QoS Management and Network Context Awareness for IPTV Services in the 3GPP Evolved Packet System

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Abstract— In today's increasingly technological environment the variety of mobile devices, and the types of services that can be offered on these, continues to grow. It becomes increasingly necessary to provide end-to-end guarantees for Quality of Service (QoS) requirements of these services, as required by the application and demanded by end users. Applications requiring stringent QoS guarantees are becoming more prevalent. An example of this is high definition video streaming.

The Systems Architecture Evolution, the name given for the 3rd Generation Partnership Project (3GPP) work item on the Evolved Packet System (EPS), has been accepted as the next generation architecture for future mobile broadband networks. The EPS comprises the Long Term Evolution (LTE) and Evolved Packet Core (EPC) as the access network and core network architectures respectively. The EPS can thus be viewed as the Next Generation Mobile Broadband Network (NGMN).

Providing enhanced QoS and Policy and Charging Control in the EPC becomes an important issue for service providers and network operators. In this paper, the implementation of a resource management framework for services transported over the 3GPP Evolved Packet Core is presented. The special case of an IMS-based IPTV service is presented to show proof of concept.

Index Terms— *QoS Management, User Context, IPTV, IMS Evolved Packet Core*

I. INTRODUCTION

The evolution of the core network, or Evolved Packet Core (EPC), is a fundamental cornerstone of the mobile broadband revolution; without it, neither the Radio Access Networks (RANs) nor mobile Internet services would realise their full potential [1]. This new core network was developed with high-bandwidth services in mind. It is designed to enable truly mobile broadband services and applications, and to ensure a smooth experience for both operators and end-users. The EPC can also be thought of as the "common core" which includes support for various radio access technologies (e.g. LTE, GSM, WCDMA/HSPA, WiMAX and WLAN). The core network is the part that links these worlds together, combining the power of high-speed radio access technologies with the power of the innovative application development enabled by the Internet. Fig. 1 illustrates the different domains within a typical mobile network deploying the EPS.

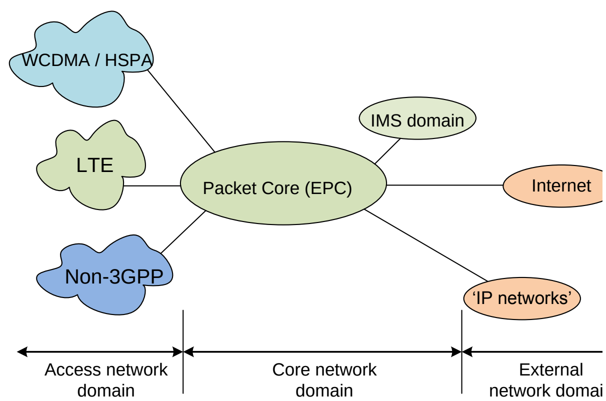

Figure 1: Mobile access and core domains

The Third Generation Partnership Project (3GPP) is a partnership between several different telecommunications associations, whose aim is to provide technical specifications for mobile network architectures [11]. The 3GPP-defined Evolved Packet System (EPS) – Long Term Evolution (LTE) access network and Evolved Packet Core (EPC) core network – has been accepted as the next generation architecture for future mobile broadband networks [2]. From the point of view of a network operator, now is the opportune time to lay the foundation for many features that will be needed in future generation networks. This will enable network operators to meet the needs of current and future users and devices.

It is apparent from current trends that services offered over mobile networks are growing increasingly diverse [3]. These services will need to be delivered to the User Equipment (UE) with their required QoS [4]. In the mobile network environment, best effort services, real time audio/video, high volume file sharing and high priority emergency services share both core and access network resources. Since the EPS is a purely packet-switched environment it becomes important to have an efficient QoS solution that ensures the user experience of each service running over the network is acceptable.

One such popular service is IPTV. Digital television continues to grow as many operators are beginning to deliver content using this technology. IPTV is a form of Digital TV that is described as "transporting a stream of video content over a network that uses the IP networking protocol" [5]. Mobile Video is projected to account for more than 66% of total mobile data traffic by 2014, compared to Mobile VoIP or content browsing (4% and 17% respectively) [3]. This indicates how popular mobile IPTV services will be in the coming years.

IPTV can be offered with varying degrees of QoS. Depending on the network resources in the access and/or core network, a user can experience SDTV or HDTV quality video streaming. QoS requirements for the type of video quality will depend on variables such as video quality, bandwidth availability and connection parameters (such as end-to-end latency, jitter and packet loss ratios etc.). Optimally, the IPTV service delivered to the end user can consider all these factors and dynamically adjust to the UE's connection conditions at any time.

This paper explores the mechanisms for enhanced resource management and QoS allocation for an IMS-based IPTV service transported over an EPC testbed network. In particular, the following issues will be investigated:

1. How does the Policy and Charging Control (PCC) architecture within a 3GPP core network (EPC), facilitate in resource management and QoS for services?
2. How does this PCC guarantee resources for each data flow taking into account the requirements for the service as well as the user's context?
3. Due to the nomadic nature of mobile communication, how does the PCC maintain these flows when the user changes to a different wireless environment (such as a vertical handoff)?
4. Additionally, for enhanced application level interaction, how does the application function interact with the PCC for service optimization based on the UE's attachment context?

Much of the work presented here is built on numerous previous works. The novelty introduced here involves the integration and interworking of several different components to showcase the possibilities of the EPS, the IP Multimedia Subsystem (IMS) and PCC. This is proved in a prototype implementation, which can be used as a foundation for future work to investigate other issues. We present a resource management solution for IMS-based IPTV services transported over the EPC. We then perform testbed experiments to determine the adaptability of service flows with relation to the user's context.

The rest of the paper is structured as follows: Section II briefly reviews the concepts of the EPC, PCC and Services; Section III presents the design of a resource management system for IMS-based IPTV in the EPC; Section IV presents an implementation of the architecture within a testbed and presents testing results and discussions; Section V concludes the paper

II. RESOURCE MANAGEMENT IN THE EPC

The EPC is expected to provide the evolution of any deployed access network technology, wireless or wired, towards a common core architecture. The benefits of this will be seen as seamless mobility between various generations of access networks and global roaming capabilities on different technologies [1]. It will also enable network designs based on high availability, reliability, scalability, and manageability paradigms, as well as efficient bandwidth usage in the access and core networks.

The EPC supports the delivery of combinations of advanced telephony and Internet services. It provides user security functions such as privacy and confidentiality, while protecting the network through functions like mutual authentication and firewalls. Finally, the EPC minimises the number of services databases and the number of service controllers, which reduces the number of provisioning points in the network. This allows it to provide an efficient charging architecture that reduces the number of network elements sending billing records and minimises the number of billing records formats [1].

EPC manages event-oriented policy-based access control, QoS and mobility in a single operator core network. This makes the EPC the next generation transport level for signalled services.

A. The EPS bearer

To understand the mechanisms of providing QoS and resource management within the EPS, it is necessary to expand on the concept of the EPS bearer. A bearer is a level of granularity for QoS control, i.e. the bearer provides a logical connection between the UE and the Packet Data Network Gateway (PDN-GW) through which IP packets can be transported. The PDN-GW functions as the exit point from the EPS extending towards external IP networks. Fig. 2 illustrates the concept of bearers in the EPS.

Essentially bearers are a logical concept. Each network entity – eNodeB (LTE Node B), Serving Gateway (S-GW) and PDN-GW – has mapped parameters that ensure that this logical transport is available to the end user. For example, the PDN-GW has functions, such as packet filtering, rate policing and mapping QoS Class Identifiers (QCI) values to DiffServ Code Points (DSCP), to facilitate that the IP flows allocated to specific bearers receive their required treatment. This is done to ensure that the end user perceives the adequate level of QoS.

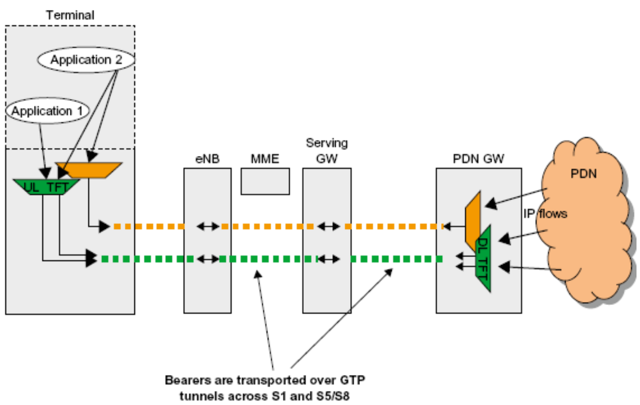

Figure 2: Bearers in the EPC [1]

B. *Policy and Charging Control (PCC) Architecture*

The Policy and Charging Control (PCC) architecture is central to ensuring that all the necessary entities within the EPC are aware of bearer related functions. The Policy and Charging Rules Function (PCRF) sets and sends policies to be implemented to the Policy and Charging Enforcement Functions (PCEF). In the EPS architecture, the PCEF is collocated within the PDN-GW. Depending on whether the EPC uses the on-path or off-path model, the PCC will have different functionalities. On-path refers to the termination of bearers at the PDN-GW; this model is used when the GPRS Tunnelling Protocol (GTP) is used for user data transportation. Off-path refers to the case when bearers terminate before the PDN-GW (i.e. at the S-GW); this model is used when the Proxy Mobile IP (PMIP) protocol is used for user data transportation. For more information on this, see [6]. Because bearers will terminate before the end of the EPC domain, at the S-GW, the off-path model requires the implementation of a Bearer Binding and Event Reporting Function (BBERF) at the S-GW. This allows for the necessary mapping needed to enforce QoS rules on packet flows at bearer level. The PCC architecture is illustrated in Fig. 3 below.

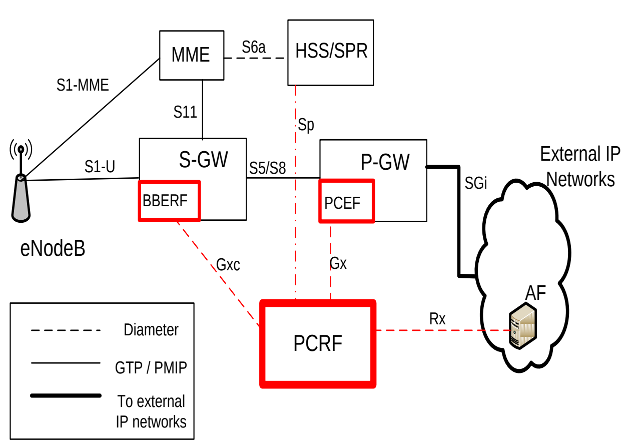

Figure 3: Policy and Charging Control architecture of the EPC.

C. *Services in the EPC*

The EPC is designed for IP services; this means that any application relying on IP communication can be delivered by the EPC. The applications that are delivered to the mobile users through the EPC can either be provided by the mobile operator or accessible over the Internet in an 'over-the-top' or OTT manner. For the case of services provided by the mobile operator, the services can be either IMS based or non-IMS based. The IMS (IP Multimedia Subsystem) was designed by 3GPP, and other standardisation bodies, to enable IP-based multimedia services for wireless, fixed and mobile networks. The IMS has been largely accepted in the Telco environment as the service management level framework when deploying the EPS. One main advantage of the IMS is that it is able to offer a controlled environment for the deployment of IP services that increase the value of the "Telco bundle". Even as there is strong interest in OTT Web-oriented developments, these are seen by Telcos as a threat, as there is no standard mechanisms in the Web 2.0 environment to offer revenue-generating real-time services [12].

D. *Requirements and Enhancements*

The focus of this work is to consider an evolved service deployment architecture where the service delivery plane of an Evolved Packet System network is optimised to be able to offer best QoS for services. In order to have a network that allows for optimized QoS control tailor-suited for services, certain requirements need to be considered. These are detailed below:

- We consider a network whereby the transport for data traffic is traversed through the EPC. This EPC also contains a PCC framework, as per 3GPP standards.
- This evolved core allows for services to be offered by Application Functions (AFs) from external IP networks, one such network being the IMS.
- This AF needs to have real time UE contextual information. This information can be the access network that the user is currently connected to, or the device capabilities of the UE.
- The AF also needs to have real time bearer information on established bearers that are transporting the service to the end user, i.e. if a bearer is modified or deleted.
- Optionally, for charging purposes, In order to allow for charging control, the information in the PCC rule identifies the service data flow and specifies the parameters for charging control. The PCC rule information may depend on subscription data.

III. Resource Management and Service Adaptation Architecture

With the development of novel applications specifically tailored for the mobile wireless environment, such as mobile IPTV, and in addition to the already successful services which will be transferred from the fixed communication and from the Circuit Switched domain, it is foreseen that the best-effort approach on delivering the services cannot sustain the required quality of experience for the mobile users. In order to face this challenge the next generation mobile network core will offer more than IP bitpipes for communication adding the QoS support. If a service is established the required resources for the service should be reserved no matter of the degree of congestion on the access networks. This is perceived as the quality of experience of the service.

A. Application Function Enhancements

The AF is central to the application level control of service delivery to the UE. This refers to the signalling and control of the service session setup and/or modification for multimedia services. As the EPC is transparent to the services, the AF has the option to subscribe to bearer session information. This will allow the AF to take different actions, for example if a handover event occurs for the end user.

The 3GPP adopts the use of the Diameter protocol to transport all Authentication, Authorization and Accounting (AAA) related messages between functions [7]. A Diameter interface is then needed at the AF to be able to communicate with the PCC framework of the EPC. Diameter is specified as a base protocol and is complemented by a set of application protocols that add on to the base protocol functionality. Diameter messages are either requests or answers. These messages contain Attribute Value Pairs (AVPs) and AVPs are containers of data. The Rx reference point, the interface between the AF and the PCC, adopts the Diameter Network Access Server Application [8]. When a new AF session is being established and media information for this session is available, the AF would open an Rx Diameter session with the PCRF for the AF session using an Authentication and/or Authorization AA-Request command [9]. The AF will then provide the full IP address of the UE (using either a Framed-IP-Address AVP or a Framed-IPv6-Prefix AVP), and the corresponding Service Information within Media-Component-Description AVPs. This process can be seen in sections A and B of Fig 3.

At this point, the AF can then subscribe to notifications of the status of the related bearer. To do so, the AF would include in the initial AA-Request command the Specific-Action AVP requesting the subscription to one or all of indicators below:

1. INDICATION_OF_LOSS_OF BEARER
2. INDICATION_OF_RELEASE_OF_BEARER
3. INDICATION_OF MODIFICATION_OF_BEARER

If the AF has successfully subscribed to change notifications in UE's Radio Access Technology (RAT) type, the PCRF shall send a Re-Auth Request (RAR) command when a corresponding event occurs, i.e. when the UE’s RAT type changes. In this case, the RAR from the PCRF shall include the Specific-Action AVP for the subscribed event and include the RAT-Type AVP for the UE's new RAT. This process can be seen in section C of Fig. 4.

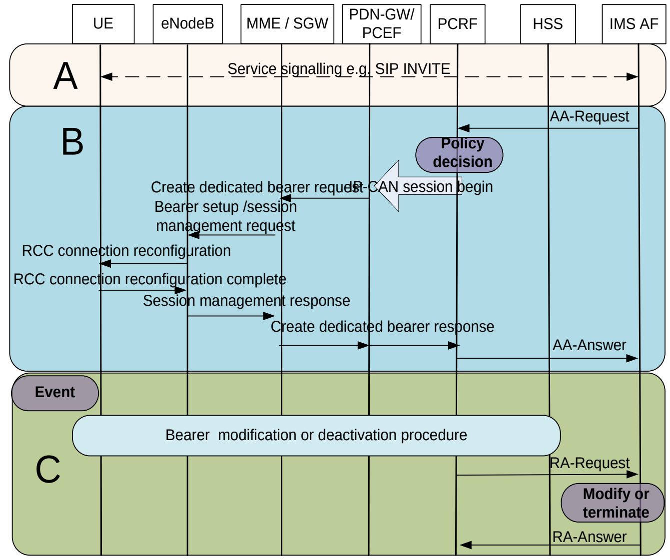

Figure 4: AF signalling procedures with the PCC

B. Architecture Building Blocks

The following components or domains would then comprise the Resource Management and Service Adaptation Architecture:

1) Access Network Domain

The network-access layer allows for the connection of EUs to connect to the EPS network. Access technologies can include fixed access (DSL, cable, modems, Ethernet), wireless access (WLAN and WiMax), and mobile access (Mobile WiMax, WCDMA, CDMA-2000, GPRS, UMTS and LTE).

2) Core Network Domain

The Packet Core domain consists of nodes and functions that provide support for packet-switched services for the Access Network Domain. The packet core domain also provides functions for subscription management and enforcement of service and bearer level policies.

3) Service Delivery Domain

The EPC is flexible to offer any IP connectivity for any type of service network. This could be the public internet, a private corporate network or an IMS network. The IMS domain consists of nodes and functions that provide support for multimedia sessions based on SIP (Session Initiation Protocol), and utilises the IP connectivity provided by the functions in the Packet Core domain.

4) Mobile User Equipment.

The ‘Terminal’, ‘End-User Terminal’, or ‘User Equipment (UE)’ are all used to denote the actual device communicating with the network. This machine or device would be able to attach to the network and receive IP connectivity.

IV. Implementation and Testing

The platform proposed is designed to expose the functionalities of the EPS. A resource management and context aware platform is proposed to work in the 3GPP Evolved Packet Core.

A. Testbed Components

The proposed framework is designed such that the four logical building blocks of the mobile network are represented. These are the User Equipment, Access Network, Core Network and Service Delivery platform. This testbed is illustrated in Fig. 5.

1) UCT IMS Client

The UCT IMS Client [9] was developed to provide an easily configurable real IMS user agent. It performs registration with the IMS Core, voice/video calling, and IPTV viewing. It implements signalling according to IETF and 3GPP standards.

2) Fraunhofer FOKUS OpenEPC

The FOKUS OpenEPC [10] platform is a non-open source EPC platform that is designed to enable academia and industry to integrate various network technologies and integrate various application platforms into a single local testbed. This platform can be used to perform research and development in the fields of QoS, mobility and security. The OpenEPC is conformant to 3GPP specifications (Release 8). This platform was chosen because of its high performance capabilities, adaptability to different deployment scenarios and configurability. This platform contains, among others, the eNodeB, S-GW, ePDG, PDN-GW, PCRF and IMS entities. This platform also emulates the WLAN and UMTS access networks through which IP clients can attach to the OpenEPC network.

3) UCT Advanced IPTV Server

IMS-based IPTV benefits from the enhanced service control capability of the IMS, e.g., QoS control, charging and billing services. The IPTV server is implemented as an indirection application server. When a user selects a TV channel or a VoD stream a request is sent to the IPTV server, which responds by sending a Real Time Streaming Protocol (RTSP) address to the client. Using the address, the client can access the requested media from the media servers. For PCC purposes, the message flow is interrupted for notification of the PCRF of service initiation, and subscription to bearer events for the service.

B. Evaluation

The tests carried out are proof of concept tests that demonstrate the functionality of the Resource Management and Network Context Awareness framework, and measure its performance impact with regard to service response times to initiation and modification of bearers for services.

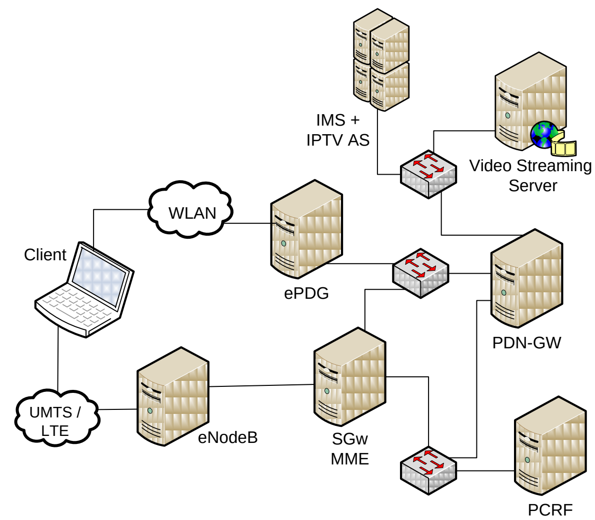

Figure 5: Testbed layout

1) Proof of concept

The IPTV Application Server (AS) functions as the AF for this scenario. When a registered IMS user initiates an IPTV session, by sending a SIP INVITE message to the application server, the PCRF is immediately contacted and the necessary functions are performed. The PCRF is the central policy control function of PCC. To allow for effective allocation of QoS to bearers, it needs to have certain information about the established bearer, as well as resource availability within the network. It receives session information over the Rx reference point and information from the network via the Gx/Gxc reference points. The PCRF considers the available information and creates service-session level policy decisions. The decisions are then provided to the PCEF (and the BBERF if the off-path model is used). The AF upon receiving a successful response from the PCRF then initiates either a SD or an HD video stream, depending on whether the user is attached to UMTS or WLAN access network respectively.

The AF needs to have real time UE contextual information and receives this by subscribing to these events from the PCRF. When the UE performs a seamless handover, the PCRF would notify the AF that the established bearer has been modified, with information about the target access network. This then allows the AF to switch between the SD or HD versions of the streamed video to the user.

2) Performance Measurement

To assess the AF's response time to dedicated bearer setup, process B in Fig. 4, the response time measurements are taken over a test case of 20 instances. These results are shown in Table 1.

Table 1: AF Response Time to Bearer Initiation

Access Network	Average Registration Time (s)	Min Time (s)	Max Time (s)
UMTS	0.297	0.237	0.347
WLAN	0.307	0.237	0.345

Furthermore, tests were conducted to gauge the response time to dedicated bearer modifications or termination (in our case when a handover event occurs). Table 2 below records the times taken to transfer an ongoing session from the "originating network" to a "destination network". The time recorded in the table below is the process C in Fig. 4.

TABLE 2: HANDOVER EVENT RESPONSE TIMES

Original Network	Destination Network	Average Switching Time (s)	Min Time (s)	Max Time (s)
UMTS	UMTS	2.227	1.769	2.556
UMTS	WLAN	2.460	1.972	2.755
WLAN	UMTS	2.446	2.158	2.765
WLAN	WLAN	2.065	1.799	2.216

3) Discussions

Proof of concept tests were carried out using different scenarios. The observed outcomes for each scenario corresponded to what was expected based on the theoretical framework. These tests validated the evaluation platform as an accurate testing environment to evaluate the proposed framework. From a Quality of Experience perspective, the user is able to notice a change in video quality as they move to different access networks.

The transition from UMTS to WLAN is smoother than that from WLAN to UMTS. This is attributed to the average 2.4 second response time for the AS to notice that the user has changed to an access network that offers less bandwidth. This could become more pronounced when more users are being serviced by the AS. Although there are noticeable delays for the end-user for that scenario, we consider the delay time to be small enough to not inconvenience the user significantly.

V. CONCLUSIONS

In this paper, we have presented the enhanced Application level QoS mechanisms for services in the EPS. We have presented a motivation for the application function to adapt to the changing context of a mobile UE in the multi-access network environment offered by the EPC. The additional call processing overhead due to the interaction with the PCC is not significant enough to cause an adverse effect on user experience. In implementing the functions of the Rx interface at the IMS AF, the IPTV server is modified with accordance to 3GPP technical specifications. The simple case of adjusting video quality depending on the access network of a UE demonstrates that proof of concept has been achieved. Furthermore, the interaction of the AF and the PCRF does not result in any service disruption as the EPC is readily designed for seamless handovers. The reaction time of the AF to these events affects the readiness to which the video stream is adjusted to the changing context.

The major contribution of this work is seen as the prototyping of services enhanced for the EPS in a practical testbed environment. This allows for further investigation into aspects such as security, charging and mobility. It is important to engage in research work that illustrates, by prototype development, the actual implementation of proposed frameworks. This gives a real life indication of the functions of these networks and how viable it is for network operators to deploy these systems in their future network architectures.

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