two domains for proof of concept evaluations.

5.1 Metrics of Interest

A key requirement for the evolved 3GPP QoS concept is a negligible effect on session setup delay [9]. An equally important metric is the effect on signaling overhead; the PCC framework introduces a number of additional messages during session establishment, this increase in signaling overhead could overwhelm network elements and decrease network utility. Transport layer QoS metrics including jitter and packet loss are considered unnecessary in this study, the concentration is not on IP QoS models where such metrics might be pertinent.

The testbed was capable of working with the end-to-end PCC architecture enabled or disabled – this provided a benchmark for evaluations. With the PCC architecture disabled no resource authorization took place and all media was treated as Best Effort.

5.2 Session Setup Delay

To analyze the affects on session setup delay, the delay when establishing sessions across domains was measured. Referring to Fig. 3 UE 1 and UE 2 were registered with open-home.net and connected via open-visited.net. When a session was setup the signaling followed the path: open-visited.net, open-home.net, open-visited.net. The inter-domain route discovery mechanism returned open-visited.net as the only domain that required resource authorization. An inter-domain request was sent from the PCRF in open-home.net to the PCRF in open-visited.net where policy, resource and subscription checks took place, and policy decisions were enforced on the PCEF in the transport layer.

The time to setup a session across domains was measured both with and without the end-to-end PCC architecture enabled. Each session request represented a typical IMS session with audio and video component. Table 2 shows the results of this experiment; while the increase is not insignificant, the fact that end-to-end QoS is guaranteed is an important trade off. Similar tests were carried out to evaluate the increase in signaling overhead and results showed an acceptable effect on this metric.

Table 2. IMS call setup delay results when establishing a session across domains

	With e2e PCC enabled	Without e2e PCC enabled
Minimum (s)	4.524	0.828
Mean (s)	4.914	1.115
95th Percentile (s)	5.701	1.346
Std Deviation(s)	0.357	0.158

5.3 Inter-domain Resource Reservation with Application Invocation

To provide a real world use case scenario a Video on Demand (VoD) Application Server (AS) was deployed in the home domain, open-home.net. Referring to Fig. 3 UE 1 was registered with open-home.net and connected via open-visited.net. UE 1 initiated a session with the VoD AS in open-home.net.

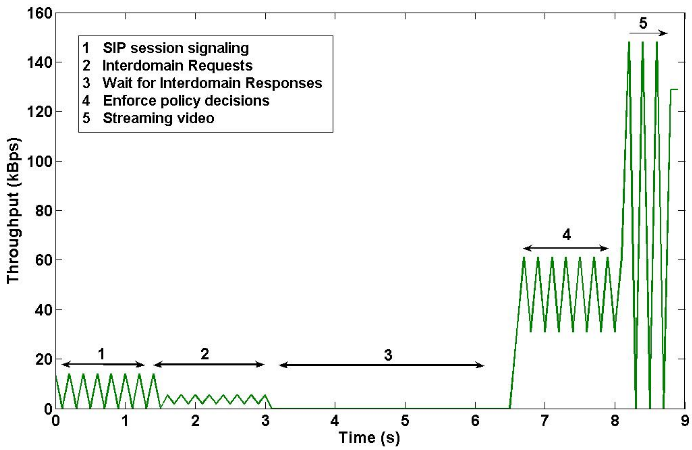

Fig. 4. The throughput graph shown here gives a clear indication of the various steps involved in the inter-domain route discovery procedure

Fig. 4 shows the throughput measured at the machine hosting the home domain elements and the VoD AS. This gives an indication of the various stages involved in the process. When UE 1 sent a VoD session request the IMS core forwarded the request to the VoD AS based on pre-set initial Filter Criteria (1). The VoD AS extracted service and route information and calculated the signaling path. An authorization request was sent to the PCRF in open-home.net (2), the inter-domain route discovery mechanism determined that open-visited.net and open-home.net required resource reservation to be performed. An authorization request was sent to the PCRF in open-visited.net, where policy, resource and subscription checks were carried out, and policy decisions were enforced in the transport layer (3). Upon receipt of the authorization response the PCRF in open-home.net enforced policy decisions in the transport layer (4), and eventually the video was streamed across an end-to-end QoS-enabled transport layer (5). These results are consistent with those reported in [11].

6 Conclusions

Resource management will be a critical factor in differentiating IMS services from typical web services. The latest evolution of the 3GPP PCC framework extends the scope of operation and introduces new interfaces; however there are still challenges that need to be addressed before deployment can be realized.

This paper has proposed an extension to the evolved PCC and IMS architectures that operates at the service control layer and uses SIP routing information to determine the paths traversed by signaling and media. This mechanism allows applications to effectively issue resource requests from their home domain and enable end-to-end QoS-connectivity. Unlike other inter-domain proposals this mechanism requires no significant transport layer modifications or the sharing of potentially sensitive internal topology information.

The evolved PCC architecture including inter-domain route discovery enhancements was implemented in a proof of concept testbed. To expose this technology to an open set of developers and encourage innovation in the field, Free and Open Source software was used throughout the implementation. Examining important metrics: session setup delay and incurred signaling overhead, the architecture performed favorably without decreasing end-user experience. Future work includes extending the framework to demonstrate QoS negotiation for advanced multimedia services.

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