A Framework to Provide Charging for Third Party Composite Services

Prepared by:

Joyce Bertha Mwangama

Supervised by:

Neco Ventura

Submitted to the Department of Electrical Engineering in fulfillment of the requirements for the degree of Master of Science in Electrical Engineering at the University of Cape Town

December 2010

Declaration

I declare that this thesis, *A Framework to Provide Charging for Third Party Composite Services*, is my own work. All sources that I have used or quoted have been indicated and acknowledged in the references. This work has not been submitted to any other university for any other degree or examination.

Joyce Mwangama

Date

Acknowledgements

I would like to thank the following individuals for their help during the course of this project.

My parents, thank you for always believing in me.

Mr. Neco Ventura, for his supervision and guidance throughout the duration of this project.

Richard Good, Vitalis Ozianyi, Richard Spiers, Phillipa Wilson, Eugene Golovins, Mphakiseng Masuabi, Michael Nyarko for their invaluable advice and assistance throughout the project.

Everyone I love, like and hate a little bit: Kefilwe Lebepe, Holiday Kadada, Ropfiwa Sithubi, Francine Nahamina, Vangile Mashinini.

Synopsis

Over the past few years the trend in the telecommunications industry has been geared towards offering new and innovative services to end users. A decade ago network operators were content with offering simple services such as voice and text messaging. However, they began to notice that these services were generating lower revenues even while the number of subscribers increased. This was a direct result of the market saturation and network operators were forced to rapidly deploy services with minimum capital investment and while maximising revenue from service usage by end users.

Network operators can achieve this by exposing the network to external content and service providers. They would create interfaces that would allow these 3rd party service and content providers to offer their applications and services to users. Composing and bundling of these services will essentially create new services for the user and achieve rapid deployment of enhanced services. The concept of offering a wide range of services that are coordinated in such a way that they deliver a unique experience has sparked interest and numerous research on Service Delivery Platforms (SDP). SDP's will enable network operators to be able to develop and offer a wide-variety service set. Given this interest on SDP standardisation bodies such as International Telecommunications Union – Telecommunications (ITU-T), Telecoms and Internet converged Servicers and Protocols for Advanced Networks) (TISPAN), 3rd Generations Partnership Project (3GPP) and Open Mobile Alliance (OMA) are leading efforts into standardising functions and protocols to enhance service delivery by network operators. Obtaining revenue from these services requires effective accounting of service usage and requires mechanisms for billing and charging of these services. The IP Multimedia Subsystem (IMS) is a Next Generation Network (NGN) architecture that provides a platform for which multimedia services can be developed and deployed by network operators. The IMS provides network operators, both fixed or mobile, with a control layer that allows them to offer services that will enable them to remain key role players within the industry. Achieving this in an environment where the network operator interacts directly with the 3rd party service providers may become complicated.

The network operator can then provide the user access to external services over their

NGN infrastructure with the aid of the IP-based service control layer of the IMS and an SDP that incorporates an open API to over the top services. The network operator can provide charging for these services by incorporating a Converged Charging System with the network to provide universal charging for all available services. The network operator is then in an optimum position to provide control for these services and thus offer the Quality of Service (QoS), security and availability that service providers may not be able to guarantee their users.

This thesis defines a framework that would allow for the effective charging and billing of services composed from third party service and content providers. The use of a service mediator that forms a gateway between an IMS network operator and the many content providers is proposed. This allows for the creating of new services that are composed from independent applications; the service mediator simplifies the technical and business aspects of service provision while ensuring that charging and billing occurs within the network. Design of the framework took into account the different requirements of all stakeholders including the end user, and aims to address the drawbacks of existing solutions found in literature. The main aim would be to offer service delivery that provides an acceptable quality of experience for the end user, despite the fact that services are external to the network operator. An evaluation platform was implemented to measure the effects of session establishment times as well as the effects of charging functions being implemented before and during established service sessions. The evaluation platform uses the Fraunhofer FOKUS Open IMS Core; the Java APIs for Integrated Networks Service Level Execution Logic (JAIN SLEE) server implementation by Mobicents and the UCT IMS Client.

Proof of concept tests confirmed the evaluation platform as a suitable testing environment for the proposed charging and service delivery framework. Tests to evaluate the effectiveness of service delivery to the end user were performed. Analysis of results showed that session setup latencies remained within acceptable parameters despite the added signaling incurred within the framework; the service mediator performed adequately even when the number of service requests increased; the charging functions required for service delivery did not adversely affect the actual service delivery for the end user. Future work includes extending the testbed to allow for higher scalability testing where more users are requesting services and modifying the network interfaces to allow for a generic service mediator that is not limited to an IMS network and that provides an interface to Internet services.

Table of Contents

List of Figures

List of Tables

List of Acronyms

3GPP	Third Generation Partnership Project
AAA	Authorisation, Authentication and Accounting
ABMF	Account Balance Management Function
ACA	Accounting Answer
ACR	Accounting Request
AF	Application Function
ALG	Accounting Logic Generator
AN	Ambient Networks
API	Application Programming Interface
AS	Application Server
ASP	Application Service Provider
AVP	Attribute Value Pair
B2BUA	Back to Back User Agent
BGCF	Border Gateway Control Function
BGF	Border Gateway Function
BGP	Border Gateway Protocol
CAMEL	Customised Applications for Mobile Network Enhanced Logic
CAP	CAMEL Application Part
CC	Credit Control
CCA	CC Answer
CCR	CC Request
CDMA	Code Division Multiple Access
CDR	Charging Data Records
CGF	Charging Gateway Function
CSCF	Call Session Control Function
CSP	Content and Service Providers
CTF	Charging Trigger Function
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server / System
DSL	Domain Specific Language

DSL	Digital Subscription Line
EBCF	Event Based Charging Function
ECUR	Event Charging Unit Reservation
EDGE	Enhanced Data Rates for GSM Evolution
EPC	Evolved Packet Core
EPS	Evolved Packet System
EPSRC	Engineering and Physical Sciences Research Council
ERG	Event Routing Gateway
ETSI	European Telecommunications Standards Institute
FHoSS	FOKUS Home Subscriber Server
GPRS	General Packet Radio Services
GSM	Global System for Mobile Communication
GSOA	Generic Service Oriented Architectures
GUI	Graphical User Interface
HSDPA	High Speed Downlink Packet Access
HSS	Home Subscriber Server
HTTP	Hypertext Transfer Protocol
I-CSCF	Interrogating - CSCF
ICT	Information, Communications and Technology
IEC	Immediate Event Charging
IETF	Internet Engineering Task Force
iFC	initial Filter Criteria
IM	Instant Messaging
IMPI	IP Multimedia Private Identity
IMPU	IP Multimedia Public Identity
IMS	IP Multimedia Subsystem
IM-SSF	IP Multimedia - Service Switching Function
IP	Internet Protocol
IPTV	Internet Protocol Television
ISC	IMS Service Control
ITU-T	International Telecommunications Union - Telecommunications Standardisation Sector

JAIN	Java APIs for Integrated Networks
KPI	Key Performance Indicator
LAN	Local Area Network
LTE	Long Term Evolution
MAP	Mobile Application Part
MBMS	Multimedia Broadcast and Multicast Services
MCF	Media Control Function
MDF	Media Distribution Function
MGCF	Media Gateway Control Function
MMS	Multimedia Messaging Service
MNO	Mobile Network Operator
MRF	Media Resource Function
MRFC	MRF Controller
MRFP	MRF Provider
MVNO	Mobile Virtual Network Operator
NGN	Next Generation Network
OCF	Online Charging Function
OCS	Online Charging System
OFCS	Offline Charging System
OMA	Open Mobile Alliance
OSA	Open Services Architecture
OSIMS	Open Source IMS Core
PCEF	Policy and Charging Enforcement Function
PCRF	Policy and Charging Rules Function
P-CSCF	Proxy - CSCF
PDF	Policy Decision Function
PLMN	Public Land Mobile Network
PoC	PPT over Cellular
PSTN	Public Switched Telephone Network
PTT	Push To Talk
QoS	Quality of Service
RAN	Radio Access Network

RF	Rating Function
RFC	Request For Comments
RTP	Real Time Protocol
RTSP	Real Time Streaming Protocol
SAE	System Architecture Evolution
SBCF	Session Based Charging Function
SCS	Service Compatibility Server
S-CSCF	Serving - CSCF
SCUR	Session Charging Unit Reservation
SDP	Service Delivery Platform
SER	SIP Express Router
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SLEE	Service Level Execution Logic
SLF	Subscription Locator Function
SMS	Short Message Service
SOA	Service-Oriented Architecture
SQL	Structured Query Language
TCP	Transmission Control Protocol
TISPAN	Telecoms and Internet converged Services and Protocols for Advanced Networks
TMF	TeleManagement Forum
UCT	University of Cape Town
UDP	User Datagram Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunications Standard
UTRAN	UMTS Terrestrial RAN
VoD	Video on Demand
VoIP	Voice over IP
WCDMA	Wideband CDMA
WLAN	Wireless LAN
XML	eXtensible Markup Language

Chapter 1

Introduction

The Public Switched Telephone Network (PSTN), which allows people to communicate with each other using natural voice, is considered to be one of the most complex systems in the world [13]. Based on this network, core network technologies for radio and mobile communication have evolved to allow communication for voice, data and multimedia service offerings in fixed and mobile networks.

Today it is estimated that 1.8 billion people worldwide make use of the internet daily [14]. In the Information, Communications and Technology (ICT) industry, as in many other modern industries, services have become the main differentiator when it comes to competing for end-users' attention. Service provisioning is among the core drivers of the telecommunications industry [1]. Application developers, service providers and content providers offer an important source of new services that telecom operators can in turn provide for their end users. Telecom operators have a good foundation in terms of infrastructure in place for the provisioning of these services however external and independent applications and service developers have deeper customer understanding. This stems from the fact that up until recently Telcos' concentrated on offering limited services such as the traditional voice and text-messaging services. They have come to realise that costumers are enticed by more exciting and innovative services and they are thus adopting their offerings.

The telecommunications industry has gone through some major transformations. These have come in many forms, from maturing markets to increased competitive pressures. Customer behaviour is also evolving and affecting the industry. We have also seen the reduction of price levels for basic services brought forth by the transition from circuit switched to packet switched networks. Table 1.1 shows the drop of VoIP revenue received from individual users over a 4 year period. In packet switched networks, the dominant services are IP based services such as multimedia messaging, streaming and content browsing. These changes have brought along their fare share of problems. These manifest as lack of available bandwidth and appropriate handsets; lack of enticing services for customers and confusing charging schemes.

Table 1.1: VoIP calling statistics in North America [23]

	2005	2006	2007	2008
Subscribers (millions)	4.2	12.1	16.3	24
Revenue per subscriber / month	$42	$29	$29	$25

Handset manufacturers have begun developing and deploying into the market place smart devices that contain impressive hardware and software. These devices continue to have high bandwidth requirements and place high demands on radio access technologies. More applications are being offered to users through systems that boast flexible architectures. This is how next generation networks came to be. It brought about the convergence between traditional telecoms and those of Internet technologies. Users can now access voice services, video services and data services anytime, anywhere and through any stationary or mobile device.

All these changes forced network operators to expand service offerings and find new sources of revenue. As infrastructures develop and become complex, current business models and ways to create value to end users are becoming outdated [1]. Network operators are presented with the challenge of offering new services to their customers. This will ensure that the network operator can retain customer attention and in turn increase revenue received from the customer. If they cannot achieve this they face the prospect of becoming mere “bit-pipes” and losing out to ‘over the top services’ and the competition that this brings to the traditional network operator.

1.1 Research Motivation

The key buzzword being thrown around is convergence. In terms of telecommunications this can mean service convergence, technology convergence, convergence of networks and device convergence. Users want to be able to access everything that they need, all the time. In terms or charging, it means that users pay one bill. In terms of business operations, it means that different domains, network operators and service providers, need to combine resources in order to achieve true convergence.

Network operators and service providers must evolve their business models to reflect these new realities. Key issues to be addressed are how to manage a value chain that contains multiple business partners. Figure 1.1 models how the flow of content and third party services reaches the end-user while revenue from these services propagates in the opposite direction. Increased service usage brings about rapid growth in volume of transactions. This equals complexities for the network operators and impacts on scalability. Bringing order to the convergence of fixed and mobile networks requires a more efficient and flexible network management infrastructure.

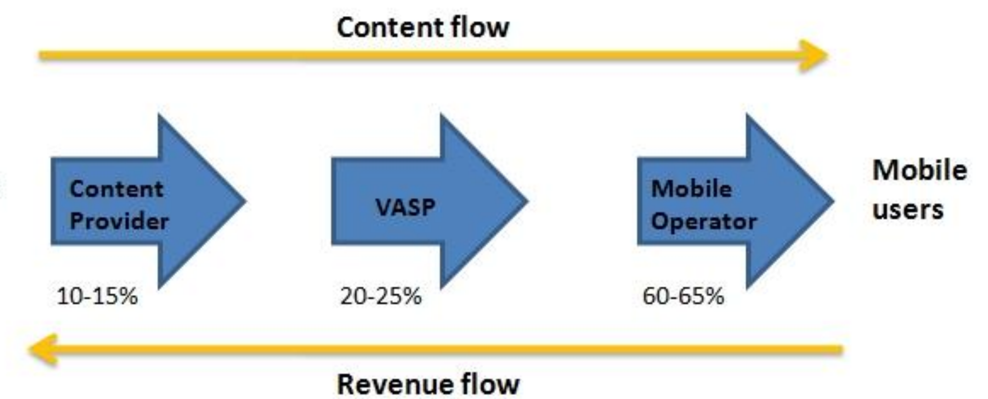


Figure 1.1: Third party content value chain

Subscribers are faced with confusing options, which act as impediments to adoptions and the slow growth of average revenue per user. Multiple pricing schemes (fixed, subscription, location based, prepaid, post-paid, pay now) complexities surrounding new technologies, user interaction and security are examples. There is a need for different types of charging depending on the type of service being used. The classic charging scheme that has been used is the flat rate charging scheme where users are charged the same rate regardless of service usage. This scheme is proving to be inadequate when dealing with the plethora of service offerings and types that are now becoming available to the end user. Figure 1.2 and Figure 1.3 show how different types of services require different charging mechanisms and options. These are taken from the 3GPP

Technical Specification on Services and System Aspects for charging and billing [50]. This document highlights in detail the high level principles and charging requirements for users, network operators and 3rd party service providers in an All-IP network.

CHARGING REQUIREMENT	DESCRIPTION
Downloaded items	User is charged for a specific item downloaded eg a music file, video clip, application
Location based services	User is charged for receiving information on his location (charging based on accuracy as an option). This could be a stand-alone location query or linked to another service
Content accessed or downloaded	User is charged according to the value of the information. Eg weather information, share price or other financial information
M-Commerce	Electronic transactions to 3rd party suppliers of goods & services
Use of portal or other site	User is charged for any access to a portal or any other site. This could be a one-off charge or based on duration or data volume of the portal or site use
APN and associated content	User is charged for access to a specific APN and for the content associated. Requirements are for further study.
Actual duration of rendered service	User is charged (e.g. for premium rate services or hotline) based on the actual duration of the rendered service

Figure 1.2: Charing requirement and description

COMPONENT	CHARGING MECHANISM OPTIONS	CHARGING TYPE OPTIONS
Voice	Charging principles as described in section 4.3.1.1	Charging by duration of session Charging by QoS requested and/or delivered One-off set-up charge
Real time Audio and Video	Charging principles as described in section 4.3.1.1	Charging by duration of session Charging by QoS requested and/or delivered One-off set-up charge
Streaming Audio and Video	Charged to the initiator of the request Charged to the sender of the audio or video	Charging by duration of session Charging by volume of data, optionally QoS-differentiated One-off set-up charge
Data (upload or download)	Charged to the initiator of the request Charged to the sender of the data	Charging by duration of session Charging by volume of data, optionally QoS-differentiated One-off set-up charge
Interactive Data	Charged to the initiator of the session	Charging by duration of session Charging by volume of data, optionally QoS-differentiated One-off set-up charge
Messaging (SMS text type)	Charged to the initiator of the message Charged to the recipient of the message	Charging by event (eg like SMS) Charging by volume of data
Unspecified content (data stream)	Charged to the initiator of the session Charged to all parties involved	Charging by duration of session Charging by volume of data (sent & received), optionally QoS-differentiated One-off set-up charge

Figure 1.3: Charging mechanism and options [50]

It is specifications such as those developed by the 3GPP that allow network operators to understand the relationship that they have with other network operators, 3rd parties cooperating with the network operator and their users in order to achieve the development of systems that cater for the requirements of all involved parties. The diagram below, taken from the specification mentioned above, also shows how the different entities are involved in charging and how they relate to each other.

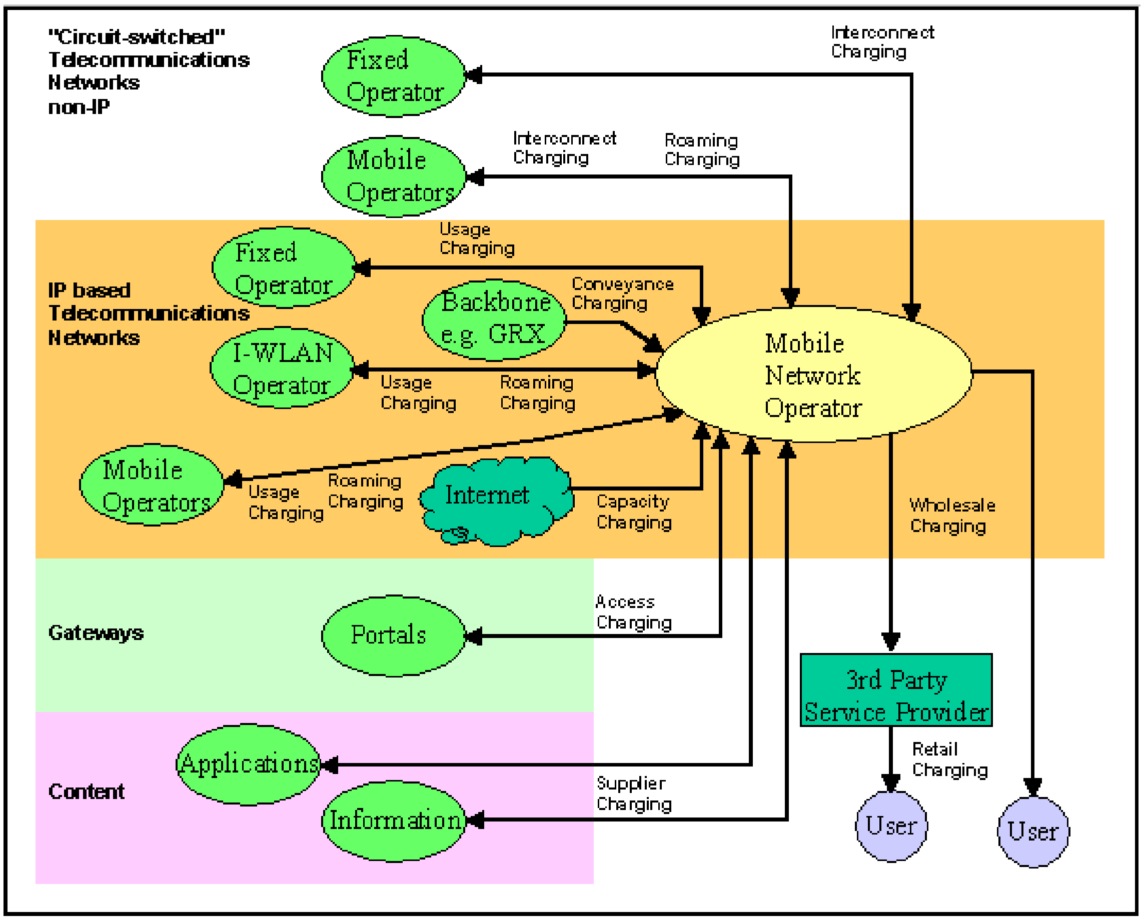


Figure 1.4: The types of entities and the relevant type of charging [50]

The network operator can choose to form business partnerships with existing service and content providers to offer services. By doing this, they will experience the advantage of achieving shorter service creation life-cycles as the services already exist and thus reduces the time to market, when compared to the alternative of manually developing services in-house.

Another advantage of having 3rd party service providers offering existing services is that these services can be arranged in such a way that when combined they can provide new functionality. The composite service would be presented to the user in such a way that the user remains unaware of actual content providers. This however greatly fragments and complicates the service environment due to the fact that multiple role players will be involved in the service value chain, thus key issues must be addressed to cater for new business relationships. All the while service life-cycles need to remain short and short time-to-market is required as the technological environment develops and more specific customer needs are assessed.

The drive for quad play (voice, video, data and mobility) is making network operators embrace the IMS. The IP Multimedia Subsystem is a next generation networking architecture that provides for interoperability between existing mobile networks and the Internet; it provides a platform on which multimedia services can be developed and deployed by network operators. The IMS enables network operators, both fixed and mobile, to offer services that will enable them to remain key role players within the industry. Deploying the IMS where many business entities are involved will prove to be challenging. The key role players can be classified either as the network operator, the service retailer or the content provider. Apportioning of revenue among all the entities is not a trivial matter. The environment should have processes that can accurately achieve charging, billing and accounting for the business partners.

1.1.1 Problem Definition

Success in this jungle marketplace will be those able to ensure that their subscribers enjoy a customer experience that is simple, consistent and transparent; one that rewards loyalties with innovative packages and engaging services. Content that is delivered through their device of choice whenever, wherever they want it, and at a fair price. And arguably most important, users will want to pay for all of it with a single bill.

In a saturating telecommunications market place network operators want to rapidly deploy services with minimum capital investment, while maximizing on revenue from service usage by customers. One way to achieve this is to create interfaces for 3rd party service and content providers to offer their applications and services to users. External and independent application developers with deeper customer understanding and more concentrated offering may shorten development times for services. This makes them focal partners to operators when creating value and providing services to end-users.

Composing and bundling of these services will essentially create new services for the user and achieve rapid deployment of enhanced services. Effective accounting of service usage requires mechanisms for billing and charging of these services. Achieving this in an environment where the network operator interacts directly with the 3rd party service and content providers may become complicated.

Existing systems do not allow services to be orchestrated almost arbitrarily depending on the changing user requirements. It remains unclear how to evolve these systems to provide essential features such as performance assurance, service-level security, accounting or fault detection for composed services [15].

There are a few issues that will need to be addressed in this type of multiple role player environments. Firstly, we now have to consider that there will be multiple administrative domains. These can belong to the network operators and the various service and content providers. Each domain may have their own way of doing things and thus makes integration a daunting task. Secondly, it is vital that services are delivered to the users with satisfactory QoS and adhering to SLA.

The issue of settlement of service usage charging across several service providers when they collectively provide application, information or communication services to an end-user is thus a key issue. Mechanisms would need to be in place such that various business and operator support systems in various domains co-operate adequately to provide seamless service provisioning to the end-user.

1.1.2 Research Questions

The main research question explored in this thesis can be summarised as follows:

- How can network operators maximise profits using IMS infrastructure and advanced converged charging and billing systems while cooperating with third party service and content providers?
- Network operators have access to systems that allow them to interface with service

and content providers but these systems are outdated in the face of emerging NGNs and related charging and billing mechanisms. How can these systems be enhanced or redesigned to cater for a shift in paradigms resulting from Telcos needing to offer services from external content and service providers (CSPs)?

- In this new environment where network operators are trying to achieve converged charging, new and innovative business models are being adopted to ensure that all parties can benefit from.
- Additionally network operators can now offer composite services that consist of different services from different CSPs. Charging of these services needs to be handled by the charging systems in an efficient and effective manner.

1.2 Thesis Objectives

The objective of this thesis is to propose a platform that allows for the composition of services offered by service providers not residing in the network operator's administrative domain. Furthermore, it highlights the additional steps that need to be followed to achieve unified charging and billing for these composite services. The framework is designed to use open API standards to allow for the charging of services composed from different service providers to be deployed over the IMS. In this work, the technical problem of providing services compositions and the subsequent charging for these is decoupled from the business problem of setting up and maintaining partnerships between the different stakeholders.

In summary, the objectives of this thesis are to:

- Present the available literature on the topics of composite services, third party service provisioning, and charging and billing frameworks for network operators.
- Analyse current implementations for composite services being offered by network operators highlighting the benefits and drawbacks of these implementations and furthermore to analyse related work in this field by bringing attention to gaps relating to the charging of users in these frameworks.
- Propose a charging and billing framework for third party composite services such that

the network operators are able to effectively deliver third party services to end users. This framework is designed to build on and fill in the identified gaps discovered in literature.

- Design the architecture of an evaluation platform that shows the achievability of such a framework being used as a meaningful solution by network operators for service provisioning with CSPs.
- In particular to analyse the effectiveness of the framework to perform service compositions of third party services, and to provide charging and billing for these services. This framework will enable testing and evaluation of the charging capabilities for third party composite services. In particular, how charging is achieved by the network operator and how CSPs can interface with the network operator in order to provide their services.

1.3 Scope and limitations

This thesis work aims to consider the business and technical relationship between a network operator and multiple service providers. The network operator has in its domain all the infrastructure that provides network resources to the end user. The third party service and content will provide their services using the infrastructure of the network operator.

Although this thesis investigates the different business aspects of a network operator forming a partnership with third party service and content providers, it does not go on to actually conclude, in a business sense, what form or partnership agreements should be undertaken by individual parties. In this sense, a partnership is seen as a cooperative agreement between two or more individual companies, in this case, the network operator and the service providers. This work does investigate the different models that can be adopted during the formation of partnerships but it does not specify which models are the best to be adopted as each adoption case will have its different influential factors for all business parties involved.

As the main aspect for this work is charging for services, the implementation of a charging framework is within the scope of this thesis. This charging framework is as specified by the 3GPP [8][9][10]. According to these specifications, charging can occur at three different levels; bearer level charging (in circuit-switched and packet-switched domains), subsystem level charging (in the IMS) and service level charging (specific to different types of services i.e. MMS, PPT, MBMS etc). Charging in the context of this thesis will focus on service level charging, and more specifically on services that do not belong to the domain of the network operator, i.e. not IMS services. This is because services residing in the network operator's domain do not introduce the charging correlation complexities that services of non-network operators have.

The scope of this thesis does not include the design and implementation of third party services. It is assumed that all services are already existing in the third party service or content providers' domains. Signalling is thus sent to these domains when service delivery is requested by a user. The composition process occurs at the network operator's domain, at a functional entity that represents the gateway between the network operator and the third parties domains. This is visually illustrated in Figure 1.5.

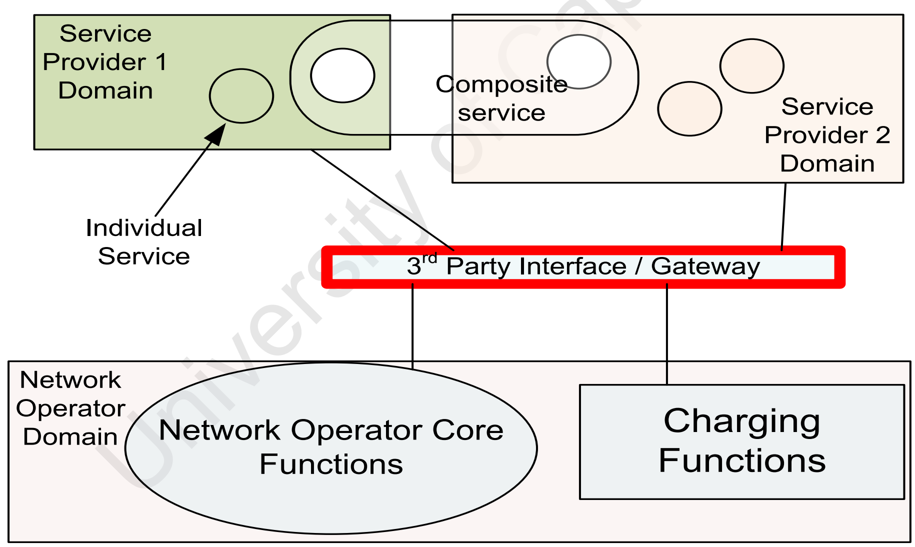


Figure 1 5: Interactions between the Network Operator and the 3rd party domain

We clarify for the purpose of this work, that the service composition process is not the composition of service functionality to be seen at the end user, it is merely the compositions of service delivery to the end user, and it is assumed that the end user equipment can adequately cater for these service compositions. This work does not investigate the composition of services offered by the network operators, residing within the domain of the IMS.

1.4 Thesis outline

The remainder of this document will be structured in the following manner:

Chapter 2 investigates related work and current research on service provisioning, charging for composite services as well as for third party services. It also investigates the charging and billing state of the art, and the business models that have been previously and are currently adopted by Telcos for service offerings. The chapter investigates the service delivery platforms that allow for interaction between network operators and other service providers and also how these can be interworked with next generation networks and future network architectures.

Chapter 3 presents the design considerations and requirements for a charging and billings platform that takes into consideration service compositions of third party services. More specifically, we take into account the requirements for the network operator, the service and content providers and the end users. We also highlight the charging requirements for specific types of services and then those for a composite service. Following on the presented considerations the design of a framework that offers charging for composite services for network operators using third party services is presented.

Chapter 4 details the design and architecture of the evaluation platform for the proposed framework. Firstly the chapter states the objectives that the evaluation framework aspires to achieve and the requirements of such a framework. The hardware and software of the framework is then presented as well as highlighting the limitations of the developed platform.

Chapter 5 analyses the evaluation platform. Proof of concept tests and performance tests were performed on the framework. The proof of concept tests are required to show that the architectural requirements of the platform are met and are a suitable testbed implementation for the stated scenarios. The performance tests ensure that the entities of the framework meet the requirement specified. This is followed by presentation and analysis of the results obtained using the test-bed.

Chapter 6 presents the conclusions and recommendations of this thesis drawn from the research study. The conclusions answer the research questions which were introduced earlier, based on the work investigated in the literature review, related works and on the evaluation of the proposed framework. The chapter also introduces potential future work which is recommended as a point of continuation from this thesis.

Chapter 2

Background and Literature Review

The previous chapter introduced the background of the Telcos environment with emphasis to the revenue generation climate of the ICT industry and how this can be improved if network operators provide capabilities for third party services. This chapter provides a brief overview of the different technical and economic aspects relating to composite service provisioning found in literature, and also how this is related to charging for the network operator.

2.1 Service Provisioning and Delivery Platforms

As previously highlighted, there has been a massive expansion in the IP-based services market. The final service set that is delivered to the end-user results in the combination of different service offerings [3]. From a service usage and accounting perspective, this new environment creates a number of important challenges, which did not apply previously in the monopolistic telecommunications environment. The delivery of these kinds of services has led standardisation efforts by several standardisation bodies such as ITU-T (International Telecommunication Union – Telecommunications) [24], TISPAN (Telecoms and Internet converged Services and Protocols for Advanced Networks) [25], 3GPP [26] and OMA (Open Mobile Alliance) [27].

These efforts have paved the way to much research and implementations of service delivery platforms for NGN, IMS and IP based services. R. Christian et al [28] discuss the role of services and service enablers within a standards-based NGN service delivery platform architecture. The authors provide a thorough background on NGN concepts and standardisation and how this directly maps to the Service Delivery Platform (SDP) concepts. The authors note that currently there is no standard for SDP design or implementation and currently most SDP deployments are proprietary. For the purposes of their implementation the authors present the concept of Generic Service Oriented Architectures (GSOAs) – expanding on the limitations of a normal Service Oriented Architecture (SOA) that is not technology independent – and implement these GSOAs using standards-based technologies. The advantage of using this approach to enhance an SDP is that GSOA is a generic template that allows for interoperability between the network operator, 3rd Party service providers and IT enterprises. One drawback of this work is they do not elaborate on which tools, they use to simulate or implement their framework, nor do they give obtainable results from tests run on their system. This work does show that successful interaction between the network operator's NGN and the application developer requires clearly standardised interfaces that provide a level of abstraction to the developer, hiding network dependent protocols.

H. Lu et al [29] discuss the evolution of SDPs (both in definition and in concept) and analyse the features and conceptual models of emerging next generation SDPs (NGSDP). They envision this NGSDP to have vast number of new features as compared to previous SDPs. These include the capability of integrating with various networks, supporting different standards, technologies and protocols; offer lower costs and lower risks to the network operator, resulting in faster return on investment; support of SOA-based and converging telecom with Web 2.0; providing an Open API Platform, and information sharing. The authors in this work do not implement a proof of concept framework but rather concentrate on developing the required definitions and technologies.

S. Maes [30] discusses similar issues to above, and in addition he also discusses the proposed Software-oriented architecture (SOA) blueprint of work tested and validated at Oracle. It highlights misconceptions within the Telcos industry such as how to develop services faster and at lower cost to the Telco. This can be done with the assistance of service enablers that can aggregate, and compose different services whether local to the operator or from 3rd party content and service providers (CSPs). The work also highlights the importance of Telcos embracing SOA; choosing to integrate Parlay with IMS and exactly how to implement the IMS Service Layer. The paper investigated Java Platform – Enterprise Edition (J2EE) as a platform to provide Telcos with a realistic realisation of OSE (OMA Service Environment) and proposed that J2EE middleware be used as a prediction or measurement to provide mobile voice and communications capabilities for 3rd Party service providers with Telcos'.

Ohnishi et al [31] highlight the requirements needed for SDP from the perspective of the network operator. These are mainly shortened application development periods; interworking with different technologies spanning multiple domains; protection of network functions and resources both from users and from 3rd party CSPs; customisation of services; and easy creation of applications and services. The work also proposes a SOA and Web service-based SDP to meet those requirements. In further work [32], the authors introduce an event routing gateway (ERG) that has virtualised endpoints that can receive notifications and forwards to the relevant scenario to provide composite services in a Telco-enterprise converged environment.

N. Blum et al [34] and [35] investigate the position of next generation telecommunication network operators and how they can securely open up their network capabilities and services to third party service providers. To allow for this requires flexible service delivery platforms, policy based service exposure, service discovery and service composition mechanisms. They present the use of their eXtended Policy based, Semantically enabled sErvice bRoker (XPOSER) which was developed over their Open SOA Telco Playground. The Open SOA Telco Playground is an IMS based NGN testbed for realizing SOA based NGN service delivery platforms. With XPOSER this work achieves intent-based NGN service discovery and allows for user-centric, automated service composition. Utilizing SOA based Operation Support Systems, this work explains requirements and solutions for dynamically managing NGN service compositions by tightly linking service creation, service fulfillment and service assurance mechanisms already at service composition time.

More related work can be found relating to SDPs, SOA, service enables and middleware platforms that propose how Telcos can interface their network capabilities with IT Web Services and external CSPs. Most of this work will provide new definitions for functional entities and APIs for Telcos thus introducing the problem of different adoption options. If there is no standardisation on interfaces for Telcos and external CSPs application developers cannot develop reusable services that are open to implementation options. Additionally this introduces an added complexity of different charging implementations from the network operator's perspective. This makes the adoption of new and innovative services even more challenging.

2.2 Third Party Applications and Services

Network operators want to see return in investments from 3G infrastructure and they are seeking this by promoting ecosystems of third party application/service providers who will be offer their services to users via their infrastructure. This is already a reality in the internet world.

There exist a number of technical limitations like the challenges of offering composed services. Dynamic service composition could be essential to offering value added services. With the steady adoption of Parlay and Parlay X type technologies within the telecoms industry, many third party applications have been developed and deployed in telecom networks [36]. It is becoming increasingly obvious that in today's telecommunications environment fierce competition lies not among enterprises, but rather among the supply chains [37].

OSA-Parlay/Parlay X defines a set of Web service APIs developed for the telecom network. It enables software developers to use the capabilities of an underlying network. These are mapped onto telecom specific protocols like the Customised Applications for Mobile Enhanced Logic (CAMEL) Application Part (CAP) and the Mobile Application Part (MAP), to provide listener-controller capabilities for different services [17]. However, extensions are required for this framework to add network reconfigurability for Quality of Service, user customisation, and support of adaptable service provision and flexible charging schemes.

Composed services can be offered by a service provider that does not reside in the same administrative domain as the network operator. Mobile Virtual Network Operator (MVNO) may be seen as service composers, since they reside between service providers and Mobile Network infrastructure Operators (MNO). However, they also manage user subscriptions and profiles. Thus to users, the MVNO appears like a conventional MNO and introduces more competition to the network operator. In addition to working with MVNO, conventional operators need to deal with non-competitor service composers to gain a stronger edge in the business.

L. Xu et al. [2] propose an architecture for automating the deployment and application of charging schemes for third party composed services in the IMS. They use a Domain Specific Language (DSL) to develop an Accounting Logic Generator (ALG) that achieves this. This work however does not take into account the implications of real-time charging on service. Additionally rating is performed in a distributed manner which means that charging is not performed in a unified solution. This introduces the complexity of having to implement charging in multiple domains.

M. Koutsopoulou et el. [4] propose a generic platform for charging, billing, and accounting in future mobile networks. This platform incorporates the functionality of existing network elements and enables any involved players to dynamically apply different charging requirements, policies and schemes. The charging capabilities of the system reside within the CPSs domain and similar to [2], requires that charging be handled in a complex and distributed manner.

J. Yim et al [39] outline how the Parlay Web service gateway can be connected to IMS. They present an implementation of one of Parlay X APIs, Third Party Call API, and how it can be utilised within the context of the IMS. Most of the above work presents solutions to the complexities of involving third party service and content providers in the value chain of network operators' service offerings with the added consideration of how to provide charging capabilities for these services. These solutions, however, do not give real-industry tested implementations that can prove beneficial to a Telco.

Anjum et el [38] present the architecture, design and implementation of ChaiTime, an open system architecture for the rapid development of advanced next-generation telephony services. ChaiTime allows communications sessions to be set up over the PSTN, the Internet or a combination of both. Services can be provided by multiple cooperating distributed service providers, some of whom use third-party software components which are invoked as needed. This work was done prior to the subsequent standardisation and deployments of NGN networks, thus although outdated, gives a prototype implementation of a tested solution that allows for composition of third party software.

2.3 Charging and Billing

The Internet Engineering Task Force (IETF) defines Authentication, Authorisation and Accounting (AAA) protocols and the related information models that can be implemented for charging and billing purposes. These protocols are explicitly defined in their respective RFCs. One such protocol that is used extensively for charging purposes is the Diameter protocol defined in RFC 3588 [6]. The Diameter base protocol is intended to provide an AAA framework for applications such as network access or IP mobility. It is also structured to provide functionality for roaming user equipment. This specific RFC defines the base protocol and higher level application protocols are defined in other RFCs. They are based on the functionality of the base protocol and the required functionality needed from the application protocol. This can be seen in figure 2.1.

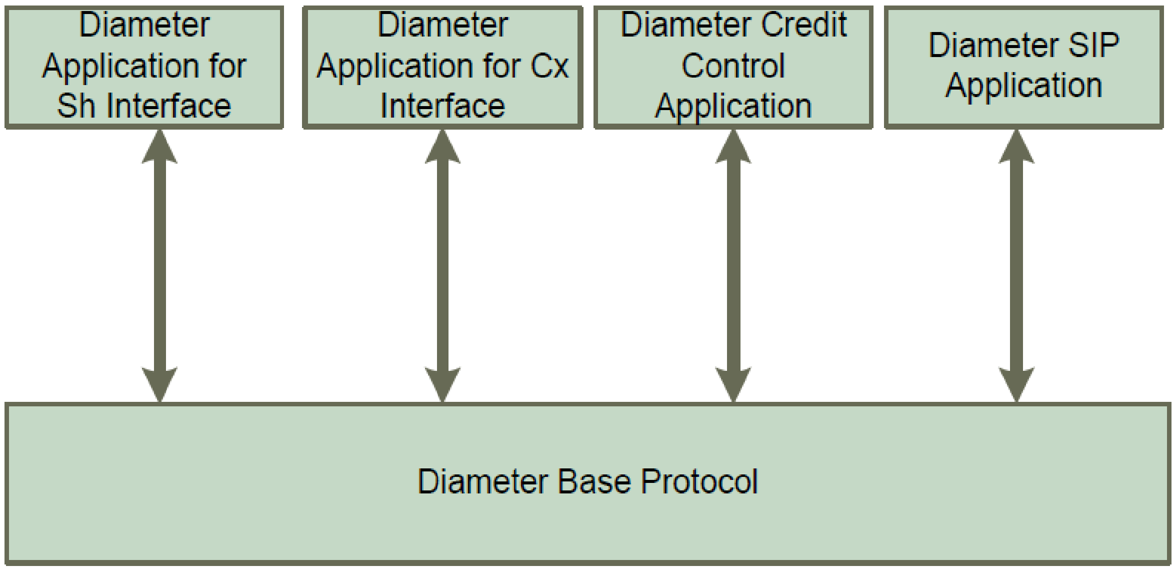


Figure 2.1: Diameter Base Protocol and Applications

The AAA protocol is used for most charging architecture specifications and is used extensively by the 3GPP in its charging specifications. For this reason all charging implementations that claim conformance to 3GPP Technical Specifications use the Diameter protocol: base protocol and application protocols. Further detail relating to the Diameter protocol can be found in Appendix C.

2.3.1 Legacy Charging

Traditional telecommunication and internet services are known to adopt simple charging mechanism such as fixed and flat-rate options. NGN introduces complexity to charging as a variety of multimedia services are offered with each having diverse and complex issues pertaining to its deployment. This makes charging difficult to implement for these services. These complexities arise because consideration of how content delivery is provided to the end user needs to be taken. New constraints are introduced such as multiple levels of Quality of Service or whether content is originally provided by third party content providers, as is the usual case in IPTV where the network operator is not the primary provider of the media content. The multitude of services results in having many different charging models that need to cater for the different types of services offered in an NGN network. Even more complexity is introduced when we consider that a user might be subscribing to different services simultaneously and the network operator has to manage the user's account both accurately and efficiently. Some networks may even choose to have fluctuating rates i.e. depending on the time of day the service was requested. All these factors emphasise the need to develop efficient standardised charging architectures to ensure commercial success for NGN networks.

T. Choi [40] highlights the new types of services that can now be offered over NGN networks and emphasises that these services require new charging capable functions. For example the service of interactive TV and VoD for mobile users would introduce a very complex billing environment due to the multiple service providers that would be involved in such an implementation. Additionally, various charging policies would need to be administered for the different service providers that could have different billing requirements. The obvious conclusion that can be gathered from such a scenario is that simple flat-rate and even time based charging might not be efficient enough to cater for the system. The author concludes by stating that to be able to develop successful NGN networks and services, one of the obstacles that stand in the way is finding ways to fill the gaps in charging implementation for these networks and their services.

2.3.2 3GPP Charging

The 3GPP has produced extensive work relating to how charging can be achieved. They produce numerous number of Technical Specifications that relate to all types of charging required in different types of networks. Networks include GPRS, WLAN, Fixed Broadband, Packet Switched networks, Circuit Switched networks, the IMS and higher service level charging implementations. Additionally, specifications are released that pertain to particular charging scenarios to provide a more in-depth perspective as to how charging should be handled at these different levels and in different networks. Examples of specifications that relate to charging are listed below:

- Policy and Charging Control Architecture [8]
- Telecommunication management; Charging management and IMS Charging [10]

- Telecommunication Management; Charging Management; Online Charging System (OCS):Applications and Interfaces [21]
- Telecommunication Management; Charging Management; Diameter Charging Applications [9]
- Overall High Level Functionality and Architecture Impacts of Flow Based Charging [22]
- Telecommunication Management; Evolved Packet Core (EPC): Charging aspects [44]

The work that the 3GPP has done in providing specifications for charging architectures makes it much easier to start developing charging systems that can be evaluated for conformance over testbeds and ultimately deployed in a commercial context.

IMS charging in 3GPP Release 8 is not isolated but is rather part of an overall charging concept. In the release a common framework for charging was created by describing the general charging functionality in a single standard. One standard is very necessary because of the growing number of technologies and services that would make individual charging functions impossible to handle over the IMS network. This should not be confused with the fact that individual charging models are needed for different types of services. The goal in IMS charging is to provide functions that can implement all these models in a centralised manner. In the release they identified common logical charging functions that provide the different aspects of the required functionality for all the charging-relevant parts of a 3GPP network and integrated them into a common logical architecture.

In this architecture, there are service specific specifications which define the exact detail in charging that must occur within the service. These specifications are divided into three groups that describe the three different charging levels defined by the 3GPP:

- Bearer-level charging – circuit-switched, packet-switched domain, and the 3GPP interworking WLAN
- Subsystem charging – in the IMS
- Service level charging – multimedia messaging service, push-to-talk over cellular, multimedia broadcast, and multicast service

Regardless of the level of charging that is employed in the system, there are two distinguishable types of charging, namely online charging and offline charging. In offline charging the actual process of charging occurs after the service has been rendered, where records are kept of how much the client used and then the client is charged accordingly. This form of charging requires no real-time charging communication to happen during the session. In direct contrast to offline charging is online charging. This type of charging involves a real-time interaction between the charging process and the service being rendered. If the user's credit runs out during the provisioning of a service then the providers could choose to end the media session. These two charging mechanisms should not be confused with prepaid and postpaid billing. Prepaid billing is billing by which a user has to purchase usage credits prior to being authorised to using network services whereas post-paid billing is billing where the user is allowed to use network services and gets billed after service usage. Although there are similarities between each pair of functions they are not the same.

2.3.3 Related work on Charging

Research work has been done in the enabling of charging for composed services offered by multiple service providers. B. Jennings et al. [15] present a framework where rating engines generate charge information for individual services and provide this info upon request to the other rating engines when these services are used as part of a composed service. These engines additionally employ a two phase rating service which allows potentially complex business agreements between providers to be reflected in composed service charges.

The future of wireless and mobile communications is dependent on the integration of telecommunications systems and IP-based networks [16]. This of course means that accounting, charging and billing mechanisms becomes difficult when we consider that users themselves are mobile and may wander from different network domains. In this sense, a domain can encompass an administrative or technological boundary. This mobility introduces difficulties as charging also needs to consider that a user might have to be handed over to another domain.

F. Eyerman et al. [16] present how these key issues are addressed by a platform that ensures that accounting is performed in a distributed manner involving network components and different domains. The work proposes that an accounting configuration is set up and maintained such that accounting data collected is consisted no matter what domain a user may fall into at any given time during service delivery.

2.4 Business Models and Changing Paradigms

Most literature on business model concepts concentrates on determining how value is provided to the end-user. However, operators also have to consider how to make their business model attractive from the perspective of the partner (this can be seen as the application developer of the third party service or content provider) [1]. In this case partners to network operators have a special role in the value creation of services to the end-user.

These third parties can opt to offers their services to the end-user via other channels (for example via the internet) and thus may not directly need to be in partnership with the network operator. This leaves the network operator facing a situation where it is merely a “bit-pipe”. External and independent application developers are usually in the position to have deeper customer understanding and more concentrated service offerings. Therefore they can be focal partners for network operators when creating value and providing new services to end-users.

Early work on the subject was highlighted in [49] which evaluates the application service provider (ASP) business model. It drew from a large scale research program funded by the European Union and the Engineering and Physical Sciences Research Council (EPSRC), into the emerging ASP industry where software is delivered as a service, priced on a per-seat, per month basis. Tracking the classification of ASPs (pure-play, vertical, horizontal, enterprise and enabler) through longitudinal case study research, the paper suggests that two major inhibitors have contributed to the slow growth of this market. The first is economic conditions evidenced by the dot.com downturn, and the second is lack of education in the potential customer marketplace. The paper tracks the strategies of two major players within the ASP industry: Cable & Wireless, a traditional UK telecoms company moving into the IP market, and Jamcracker, a recently established US enterprise web services company. Through careful evaluation of key performance indicators (KPIs) for evaluating ASPs and customer perceptions of the software-as-a-service proposition (and e-business broadly conceived), the paper argues that integration of applications will be the major challenge if the ASP business model is to survive in the overcrowded and intensely competitive e-business sector.

K. Jarvi et al. [1] investigate an alternative to network operators concentrating on business models that determine how value is created for the end-user and also consider how network operators can make their business models attractive from the perspective of a business partner i.e. an application developer. This in turn ensures value creation for the end users. They propose a partnership business model concept, and analyse inter-firm cooperation with a case study of the IMS service development platform from the operator perspective. Additionally a survey of 14 companies was conducted with the ultimate goal of finding out why the network operator would be a preferred channel for service delivery for the third party application developer. The results of the study suggest that partners evaluate the attractiveness of the business model of an operator in terms of value and resources. Therefore, the partnership business model construct provides valuable perspectives to companies who have to consider how to attract good partners to stay competitive.

Current telecoms market pressures are inducing the traditional, vertically integrated network operators to embrace new business models and consider innovative partnerships. Specifically, the increasingly rapid and complex technology migration, strict regulatory requirements, high customer expectations with regards to innovative services and quality of service, and high capital expenditures on one side, and the competitive environments, saturated markets, and pressure on profit margins on the other side are forcing the operators to become more efficient, while securing access to skills and sufficient scale of operations. Taking together this and the opportunities arising from the vertical division of the value chain and the standardisation of interfaces, a new breed of horizontal partnerships between operators and new vertical business models including suppliers and 3rd parties are gaining footprint in the telecoms markets. In addition to technical aspects, economic issues have to be considered. Both strategic and operational impacts arising from the new business models need to be evaluated. T. Frisanco [45] presents a top-down, approach for evaluating the impacts of various scopes of outsourcing, and managed services. The approach adopts a structured method that takes into account operator characteristics, network technologies, network layers, geographies, processes, delivery options, and potential extensions of the business model, such as infrastructure sharing and resource sharing. Demonstrations using real-world cases show which items have the largest potential for optimisation, and uncover the approximate efficiency gains that one can expect by applying various constraints on the sharing of delivery platforms by the managed services provider. Figure

2.2 summarises the factors that would cause a network operator to outsource network resources to third parties.

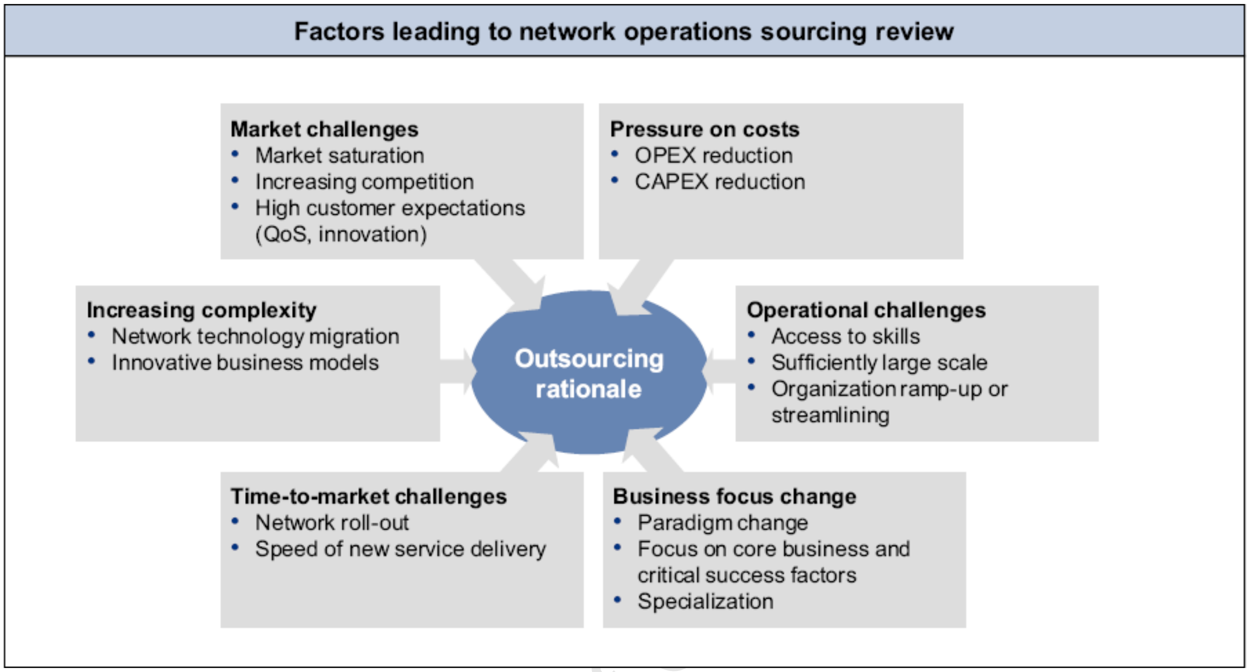


Figure 2.2: Key factors driving network operations outsourcing [41]

E. Bertin et al. [41] highlight that Next Generation Networks are expected to deliver services that are tailored to individual preferences. This leads to next generation services that rely on multiple cooperating service platforms. The authors propose to define a business view for the usage of NGN services. NGN operators may use this business view in order to assure coherence between all NGN services from the end-user point of view. The TeleManagement Forum (TMF) has produced concepts for modeling business processes concerning the customer by specifying a set of processes for fulfillment, assurances and billing of services [42][43].

G. Huitema et al. [46] introduce the concept of compensation in Ambient Networks (ANs) as a step towards the anywhere, anytime, anyhow paradigm by enabling dynamic compensation negotiation between operators and end-users. This dynamic negotiation encompasses the limitations of the current, merely subscription-based business models. It allows for tariff negotiations between a mobile user and a visited network. In addition, it enables end-users to act as small providers and aims to support compensation ranging from classical payments (e.g. postpaid, prepaid) to alternative ways of compensation in the sense of barter transactions or micro payment schemes. In summary, the way compensation is integrated into ANs allows for easy addition of new services and entire networks into the infrastructure of a provider. The authors strongly believe that the depicted dynamic charging and billing concepts and mechanisms will prove to be useful for the development of next-generation charging and billing architectures.

Current charging- and billing-related approaches concentrate only on the delivery part of the business processes and leave the negotiation pre-phase out of scope. For example, 3GPP's and IETF's AAA charging and accounting architectures only deal with charging and accounting and how to transfer charging information to the billing domain. Several research projects have already dealt with the limitations of these standardised solutions, like missing possibilities for automatic configurability and coordination between the system parts, or extending their scope, e.g. by adding charging capabilities to AAA servers. However, up until now none has considered an overall solution that comprises the whole compensation process from accounting, charging, and billing to presentment and settlement including the possibility to dynamically negotiate and configure the composition process.

2.5 Next Generation Networks and the IMS

The IP Multimedia Subsystem (IMS) was originally defined by the 3rd Generation Partnership Project (3GPP) as a mobile network infrastructure that enabled the integration of data, speech and mobile network technology over a common IP base. This was later changed to allow for the support of other networks besides traditional mobile networks. These networks include WLAN, CDMA2000 and fixed line.

IMS was designed to fill the gap in existing telecommunication technology and internet technology [17]. This meant that mobile technology could now be blended with the rich applications that were already being offered on the internet. IMS especially helps for the provisioning of real time mobile services such as internet telephony, video telephony, instant messaging, and push services. An increase in the amount of bandwidth available could not alone be able to achieve this and the IMS allows operators to be able to offer new and innovative services to the end user.

There are many reasons why IMS is fast becoming the most desirable architecture to allow for the delivery of multimedia services in next generation networks. Firstly it allows for the blending of services, where previously different types of services were separated from each other. This is appealing to the end user as they feel they get more value for money from their service providers. Secondly it is a subsystem and allows for different access technologies. This means that most users will be catered for under the framework. Thirdly because the IMS has a common horizontal signaling and control layer, it makes it easier for the development of services as they do not need to have their own control functions.

2.6 Beyond 3G Networks and SAE

As circuit-switched networks will eventually be phased out, network infrastructures are more packet-switched in accordance to an all-IP based architecture. Network operators used to only offer voice and text messaging services in the past, however they are increasing offering more exciting and user enticing services like data, VoIP and video streaming. New paradigms emerged with the emergence of 3G mobile networks which means users can access a plethora of services anytime, with mechanisms available to support mobility and roaming.

And yet there is still a need for evolution as all these new and exciting services start to require that high bandwidths are available to the user to support the demand. This means that core networks need to be able to support these new bandwidth hungry services. The evolution of the GSM/UMSTS core network, or Evolved Packet Core (EPC), is at the heart of mobile broadband revolution.

System Architecture Evolution (SAE) is the name given to the standardisation work done by the 3GPP to evolve the packet core network [20]. Long Term Evolution or LTE refers to the evolution of the radio network. As operators start to invest in these new infrastructures, the revenue generating options remain a key factor for the business cycle. Hence it is important to take into account how charging systems will be integrated to future network architectures.

The 3GPP charging infrastructure principles and mechanisms do not change due to the EPS, but rather entities have been included within the existing infrastructure [44]. This is shown in the figure below.

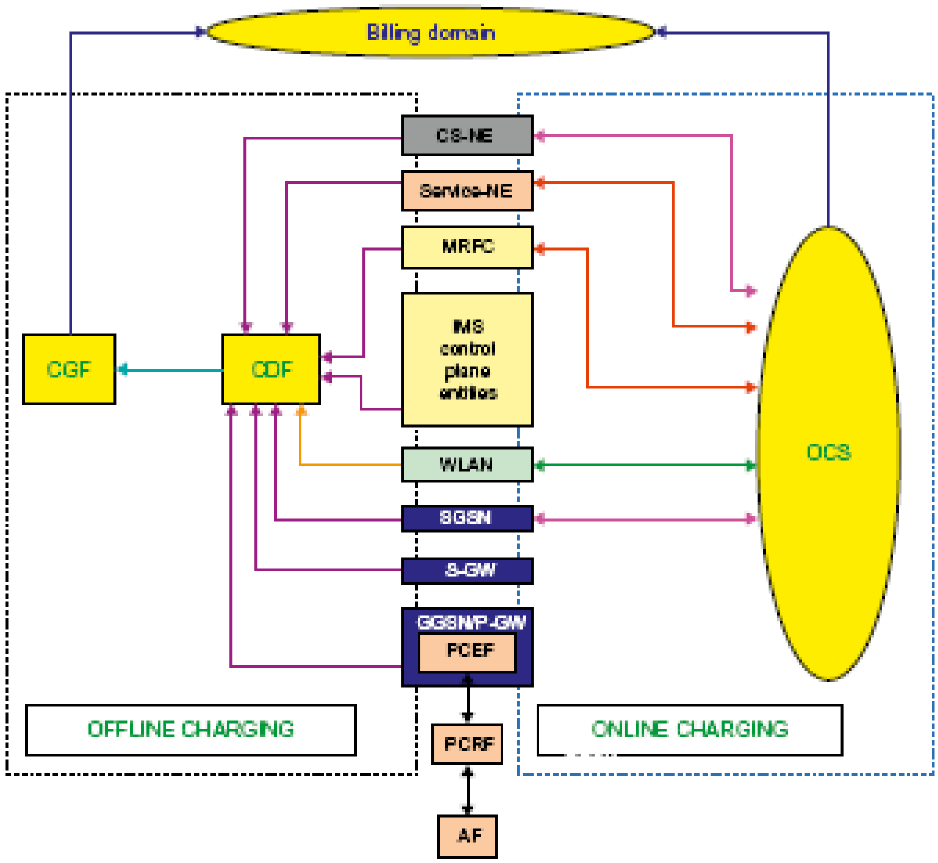


Figure 2.3: 3GPP Charging Principles Architecture

EPS is an all-IP based network where Diameter is used for all charging data collection related functions within the EPS. Support for CAP and other older protocols remain due to existing widely deployed and used billing systems by the operators as well as for interworking and backwards compatibility with 2G/3G networks. The interfaces towards the billing system rely heavily on the operators' business model and billing principles and may involve third-party service providers which affect the end-users directly and may be visible towards the end-users if changed drastically.

2.7 Chapter Discussions

Figure 2.4 summarises the chapter and illustrates the need of third party interaction for the network operator and how this is coupled with the need to provide charging solutions for these services so that Telcos can benefit from partnerships.

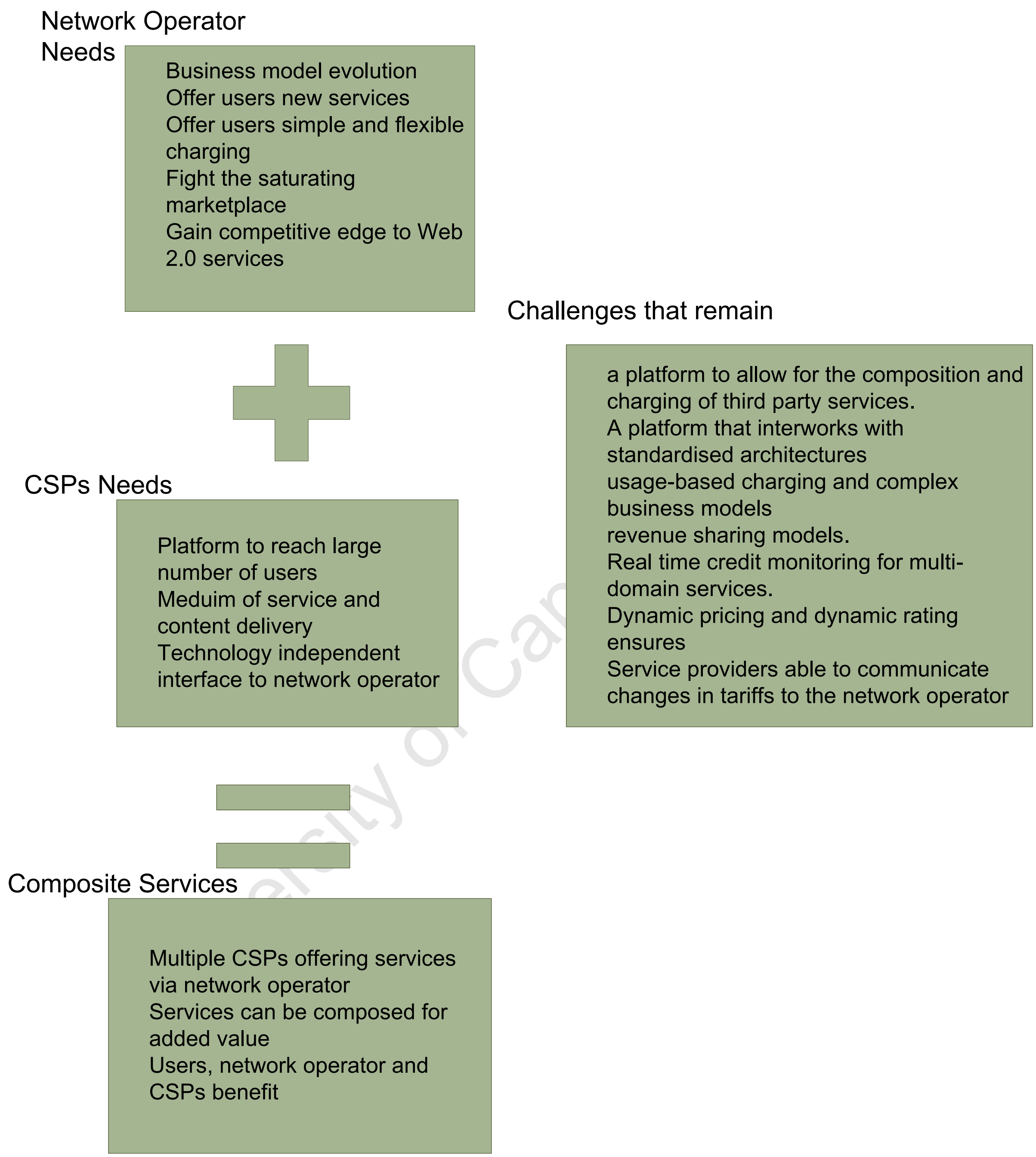


Figure 2.4: Need for network operator and CSP cooperation

This chapter highlighted the research efforts that are going into the concepts of SDPs, service enablers and SOA. This work is important to the network operator as it will allow for the creation and deployment of rich-content, applications and services for the end user. Additionally work is also being done on providing management and charging for these services. However, these systems do not provide a unified system approach that incorporates the charging concepts and complexities introduced by the plethora of services to be introduced.

In the next chapter an architectural framework that takes into consideration gaps left in current systems will be introduced, taking into consideration the requirements of all parties involved to allow for the delivery of third party services to end user.

Chapter 3

Requirements of a Charging Architecture for third Party Composite Services

Chapter 2 gave an overview of the state of the art literature and related works on the topic of service composition from a Telco's viewpoint and more specifically how this can relate to the charging and billing of these services. Chapter 2 also gave some background on standards that are currently addressing these issues and how different vendors or authors are choosing to implement solutions based on these standards.

This chapter presents a framework to enable composition of services and to allow for the charging of the services for the network operator. The framework addresses the research problem presented in Chapter 1 and the drawbacks of related works presented in Chapter 2. The design of the framework presents a solution that would allow network operators the ability to interface with external CSPs to achieve the aim of rapid service creation and revenue generation.

3.1 Design Considerations

To ensure that the charging and billing platform for third party service providers is suitable for all stakeholders involved, a number of key requirements need to be understood for the different parties. We identified the stakeholders to be the Network Operator, the Service Provider and the Content Provider. Equally important a stakeholder to be considered is the end user.

3.1.1 The Network Operators

Network operators realise that they need to start offering a wider variety of services with the intention of keeping end user attention. They will require that all these services have itemised billing within the domain of the network operator. This will mean that they are aware of the invocation of all services by users. Network operators would also like charging information for all actions incurred and requiring settlement between the different commercial roles to be kept track of. From a network operator's point of view, this is one of the key requirements for any system that they would develop and deploy.

They may have the option to provide different user profiles for the customer. For example they may have prepay and postpay mechanisms. In the case of prepay, they will need to monitor in near real-time the network resource usage of the customer so that they can charge accordingly. This is more important for prepay usage of services as the network operator will need to know the amount credit a user consumes so that they will be able to refuse services when credit has been exhausted. However, the network operator may favour simplistic or less network overhead inducing charging mechanisms as complex charging signalling can itself take up network resources and thus be costly to the network operator. A balance of these two requirements will need to be met.

Network operators will need to charge users depending on resource usage for services. For example, some services will require more resource usage (such a streaming of high definition content). Additionally service information will need to be provided from the service/content providers relating to tariffs. If dynamic pricing for services is supported within the network then this information will continuously need to be kept up to date. Accurate collection of accounting information relating to each user needs to be captured for charging purposes and also for records purposes.

3.1.2 The Service and Content Providers

The service and content providers (CSP) can essentially be seen as one entity from the requirements viewpoint. They all have similar outcomes which they would expect from a partnership with a network operator. These have been listed as follows:

- To received revenue from use of their services and that there is fair sharing of revenues between the CSP and the network operator

- CSP will favour resource usage charging mechanisms as they give a fair remuneration to the CSP of services rendered.
- CSP will need to provide accurate tariff information to the operators that is always up-to-date especially in the case of online charging mechanisms
- Be aware of users and only provide services to subscribed users if so desired
- Provide accurate information to the network operator about themselves
- Allows their services to cater for the charging scheme needed from composition of their services.

3.1.3 Charging requirements for the User

In an environment where there are many service providers offering their services to users, the user requires to be aware of all the services available to them and also to know the cost of these services i.e. which services and events will incur a charge. They also require that charging be fair to them depending on the QoS agreed on or being offered by the network operator. Should a user be on a prepay option they should be informed when their credit has expired. The user would thus prefer to have to settle charging matters with one entity, preferably the network operator who then shares revenue with all other parties.

3.1.4 Charging requirements for specific services

The plethora of services being offered will each have different requirements that are caused by the inherent nature of each of the services. VoIP favours duration based charging in high bandwidth networks and volume based for low bandwidth networks. IPTV favours volume based (especially when QoS is involved) or duration based with QoS considered. PTT favours session based charging whereas simple messaging prefers once off (per event) charging. Presence and IM rely on duration based charging schemes, however if other types of data are transferred within that IM session, like streaming or file transfers, those will incur separate charging. File downloads are volume based and Location based services could be once off (per event). The following table gives a summary of service type versus charging mechanism.

Table 3.1: Service types relating to charging mechanisms

	Event (once off) Charging	Duration Based	Volume Based	QoS based Charging
VoIP		•	•	
IPTV		•		•
PoC		•		
Presence and IM*		•		
File Download			•	
Location based services	•			

3.1.5 Charging Requirements for composite services

We have defined composite services as services that comprise of different atomic services. We thus need to consider the requirements for having such a service being offered to the user. These have been highlighted as follows:

- Require revenue sharing among the service providers involved in that composite service
- Clear specification of business relationships between the different CSPs and the network operator
- SLA between operator and user, they must also agree on QoS
- SLA between operator and service provider, agree on charging and billing
- Prevention of service overuse i.e. if credit for user finishes for the different services
- Restriction of service use to user not permitted by service/provider if this applies

The high level objectives are thus to provide charging and billing management in a multiple CSP environment. Provide management for service differentiated, usage based, application (service) specific charging and billing as well as management for equitable cost allocation and revenue sharing. The final objective is to provide composite services to the user.

3.2 Functional Requirements

The main focus in this work is to consider the business relationship between a network operator and multiple service providers. In the considered scenario the network operator deploys the IMS within its domain. This happens at the control plane where the IMS functional entities would reside. Also within the control of the network operator will be the primary and universal charging functions, namely the offline charging functions and the online charging function. These charging functions constitute the converged charging system for that network operator. The main advantage of having a converged charging system is that it eliminates the need for every business player to deploy their own charging and billing functional entities. The service providers will then reside in the service plane. The network operator can have its own services which can be provided with the use of SIP IMS application servers however this falls out of the scope of this scenario. The third party service providers would have access to the IMS either via a Service Compatibility Server (SCS) for OSA application servers or the IP Multimedia – Service Switching Function (IM-SSF) for the Camel development environment. In the network operator's IMS domain will reside an OSA Gateway that communicates with the OSA API in the service providers' domain. Services can then be offered individually or composed together to allow for value added service creation. This is illustrated in Figure 3.1

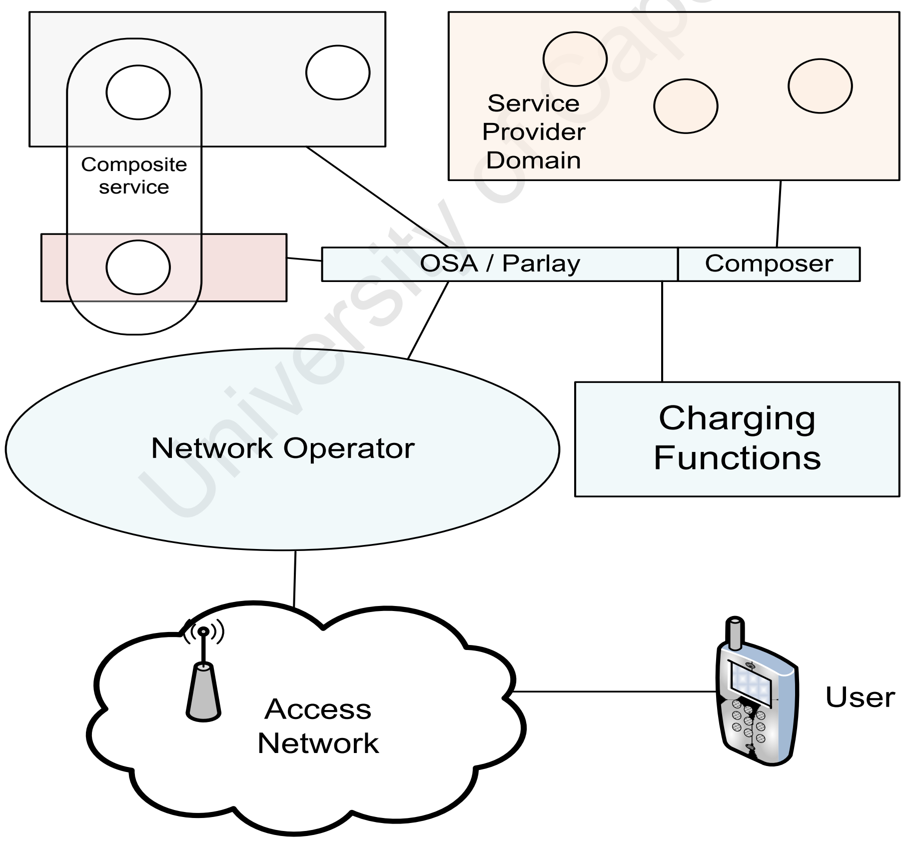


Figure 3.1: Multi-domain services scenario

The requirements of the operator are based on the adoption of a Network Operator

Centric Business Model [11]. This model is chosen because the network operator is the entity that is in charge of the IMS management. This management includes having most of the information about the user, such as service capabilities, charging options etc. As the charging functions will perform either postpaid or prepaid charging on a user's account the network operator should then be able to provide all information on charging actions that occur as well as enforce settlement between the different commercial roles. The operator should also provide an interface to the service providers and also have the capabilities to compose services as required and perform charging of the services.

When service providers relinquish the ability to perform their own charging and use network operators as channels for service delivery, the end-users usually only see the operator from the whole delivery chain. In such interactions it is easy for the network operator to dictate protocols used within the environment. Service providers require that all operations performed by the network operator be transparent. When this is achieved fair allocation of revenues can be performed as all the involved parties know exactly how their services were used by the user.

An architecture that achieves the above requirements should be able to provide the required revenue sharing among the network operator and service providers. This requires a clearly specified business relationship between the network operator and an individual service provider. Revenue generated from the user can then be apportioned based on this contract between the operator and the service provider. Data that traverses from the different business domains will need to be specified in such a way that the format is understood by all parties. Charging for each service can be performed in a best-charged manner depending on the type of service that is being offered.

3.3 Proposed Charging and Billing Platform for Composite Services

The platform proposed is designed to use existing network elements that have been defined by the 3GPP and the Parlay Group standardisation bodies. It defines new entities to allow for the composition of services and the interfacing of service providers and the network operator.

3.3.1 Network Operator Architecture

The IMS is essentially the ideal platform for the provisioning of services from the network operator perspective. Deploying IMS has many benefits [1]:

- integrated registration and user authentication
- session management
- integration of existing NGN services e.g. IM or presence
- roaming
- QoS
- unified billing and charging

The NGN functional architecture has three main layers: transport, control, and service. IMS is at the architecture's core. The following figure depicts this architecture.

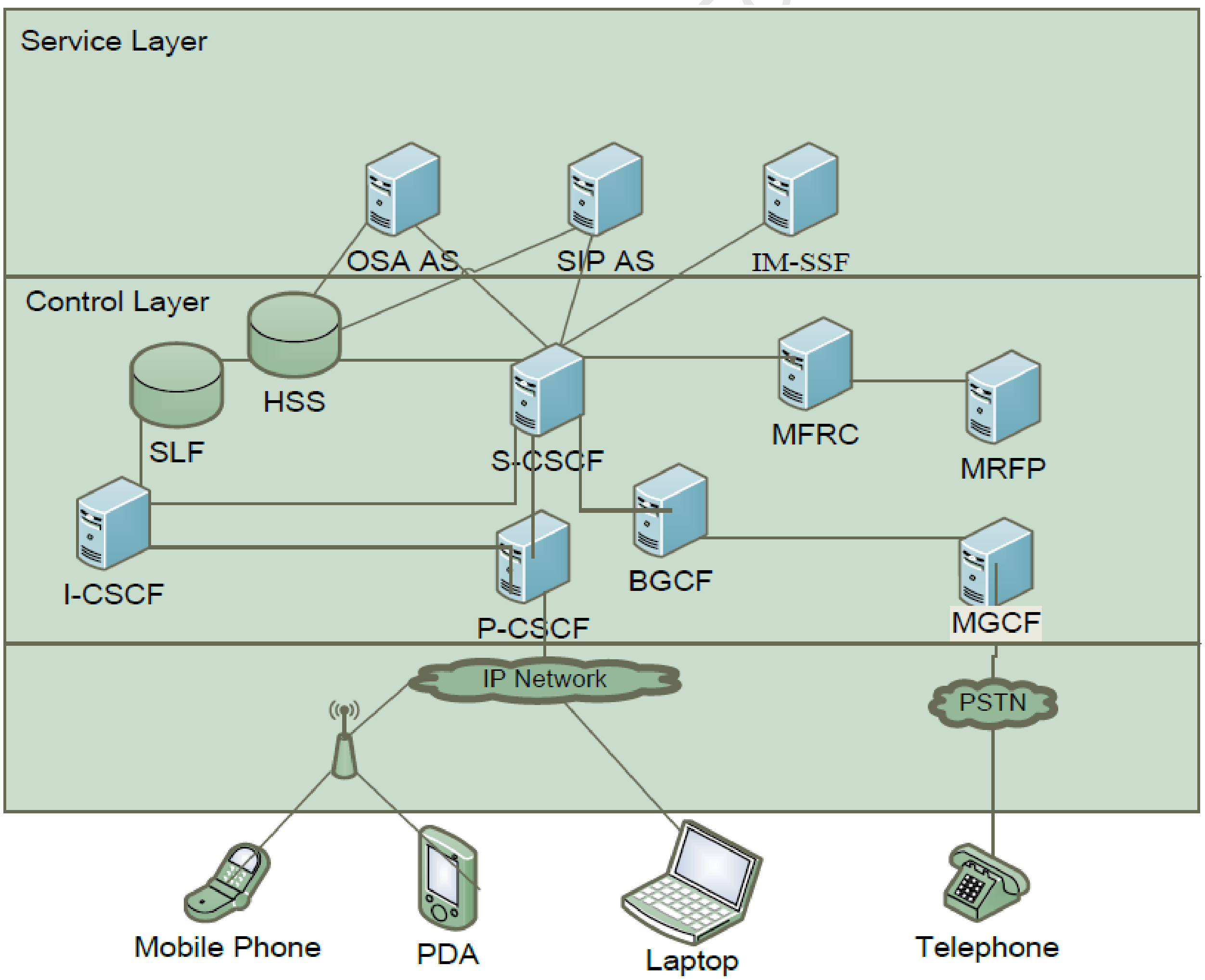


Figure 3.2: Network Operator Architecture

3.3.1.1 Transport Layer

The transport layer is the network-access layer. It lets different IMS devices and user equipment connect to the IMS network. IMS devices connect to the IP network in the transport layer using various technologies, including fixed access (DSL, cable, modems, Ethernet), mobile access (WCDMA, CDMA-2000, GPRS and UMTS) and wireless access (WLAN and WiMax). The transport layer also lets IMS devices place and receive calls to and from the public switched telephone network (PSTN) or other circuit-switched networks through the media gateway.

3.3.1.2 Control Layer

The control layer consists of some of the most important nodes in the IMS. The HSS is located at this layer and is responsible for storing user information. Also at this layer are the Call Service Control Functions (CSCFs), Media Resource Functions and the Border Gateway Controller Function.

3.3.1.2.1 HSS and SLF

The HSS is the central repository for user related information. This information can include subscriptions related data that is used to handle multimedia sessions such as:

- Location information
- Authentication information
- Authorisation information
- User profile information
- S-CSCF allocated to user

If there is more than one HSS in the home network then a Subscription Locator Function will also reside in the home network so that information can be routed to the correct HSS. Along with the SLF (if there is one present) the HSS has links to the I-CSCF and the S-CSCF through the Cx interface (if there is a SLF then the Dx interface will connect the SLF with the two CSCFs). The Cx and Dx interfaces only allow for the sending of Diameter Protocol messages which relay AAA information.

3.3.1.2.2 P-CSCF

The P-CSCF is the first point of contact in the signalling plane that the IMS terminal will have with the IMS network. The P-CSCF is allocated to the IMS terminal during registration.

Before any communication can take place the IMS terminal needs to know the address of the P-CSCF, usually it can find this with the help of a DHCP server. The P-CSCF is essentially a SIP message forwarder as it forwards SIP messages from the terminal into the network and forwards all SIP messages originating from the network to the terminal. It will never generate any terminal related messages on its own.

The P-CSCF will perform security checks on all SIP messages that it received from the IMS terminal to make sure that they indeed originated from the terminal and where not altered along the way. Once the user is authenticated, it will assert this to the other nodes in the network so that they do not need to perform any security checks of their own. The P-CSCF will also verify the correctness of all SIP messages that it receives from the IMS terminal, pass on valid messages and filter out the incorrect ones. It can also act as a compressor and decompressor of SIP messages; it does this because SIP messages can tend to be quite large based on the fact that SIP is a text based protocol. Reducing the size of the messages will reduce the time it takes to transmit the message. A P-CSCF can include a Policy Decision Function (PDF). This function will authorise the use of media plane resources and control QoS over the media plane. It can also forward charging information to the Charging Collector Node. The P-CSCF will only be directly linked to IMS terminal, the I-CSCF and the S-CSCF. The P-CSCF assigned to an IMS terminal can reside in the home network or the visited network.

3.3.1.2.3 I-CSCF

The I-CSCF is located at the edge of the administration domain. The address of the I-CSCF will be in the DNS records on the domain. When a SIP server needs to find the next hop for a SIP message it will obtain the address of an I-CSCF in the destination domain and in this way, it functions as a SIP proxy server. Otherwise, it has links with the SLF and HSS in the domain that is used to request location information from. It will also direct SIP messages to the allocated S-CSCF. The I-CSCF is usually located in the home network.

3.3.1.2.4 S-CSCF

The S-CSCF is the central node in the signalling plane. As opposed to the I-CSCF and the P-CSCF, the S-CSCF is a SIP server where the other two are SIP proxies. The S-CSCF performs session control where it will manage all media sessions that are ongoing to an IMS terminal. It can also perform as a registrar that will bind user location information such as the terminal's IP address and the user's SIP address which is also known as the Public User Identity.

The S-CSCF will also implement a Diameter protocol Dialogue with the HSS. It does this to obtain the following information:

- Download authentication vectors of the user trying to register with the IMS and use these to perform authentication on the user
- Obtain all user profile information that will include the service profile that a specific user will have. It will also include a set of triggers that may cause the invocation of one of the application servers.
- Tell the HSS that it is the S-CSCF for a specific user for the duration of registration

All SIP signalling from and to the IMS terminal will go through the allocated S-CSCF. It is always located in the home network.

3.3.1.2.5 MRF, BGCF AND MGCF

The Media Resource Function provides a source of media in the home network. It handles most of the media related broadcasts within the network. This node can further be broken up into the MRFC and the MRFP:

- Media Resource Function Controller is the signalling plane node
- Media Resource Function Provider is the media plane signalling node
- The MRF is always located in the home network.

The BGCF and MGCF are SIP servers that provide the link between the IMS and circuit-switched networks such as PSTN and PLMN networks. They contain addresses of users that reside in these circuit-switched domains. The MRF, BGCF and MGCF are mentioned here for completeness, as they form part of a standardised IMS architecture.

3.3.1.3 Service Layer

This layer can alternatively be called the application layer, as this is where services reside. The transport and control layers provide an integrated and standardised network platform to let service providers' offer various multimedia services in the service layer. Application servers host and execute the services and provide the interface with the control layer using the SIP protocol

3.3.1.3.1 AS

The AS (Application Server) is an entity that hosts and executes services. There are three types of AS that can reside in the IMS network.

- SIP AS (Application Server): this is the native Application Server that hosts and executes IP Multimedia Services based on SIP. It is expected that new IMS-specific services will likely be developed in SIP Application Servers.
- OSA-SCS (Open Service Access-Service Capability Server): this application server provides an interface to the OSA framework Application Server. It inherits all the OSA capabilities, especially the capability to access the IMS securely from external networks
- IM-SSF (IP Multimedia Service Switching Function): this specialised application server allows us to reuse CAMEL services that were developed for GSM in the IMS.

3.3.2 External Services Gateway

The OSA/Parlay provides a framework that specifies an open set of standards and network-independent APIs that enable authorised service providers to control a selected range of network capabilities. This allows for the rapid creation of value added services by independent third party service providers. The open network services offered to authorised entities concern mobility and location information management, call control, and content-based charging. The gateway provides an interface for communication between the third party application servers and the IMS control plane. In this architecture it is the composer that takes on the additional functions that do not currently exist in the IMS network or in the OSA/Parlay.

3.3.2.1 Service Composer

In this architecture, the composer would take on the additional roles required by the gateway to cater for composite services. These include modules to complement the functions of the gateway so as to provide the lacking mechanisms in the system for charging of third party services to take place.

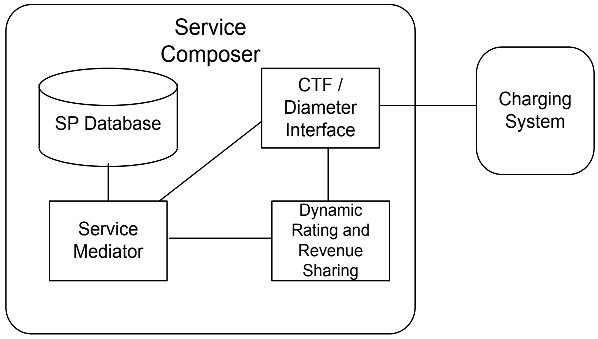


Figure 3.3: Detailed components of gateway

3.3.2.1.1 Service mediator

This entity oversees the formation and management of composite services from other base services, depending on the requirements of the user. The mediator acts as an orchestration engine for the implementation of the service compositions. Each service can be viewed as a process that awaits requests from the mediator and responds accordingly. Service composition can be complex as services can reside in multiple administration domains. Each domain can have different usage policies, pricing models and varying service types. The service compositions process will depend on the user's requirements, which can change dynamically. The service mediator will need to provide mechanisms and tools that realise the goals of both the service providers and the users.

Service composition model

Each atomic service needs a high-level description that can be used to advertise the features of that service to users. This abstraction is contained in the *ServiceProfile*. The profile contains information about what kind of service it is and which service operator the service belongs to (*ServiceProvider* and *ServiceProviderID*)

.

Table 3.2: Service Profile

Model component	Component type
ServiceProvider	String type
ServiceProviderID	Integer type
ServiceType	Integer type
DiscountSPPartners	Integer container
RatingModel	Integer type

All the services that are available to the user would be stored in a database along with the service profile information so as to allow for seamless composition by the service mediator. When a user requests a third party service or services the mediator would retrieve the service profiles to gather all the required information on these services. To complete the composition process, it would create a *ServiceSession* object that contains the service profile information about all the services that belong to a unique user session as well as a unique session identifier belonging to that *ServiceSession* (*SessionID*) and the user that is using that service composition group (*UserID*).

Service composition algorithm

The process of forming a composite service is represented in the following pseudo function:

```
Wait for external event
    If event = service request
        If initial request
            Create ServiceSession object
            Attach UserID and SessionID
        Else subsequent request
            Find SeviceSession related to request
        Then for all requested services
            Retrieve  ServiceProfile
            Attach ServiceProfile to object
    If event = terminate service
        Find SeviceSession related to request
            Remove ServiceProfile from object
            If no more services in object
                    Terminate object
```

3.3.2.1.2 CTF and Diameter interface

The Charging Trigger Function (CTF) is integrated to the composer as it would to any other IMS Application Server (AS). Normally an AS will start to send charging information to the offline charging function or the online charging function whenever a service has been requested by a user. In the case of offline charging the CTF would pass on information that maps the captured resource usage so that subsequent billing can be performed. In the case of online charging a service needs to be authorised by the charging functions before it can be accessed by the user. This requires credit control to enforce, in real time, service usage. The CTF would then send requests to the online charging function and await positive response before the service can be delivered.

The IMS uses the Diameter protocol to transport all AAA messages between functions. A Diameter interface is then needed to be able to communicate with the charging functions. Diameter is specified as a base protocol and is complemented by as 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). AVPs are containers of data. When services are requested the CTF will send charging requests to the appropriate charging function credit-control request (CCR) or an accounting request (ACR). The case for offline charging is less complicated than that of online charging. In offline charging the CTF will send charging information to the charging function to relay information of service usage. The diameter messages will contain additional AVPs that can relay the contents of the service requests to the charging functions. The *Session-Id* AVP contains the *SessionID* which is the unique identifier for that user's session composite service.

In online charging, the *CC-Request-Type* AVP contains the type of the CCR message: whether it is an initial, update or terminate type. Diameter credit-control defines the *Multiple-Services-Credit-Control* AVP that can be used to support independent credit-control of multiple services in a single credit control session for service elements that have such capabilities e.g. a composite service. This makes it possible to request and allocate resources as a credit pool that is shared between services or rating groups. To use this feature the composer needs to inform the charging functions by sending a *Multiple-Service-Indicator* AVP in the initial CCR request. The *Multiple-Services-Credit-Control* AVP is used for each atomic service associated with that composite service. The charging function rates the service according to the *Service-Id* and *Rating-Group* and associates all services in that session to a *Pool-Id*. This *Pool-Id* is used for all subsequent credit authorisations for UPDATE_REQUESTS to the charging function. When the user request services that have not yet been authorised a CCR of type UPDATE_REQUEST will be sent.

3.3.2.1.3 Dynamic rating and revenue sharing module

This function is mostly relevant when online charging is being performed. When the tariff information of a service changes, the service provider would be able to inform the service mediator of the change. This information can be relayed to the online charging function and rating can be performed with the new tariff values. The credit control client shall report the quota usage under a number of circumstances. When this happens the reason is sent to the server through the use of the *Reporting-Reason* AVP in the CCR. The reason for reporting credit usage can occur directly in the *Multiple-Services-Credit-Control* AVP, or in the *Used-Service-Units* AVP, depending on whether it applies for all quota types or a particular quota type respectively. When the reason is RATING_CONDITION_CHANGE, the *Trigger* AVP shall also be included to indicate the specific armed trigger events which caused the reporting and reauthorisation. Thus if a service provider chooses to change its rating, it will inform the composer who then informs the charging function using the RATING_CONDITION_CHANGE request [9].

Services may or may not offer discounts depending on whether they were invoked as an atomic service or as part of a composite service with a partner service provider. Such information needs to be available before the composite service comes into existence and is stored in the *ServiceProfile*. This way the composer will inform the charging function which rating to perform as it is aware which services are currently being provided to the user.

*CCR(***initial**,

Multiple-Services-CC (Requested-Units(), Service-Id 3,

Rating-Group 2)

Multiple-Services-CC (Requested-Units(), Service-Id 4

Rating-Group 3))

CCA(Multiple-Services-CC (Granted-Units(Total-Octets),

Service-Id 3, Rating-Group 2,

Validity-time,|

G-S-U-Pool-Reference (Pool-Id 2,

Multiplier 2)),

Multiple-Services-CC (Granted-Units(Total-Octets),

Service-Id 4, Rating-Group 3,

Validity-time,|

G-S-U-Pool-Reference (Pool-Id 2,

Multiplier 5))

3.3.3 Charging system

The figure 3.5 depicts the proposed structure of the charging system in the framework.

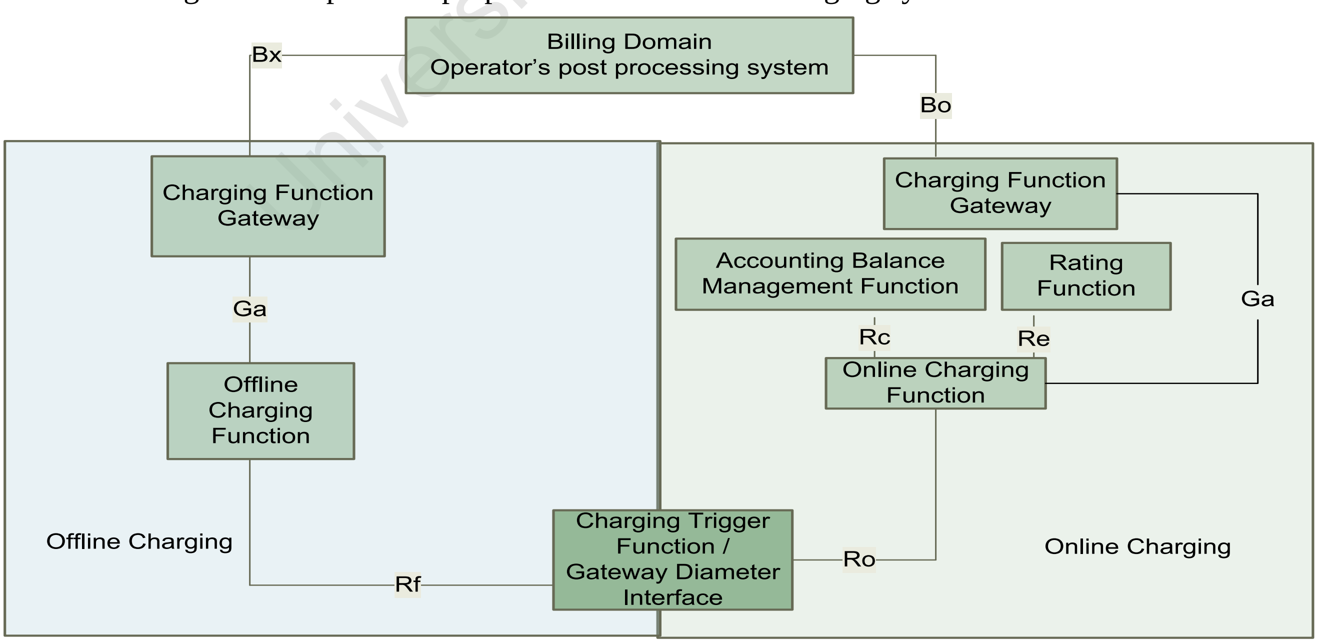


Figure 3.5: The Charging System

The charging system is comprised of two charging functions, namely the Offline Charging System (OFCS) and the Online Charging System (OCS). These are in accordance with the ability of the system to perform offline charging and online charging. In addition to these function, there are two types of charging functionalities within the charging system, these are event based charging and session based charging. An example of event based charging is charging for the sending of a multimedia message, the charge occurs once of at the time the message is sent. Session based charging is more suited for services that last for an ongoing amount of time.

The OFCS is the logical entity that would be responsible for the generation of charging data records (CDR) from the information that was passed on to it through the Rf interface from the CTF. The OFCS then sends these CDRs to the Charging Gateway Function, which acts as a gateway between the IMS and the billing domain. The OCS is comprised of four functional entities, namely the Online Charging Function (OCF), the Charging Gateway Function (CGF), the Rating Function (RF) and the Account Balance Management Function (ABMF). The OCF is further subdivided into two functional entities: the Session Based Charging Function (SBCF) and the Event Based Charging Function (EBCF) [10].

For online charging, event based charging is performed by the EBCF. The chargeable event is authorised after successfully performing credit control on the subscribers account. Event based charging can be achieved by direct debiting, i.e., Immediate Event Charging (IEC). It can also be achieved by the reservation of credit units, i.e., Event Charging with Unit Reservation (ECUR). In ECUR the subscriber's account only reflects a change after successful delivery of the service or network resource to the subscriber. The EBCF communicates with the Rating Function in order to determine the value of the requested service. It communicates with the Account Balance Management Function to query and update the subscriber's account. When a correlation process is enabled a correlation context may be consulted or created. If multiple chargeable events exist in the correlation context a combined request will be issued to the Rating Function as is the case for a composite service. In session based charging, an 'initial' charging event (session start) is transferred to the SBCF via the Ro interface. The start of a user session is authorised after successfully performing credit control on the subscriber's account.

Session based charging always involves reservation of units from the subscriber's account, i.e., Session Based Charging with Unit Reservation (SCUR). The reserved credits quota is sent to the CTF responsible for the chargeable event to authorise usage of resources, i.e., traffic volume in bytes or time in minutes. If another chargeable event occurs for the established session, or if the allocated quota is almost exhausted, an 'interim' charging event is sent to the OCS. The OCS would deduct used credits from the user's account, and reserve more credits for further resource usage. If in the cause of processing the 'interim' charging event the subscriber's account runs out of credits, the OCS will signal the CTF to terminate resource usage. If the subscriber terminates the session then a 'final' charging event will be sent to the OCS. The OCS will update the subscriber's account accordingly. This process must occur in real-time. Several concurrent services may invoke a charging session for the same user, requiring parallel operation of the credit management functions.

3.4 Chapter Discussion

This chapter has discussed the various requirements of a charging architecture that interfaces the network operator with services provider by external CSPs. All the requirements from the different stakeholders were highlighted and an architecture that best suits all these requirements was presented. The focal component of the architecture is the external services gateway that is designed to add the functionality lacking in current solutions.

The framework is designed to use standard IMS and NGN functions, interfaces and protocols defined by 3GPP and ETSI TISPAN. A suitable evaluation platform is needed to evaluate that proof of concept has been achieved and further to measure the performance of the framework. More specifically, the framework should allow for the evaluation of service bundling, service delivery and the effects that charging for services may have on the actual service delivery. The addition of an external services gateway and the performing of charging functions will have an effect on service session setup times and these latencies need to remain below a level that is acceptable for the end user. This is of importance as the user's perception of Quality of Experience will be affected by significant session setup delays and would thus render the framework unsuccessful in meeting an important initial requirement. Additionally, metrics relating to charging that would be required for this type of service coordination may introduce additional network resource utilisation than charging that is performed for normal intra-domain services. The messages exchanged between the charging entities needs to be kept to a minimal value as well as to a minimum size so as to not overwhelm the network with signalling or control traffic.

The next chapter will detail the platform that was used to evaluate the proposed framework. Chapter 5 will then detail the proof of concept tests as well as the performance evaluation results that relate to the service composition and charging functions of the framework.

Chapter 4

The Evaluation Framework

This chapter presents the objectives, requirements and limitations of the evaluation platform used to test that the proposed architecture is feasible in typical deployment scenarios. This architecture needs to be implemented in a practical testbed where evaluations can be carried out to show the performance of the framework in a realistic environment.

The implementation of a prototype service composition charging system which interfaces with a 3rd party domain was developed. It utilises a number of open source software, licensed under the GNU General Public License (version 2 and 3). These include the Open Source IMS (OSIMS) project and additional projects [8] by the Fraunhofer FOKUS institute in Germany; the Java APIs for Integrated Networks Service Level Execution Logic (JAIN SLEE) server 1.1 implementation by Mobicents and the UCT IMS Client developed by the Communications Research Group at the University of Cape Town. The testbed is built on the Linux operating system; furthermore it uses open source packages and libraries to achieve extensibility and customisation.

4.1 Evaluation Framework Objectives

In order for an evaluation platform to provide meaningful test results, it is necessary to first perform proof of concept tests to gauge the suitability of the evaluation platform as a viable environment for the proposed framework. Once the evaluation framework has been validated, further tests that prove the meaningfulness of the framework may be carried out. The objectives of these tests are to evaluate the effect of the additional gateway element on the service provisioning of the network operator, focusing on service delivery, service composition and charging overheads incurred.

The key objectives of the evaluation framework are:

- To integrate a service composition framework to a network operator functional architecture
- To test the feasibility of integrating this framework with a third party development platform
- To integrate the charging and billing aspects of service provisioning within the system.
- Finally to validate the system to conform with initial specified requirements

4.2 Requirements of the Evaluation Framework

In order to satisfy the objectives of the evaluation framework suitable testbed architecture must be designed and implemented. The testbed should satisfy the following requirements;

- It must be integrated with an IMS framework and allow for client access via multiple network access methods. The IMS framework represents the network functional architecture of the network operator.
- It must implement a client that is able to communicate with multiple service providers both within and out of the network operator's domain. For the purposes of this thesis, an IMS client will be considered.
- It must implement the third party gateway function and charging functions conforming to ETSI TISPAN and 3GPP standards. This will ensure that the implemented solution can be used in any context where standard conformance has been achieved.
- It must integrate the service composition scheme proposed in this thesis and be able to provide charging and billing for different services that would comprise of composed services.

4.3 Limitations of the Evaluation Framework

A testbed was chosen as an evaluation platform as opposed to a simulation framework. Simulations have the advantage of allowing to test for scalability and modelling of scenarios that are otherwise limited by testbeds. For a testbed to achieve the similar ability of testing for scalability of modelling of complex scenarios it would increase the cost and performance requirements of the framework. The disadvantages of choosing a simulation, however, is that these frameworks do not give a realistic environment to test for the reliability and performance of the framework proposed, as a simulation will most likely adjust for assumptions would simply the problem and not take into account what factors may attribute in a practical network.

Limitations exist in the operation of the testbed that cause it to slightly differ from the proposed framework proposed in the previous chapter. These are caused by the complexities that were observed when attempting to achieve some of the functionality of the framework. These differences are detailed below:

- The charging functions are implemented as a single entity i.e. they are not implemented as separate functions.
- The OSA Parlay interface proposed is implemented with a SIP interface to the third party domain. This was done because the SIP protocol provided the needed functionality to communicate with the external domain. The alternative of implementing a Parlay interface would have added unnecessary complexity to service mediator.

These differences do not cause the system to behave in a dramatically different way from the proposed scheme and can still be considered a suitable platform for the evaluation of the proposed framework.

4.4 Software

This section provides details of the software used in the testbed implementation. It further expands on how the design framework presented in chapter 3 was achieved in a practical implementation of these software elements.

4.4.1 UCT IMS Client

The UCT IMS Client is an open source client developed by researchers in the Communications Research Group, at the University of Cape Town. The UCT IMS client [53] was developed to provide an easily configurable real IMS user agent. The client, written in C, supports a number of features such as registration with the IMS core, voice and video calling, instant messaging and presence, uploading and downloading of XCAP documents and IPTV viewing. It implements signaling according to IETF and 3GPP standards. For the purposes of requesting additional services the client was modified to provide a GUI to facilitate this.

SIP signaling from the client to the IMS network is achieved by the use of the eXosip software package; it provides a convenient API for sending and receiving SIP messages. This allows the client to initiate and catch specific SIP events to and from the network operator. Figure 4.1 shows a screenshot of the client with the additional functions for service invocation.

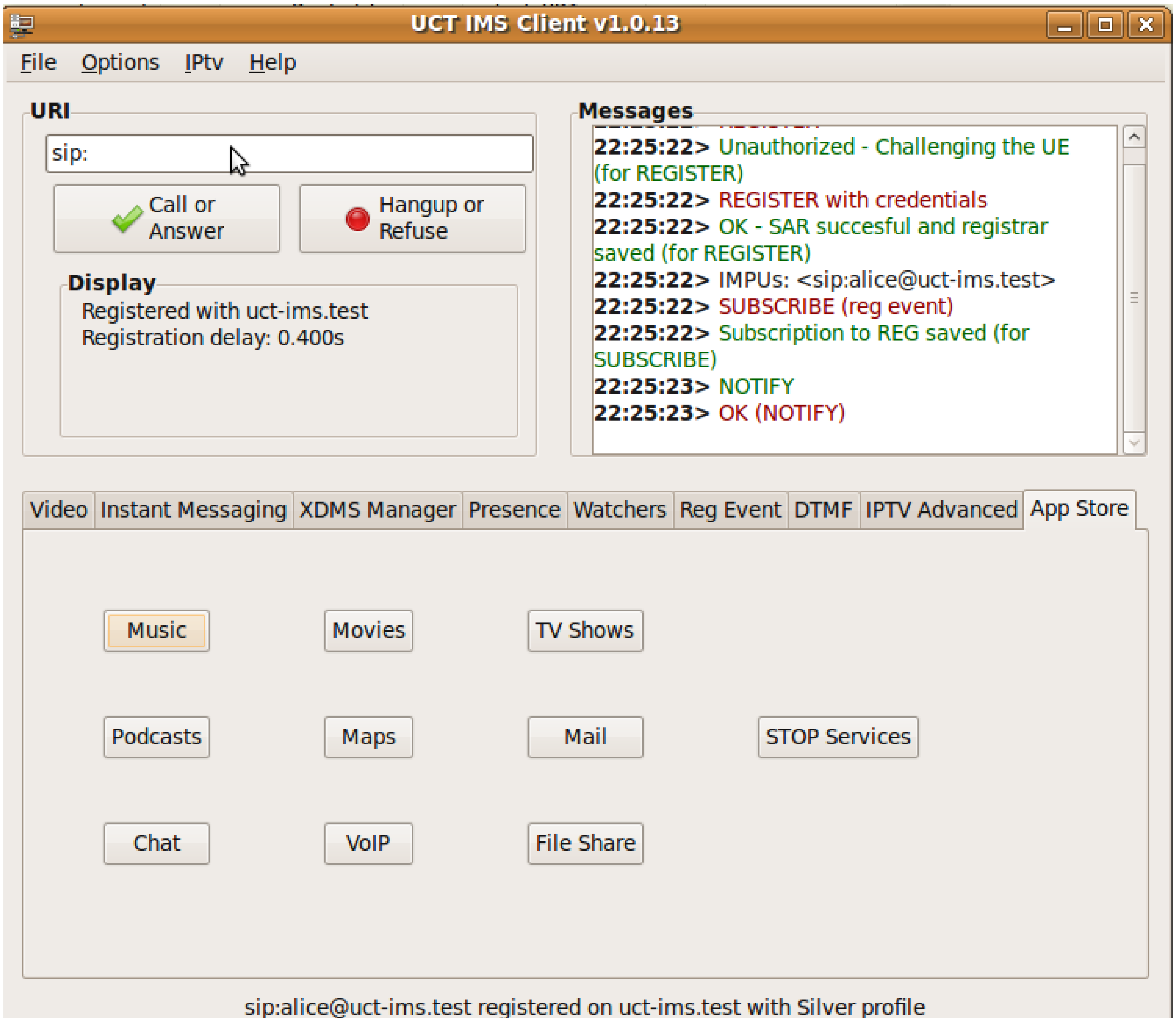


Figure 4.1: The UCT IMS Client

4.4.2 The Service Delivery Platform

To emulate the service control architecture of a network operator the IMS can be used to provide signaling needed for network operators to be able to expose and provide services to their end users. The FOKUS Open IMS Core was used to provide this environment. All the components contained in the Open IMS Core make use of Open Source software (e.g. the SIP Express Router (SER) or MySQL) [54].

This IMS Core can be broken up into four important modules:

- Home Subscriber Server – HSS
- The Call Service Control Functions – CSCFs
- The Java Diameter Peer
- The C Diameter Peer

The HSS in the Open IMS Core is written in Java and incorporates database functionality. It utilises the Java Diameter Peer module to send and receive the necessary Diameter messages in order to support the different AAA messages. The HSS has a web interface that allows for the configuration of network characteristics such as adding an AS or creating service triggering parameters. The CSCFs are all written in C. They all incorporate the use of the SIP Express Router to provide the ability to send, receive and process SIP messages. In addition the S-CSCF and the I-CSCF contain the C Diameter Peer which gives the functions the ability to send and receive Diameter messages to and from the HSS.

The FOKUS Open IMS Core is ideal for developing a charging system and services gateway as it provides a reference IMS core implementation. This implementation can be used for testing IMS technology and prototyping IMS applications for research purposes. Clients register with the Open IMS Core before they can request any additional services from the network. The Open IMS Core is responsible for the routing of IMS SIP signalling between the client and the external services gateway.

4.4.3 Service Composer

The Service Composer is implemented as a redirection application server in the application plane. When a user sends a SIP request for a service, the Service Composer first retrieves the service profile information from the Service provider database and then sends a message to receive authorisation from the charging system to allow service usage to the user. It then sends a message to the specific third party application server to provide the service to the user.

The service composer uses Structure Query Language (SQL) for data storage. The service provider database contains information about what services are available to the user from the 3rd party domain, which service providers the services belong to and other information relating to the charging of the services.

The service composer also acts as a Diameter Peer for the purposes of sending and receiving Diameter requests to the charging system. To be able to achieve this, a CTF was implemented. The CTF extends the Rf and Ro interfaces and sends charging Diameter request to the respective charging entity.

4.4.4 UCT Charging System

3GPP standards are complete and very detailed, and provide insight into how the fixed and mobile communication industry works. 3GPP systems are deployed across much of these markets. To consider developing a charging system for network operator, we needed to follow very closely the specifications defined by the 3GPP, as these are the systems that are likely to be used in industry.

The implementation of the offline and online charging functions were aided with the use of the C Diameter Peer modules developed by the Fraunhofer FOKUS Institute under a sub-project to the Open IMS Core project; the CSCFs implemented in this project were done with the C Diameter Peer. This allows the implemented charging system to send and receive Diameter messages that are standards compliant. This module has functions that allow for the creation and sending of AAA. Messages can be sent synchronously or asynchronously, depending on the desired result. As most Diameter messages are usually sent in pairs it is better to send them synchronously and block until a reply for the message has been received.

The charging system was modified so that charging for multiple services in a single session can occur. For this to be facilitated the system needed to keep track of which services where currently in use by a user during the session.

4.4.5 Third Party Application Servers

The JAIN Service Logic Execution Environment (SLEE) was used as a portal to implement services that can represent 3rd party service and content provider application servers [13]. The JAIN SLEE provides a highly scalable event-driven module with a robust component model and fault-tolerance execution environment. Services can be preloaded onto the SLEE application server such that if a request is received by the SLEE it can be redirected to the specific service.

The use of a Converged Shopping demo on the SLEE platform was implemented to provide insight into the impact of service performance when the proposed framework was adopted [51] [52]. The idea is to have a converged application that shows how an external service can be delivered to the user. This example is built using the Seam and JAIN SLEE service deployed on Mobicents. The application can leverage Mobicents to have voice, message and data transfer seamlessly to the user.

Further information on the setting up of the example service can be found in Appendix A

4.4.6 Operation of the Evaluation Platform

The sequence of events that occurs when a user first requests an external service is mapped in the following stages.

1st Stage: The UCT IMS Client creates a SIP INVITE request for one of the external services and sends this request to the Service Composer. A prior knowledge of available content is still needed. The SIP invite would contain information about the requested service for further action of the service composer.

2nd Stage: The service composer will look up the service for further information. It scans through the database to find the correlating entry. The services database contains a list of services available in the 3rd Party domain: the Service Provider the service belongs to; the rating model of the service; the service provider ID; and the service charging type.

No.	Service Name	Service Provider	Rating Model	Service Provider ID	Service Type	Update	Remove
1	music	Musica	1	2	1	edit	delete
2	movies	Sterkinekor	1	3	1	edit	delete
3	tv_shows	DSTV	1	4	1	edit	delete
4	podcasts	iTunes	0	5	1	edit	delete
5	maps	GMaps	1	6	3	edit	delete
6	mail	Webmail	1	7	2	edit	delete
7	chat	Mxit	1	8	3	edit	delete
8	voip	Skype	1	9	3	edit	delete
9	file_share	Rapidshare	0	10	2	edit	delete
10	file_share1	Hotfile	1	11	2	edit	delete
11	music1	Express	0	12	3	edit	delete
12	movies1	MovieMagic	1	14	3	edit	delete
13	tv_shows1	etv	1	15	3	edit	delete
14	podcasts1	OnionRadio	1	16	1	edit	delete
15	maps1	BingMaps	0	17	2	edit	delete
16	mail1	Groupwise	1	18	2	edit	delete
17	chat1	Fring	1	19	3	edit	delete
18	voip1	GooglePhone	1	20	3	edit	delete
19	file_share2	Telkom	1	1	2	edit	delete
20	file_share5	Telkom	1	1	2	edit	delete
21	voip2	Telkom	1	1	3	edit	delete
22	file_share3	Telkom	1	1	2	edit	delete

Figure 4.2: Services look-up table

If the service composer cannot find the correlating entry, i.e. that service request cannot be attended to, the service composer sends back SIP 402 message indicating that service delivery cannot continue. If the service composer finds the entry it builds a service composition object with the information retrieved from the database.

3rd Stage: The service composer would then send the required messages to the online and offline functions. To the offline function the AS would send a:

- *cdf = Rf_ACR(session_id, origin_host ,origin_realm, destination_realm,* ***START****, acr_number, destination_host)* this Diameter message contains all the AVPs for a ACR message as stated in the table below. The values for the AVP are shown in the table 4.1 below:

Table 4.1: Offline Charging Diameter Message

Attribute Name	AVP Value
Session Identifier	Unique session generated ID
Origin Host	osa.uct-ims.test
Origin Realm	uct-ims.test
Destination Realm	uct-ims.test
Accounting Request Type	START
Accounting Request Number	Unique request number
Destination Host	ofcs.uct-ims.test

To the online function the AS would send a:

- *ocf = Rf_ACR(session_id, origing_host, origin_realm, destination_realm,* ***INITIAL_REQUEST****, cc_number, destination_host)* this Diameter message contains all the AVPs for a CCR message as stated in table 4.2.

In both cases the Service Composer will wait until it receives a response from the charging functions before it carries on with servicing the client request. The sent message contains the AVPs necessary for the charging functions to initialise charging activities. Calling these functions invokes the CTF to create Diameter messages and wait for the corresponding responses to those specific messages. In the case of Offline charging, sending an Accounting Record Request should be replied with an Accounting Record Answer with the corresponding Session Id and a Result code of Success. Similarly in the case of Online charging, sending a Credit Control Request should be replied with a Credit Control Answer with the corresponding Session ID and a Result code of Success

Table 4.2: Online Charging Diameter Message

Attribute Name	AVP Value
Session Identifier	Unique session generated ID
Origin Host	osa.uct-ims.test
Origin Realm	uct-ims.test
Destination Realm	uct-ims.test
Credit Control Request Type	INITIAL_REQUEST
Credit Control Request Number	Unique request number
Destination Host	ocf.uct-ims.test

Table 4.3: Multiple Services AVP Group

Attribute Name	AVP Value
Service Identifier	Unique service D
Rating Group	Rating model (discounts)
Service Provider	Name of SP
GSU Pool ID	The credit pool
Multiple service count	Number of services in current session
Credit Control Request Num	Unique request number

Additionally, the AVP Multiple Service Indicator will be sent to indicate that credit control for multiple services should be supported for this session. The AVP Multiple Services credit control will be sent in the same message; the AVP is a group AVP with values as indicated in table 3:

4th Stage: once the charging system receives the request for the user, it will check if the user exists in the database. This is done by a lookup of the user profile database that contains information of known users in the network. This database also contains charging information relating to the user; such has how much credit each users currently has etc. The charging functions will then perform authorisations on the user and reply to the Service Composer accordingly.

No.	IMPU	Names	Age	Gender	Credits	Update	Remove
1	alice	Alice Keys	33	2	83	edit	delete
2	bob	Bob Martin	23	1	2	edit	delete
2	alex	Alex Green	54	2	2	edit	delete
3	jane	Jane Doe	34	2	2	edit	delete
4	joe	Joe Soap	41	1	2	edit	delete
5	john	John Smith	76	1	2	edit	delete

Figure 4.3: User Charging Information

5th Stage: Once the composer receives the responses from the charging functions (and after checking that they contain a result code indicating that it was a successful response) the composer can then send a request to the 3rd Party domain's service provider indicating that services should be delivered to the requesting user. When it has received confirmation from the SLEE server, the composer sends to the UCT IMS Client in a SIP 200 OK response.

5th Stage: The Service Composer enters into a listening state for further service request from the user. The CTF will also send regular update messages to the charging functions to make sure that the user is still authorised for services with regard to credit balances.

4.5 Hardware

The testbed architecture is shown in figure 4.4. It consists of 5 machines connected by 100Mbps Ethernet connection. Two machines run the IMS core (one runs the P-CSCF and the I-CSCF, another S-CSCF and the HSS). The Service composer and the charging system are collocated on one machine and the Jain SLEE server runs on another machine. Lastly one machine on the Ethernet network runs the extended UCT IMS Client software. The details of each machine can be found in Appendix B. The testbed architecture also includes the use of three different access networks technologies namely 100BASE-T Ethernet LAN, IEEE 802.11g (WLAN) and IEEE 802.16d (WiMax).

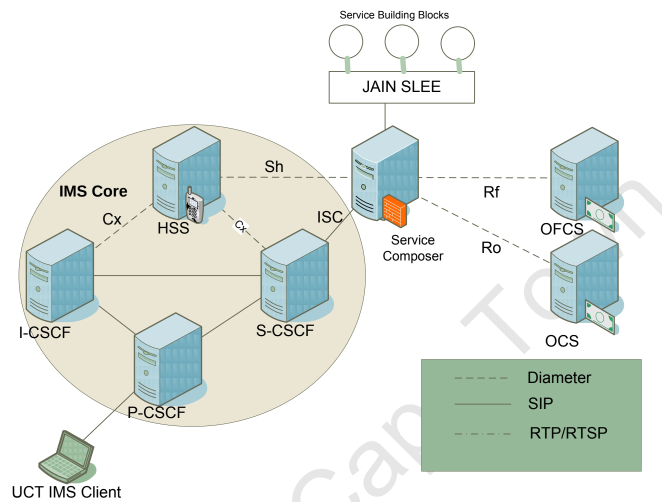


Figure 4.4: Testbed Hardware Architecture

4.6 Chapter Discussion

This chapter outlined the architecture of the evaluation framework. The chapter further discussed the requirements and limitations of the framework. The testbed software and hardware elements were then discussed as well as the operation of the platform.

The following chapter details the proof of concept tests performed to validate the testbed as an adequate evaluation environment. Further tests to measure the response times vs. the number of services requested simultaneously, delays introduced by the service lookup, composition and charging will be performed. The next chapter will present the results obtained.

Chapter 5

Verification, Evaluation and Analysis

Chapter 4 presented the architectural testbed design of the proposed framework that would provide charging for 3rd party composite services. This testbed provides an environment to evaluate the framework to demonstrate that proof of concept has been achieved. Additionally tests were performed to investigate metrics relevant to charging, service composition and service delivery for the end user.

This chapter investigates the effectiveness of the proposed platform by subjecting the testbed to different use case scenarios and observing if the desired outcomes are achieved. Additionally an example Converged Shopping demo scenario provides a 3rd party service delivery example. From this example results obtained give insight on service delivery metrics such as session setup delays, which is important to observe as an increased overhead is expected to be incurred by the additional signaling within the network.

The charging functions will also be subjected to tests that aim to prove the effectiveness of service charging for the different services. Also investigated was the impact different charging related messages would have on network utilisation and overall efficiency. The results obtained aim to demonstrate the effectiveness of the proposed solution and limitations to provide a stepping point for future work.

5.1 Verification of the Evaluation Platform

In this section, the functionality of the overall platform is presented with the execution of 3 composite service scenarios. The first scenario deals with the composition and charging of three services offered by three service providers. The three services could be arbitrary services. For example, one could represent the services as an IPTV service, an Advertising service and a VoIP calling service (Service A, Service B and Service C respectively). This information is stored in the service provider database. After some time, the user invokes Service C. The user opted for prepaid charging thus the OCS is contacted to perform charging.

The second scenario demonstrates actual service delivery by use of a built in service of the JAIN SLEE service development platform [52]. The service allows a user to view videos that are available for purchase from the Video Portal in the third party domain. Users are also able to view trailers of the videos that are streamed to the user from a streaming server which also resides in the service providers' domain.

The last scenario demonstrates the charging capabilities of the system by having a user incrementally invoke services. The credit usage of the user should reflect the number of services that the user is currently subscribing to. Additionally this scenario should demonstrate that the user is only able to view services for the period that he is authorised.

5.1.1 Scenario 1: Invocation of 3 Services

Figure 5.1 shows the signaling flow for the invocation of 3 services. The first phase of the scenario is represented in purple on the diagram. Initially a registered user would create a session with a request of the services. This is represented with a SIP INVITE message being sent to the service mediator. The SIP message traverses the IMS core and arrives at the S-CSCF. The service mediator is configured as an Application Server and an Initial Filter Criteria (IFC) check will forward the request to the service mediator. The service mediator receives the request and retrieves profile information from the service provider database relating to the service in the SIP INVITE message. Once the service mediator has all relevant information about the services and respective service providers, the mediator would then inform the CTF to make a CCR_INITIAL() request to the OCS. This initial message will include the *Multiple-Services-CC* AVP with the relative information about Service A. The OCS would then perform rating on the service and reserve quota for the service provided that the user has sufficient credit for the requested service. The OCS then responds to the CTF with a CCA() with the amount of quota allocated for Service A. The Service mediator contacts the service provider of the service to provide services to the user. Almost immediately the user turns on Service B. This is also sent as a SIP INVITE to the service mediator. The user would then receive services A and B.

The second phase represented in blue on Figure 5.1 represents the charging interim messages required for online charging. After a certain interim period that is determined by how much quota was allocated the CTF has to request more quota to continue with the service session. In this case the services are set to be validated for an interim period of 30 seconds. The CTF would send a CCR_UPDATE() to the OCS. The OCS performs the credit reservation of new quota and deducts the previously reserved quota from the user's account. The OCS then responds with a CCA() with the new amount allocated quota.

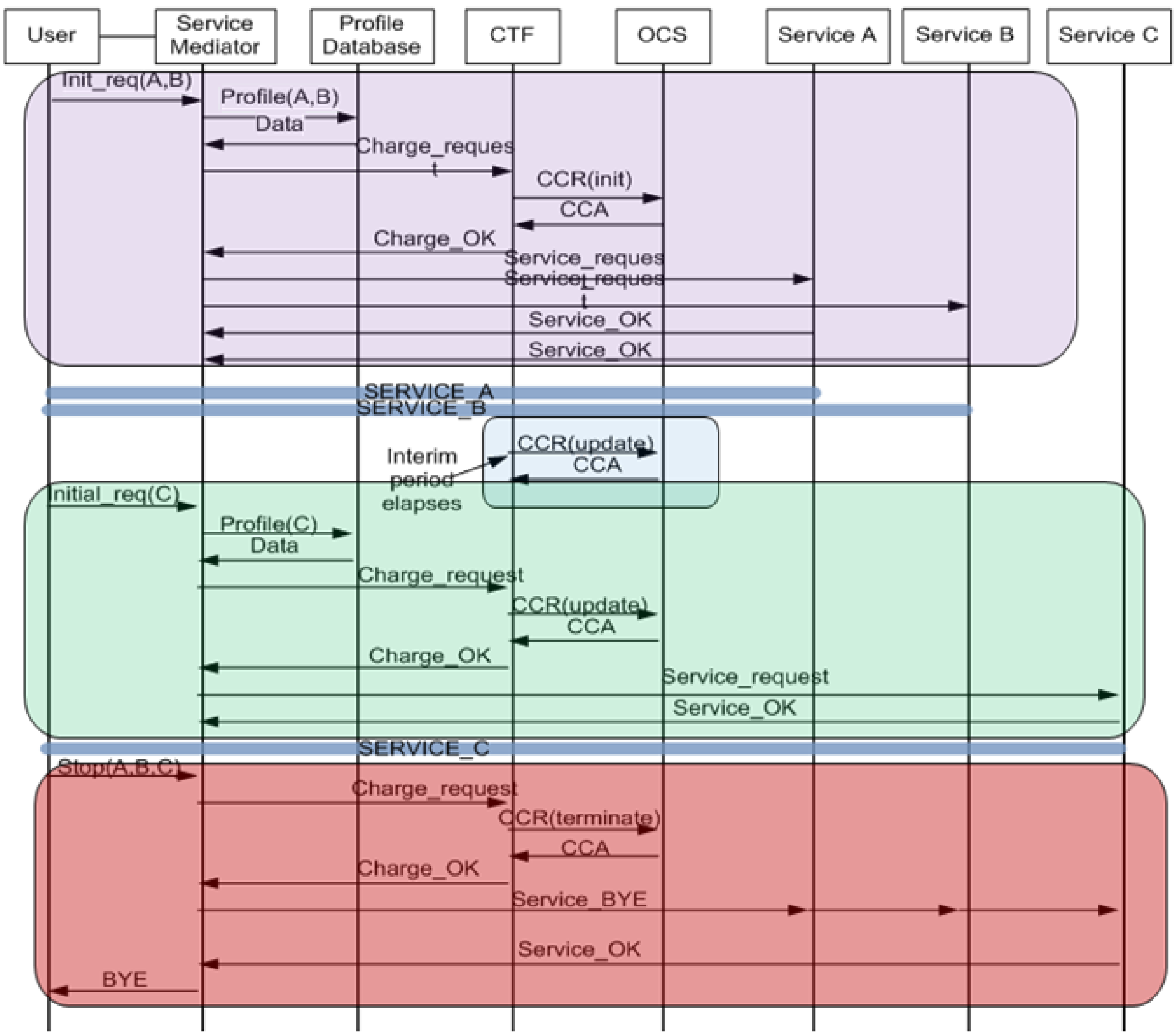


Figure 5.1: Composition and charging process of scenario 1

The third phase of requesting Service C is represented in green on Figure 5.1. The user requests for a third service, Service C from the network one minute after requesting the initial services. After the profile information has been retrieved from the database the service mediator immediately informs the CTF to send a CCR_UPDATE to the OCS with new information about Service C. This CCR_UPDATE also has an updated *Multiple-Services-CC* AVP that contains the charging information of services A, B and C as well as an updated service count for the current session. The OCS performs rating on the new service, reserves quota for the new service as well as reallocating reservation quota for the old services and deducting credit from the users account from the last interim period.

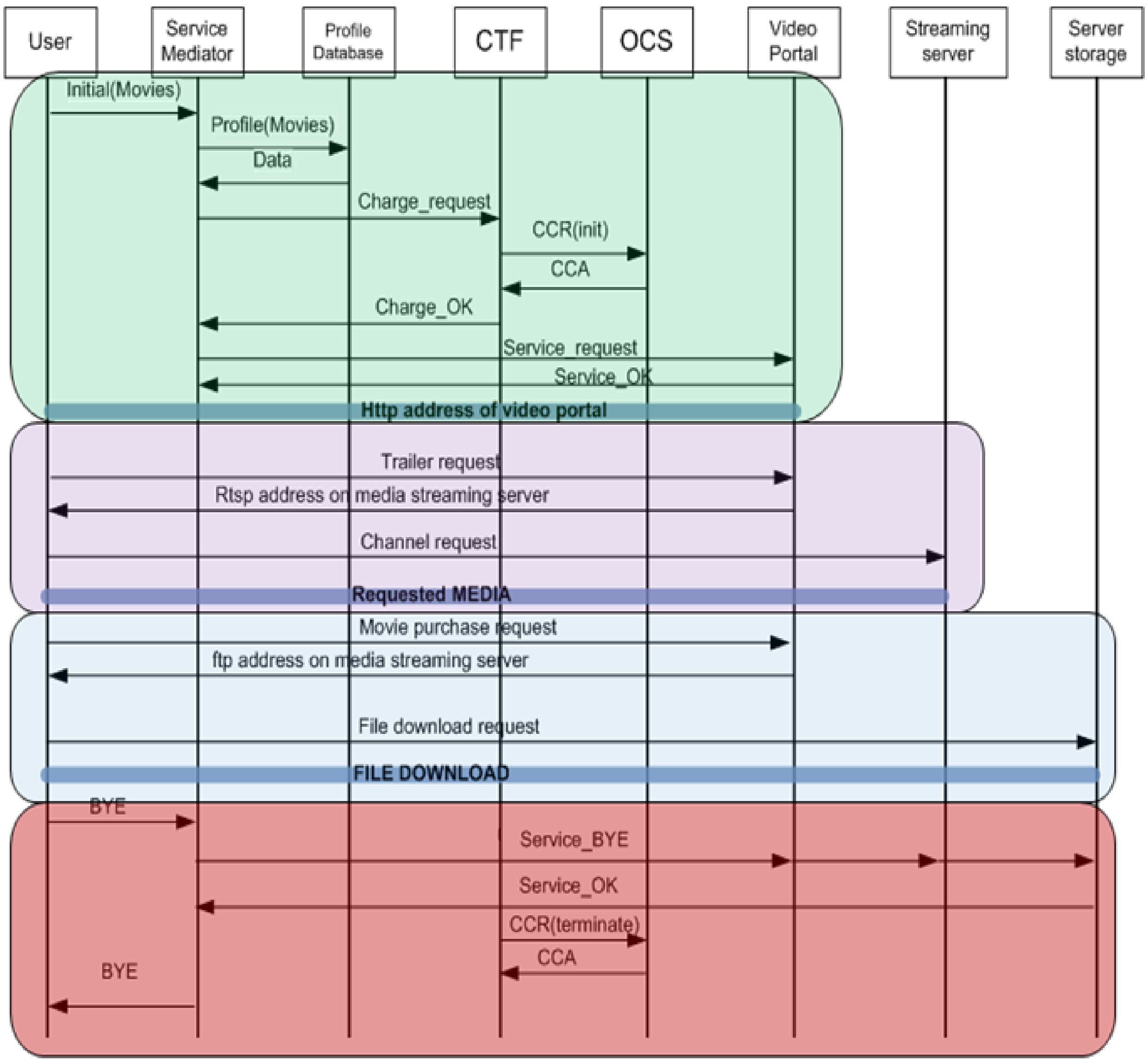
The last phase of ending all service sessions is represented in red on Figure 5.1. When the user requests to terminate the services the service mediator informs the OCS to stop performing online charging as well as to inform the service providers to stop delivering services to the user. The termination of services can also be instigated by the OCS when the user's credit is insufficient.

5.1.2 Scenario 2: Converged Shopping Demonstration

Figure 5.2 shows the signaling flow of the Converged Shopping Demonstration example. The first phase of the scenario is represented in green on the diagram. A registered user (Alice) requests the Movies Service from the available Applications Store on the IMS Client. A SIP INVITE message is sent to the service mediator. The service mediator performs the functions of service lookup in the database; requesting service authorisation from the charging functions; and sends a SIP INVITE request for the service to the 3rd party application server. Alice receives a SIP OK message with a web address for a video shopping portal embedded in the content header of the SIP 200 OK message. On receipt of the SIP 200 OK message the UCT IMS Client is configured to launch a Firefox session.

Alice is then presented with a web interface that allows her to register or login. An unregistered user is able to browse videos that are available for purchase but is unable to view the available trailers. Once Alice has logged into the video sharing portal she may click to view a trailer. Clicking on the view trailer button would send a SIP INVITE from the 3rd party application server to the register user (Alice) on the UCT IMS Client. The IMS Client would respond with a RE-INIVTE to the 3rd party application service. A SIP 200 OK response will be sent to Alice and will contain the RTSP address of the trailer that is available on demand from the streaming media server in the third party domain. The UCT IMS client would then open a VoD window which will then play the trailer of the movie requested. This is shown in purple on Figure 5.2. The web interface and VoD streaming is shown in Figure 5.3.

Figure 5.2: Signalling Diagram for Converged Shopping Demonstration



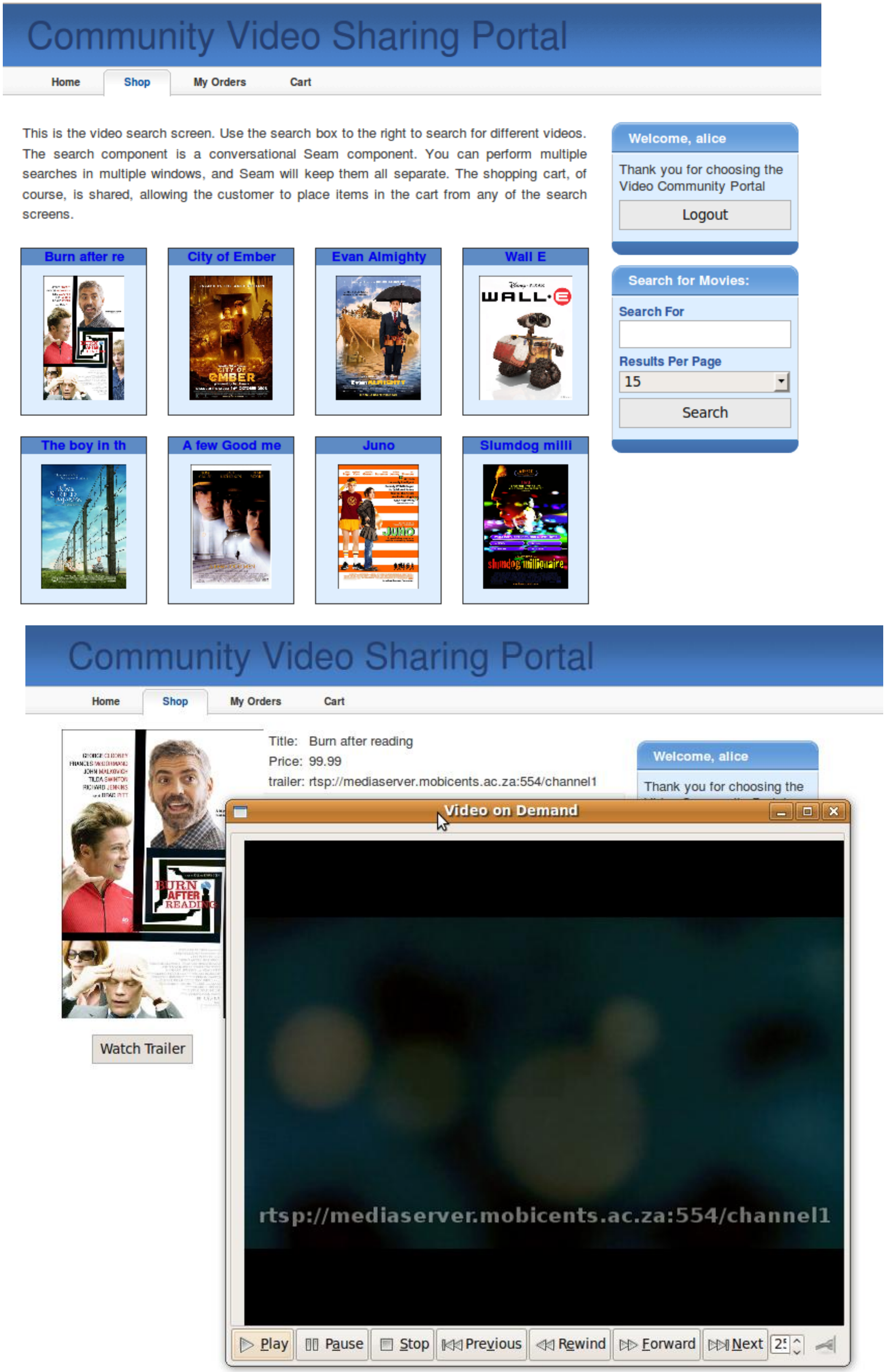


Figure 5.3: Web interface and VoD streaming

The user can then choose to purchase the whole video. After checkout a SIP INVITE is once again sent to the registered user on the UCT IMS client. The client will send a SIP RE-INVITE and receive a SIP 200 OK message that will contain the FTP address where the video is stored on the 3rd party server. This video is then available for download within the Firefox window. This is shown in blue in Figure 5.2.

Shown in red on Figure 5.2 is the signaling for session termination. The UCT IMS Client would send a SIP BYE message to the service mediator. The service mediator sends SIP BYE messages to the 3rd party application server. The service mediator also sends a CCR_TERMINATE Diameter message to the charging function. Lastly the service mediator responds to the UCT IMS Client with a SIP OK corresponding to the SIP BYE message received.

This scenario's setup is further explained in Appendix C. The Mobicents JAIN SLEE server converged shopping demo provides a good reference point of how a service can have multiple workflows to provide the user with a service that incorporates multiple service components. Services observed in this example are file download, video streaming and content browsing.

5.1.3 Scenario 3: Invocation of services with limited user credit

An increased rate of credit consumption is expected as the number of service requests for an individual session increase. For example, a user would run out of credit much quicker if he requests four services compared to if he only requests one service. To test this two scenarios are run. In the first scenario a user begins with a balance of 500 credits and requests one service for the duration of the established session. In the second scenario a user begins his session with a balance of 500 credits and incrementally requests more services. Initially the user requests one service, then after 20 seconds requests another service. After a further 40 seconds he requests a third service and finally after 70 seconds, requests a fourth service. This is compared to the case when the user only requests a single service. The credit balance in each scenario is tracked and presented in Figure 5.4 as a function of time.

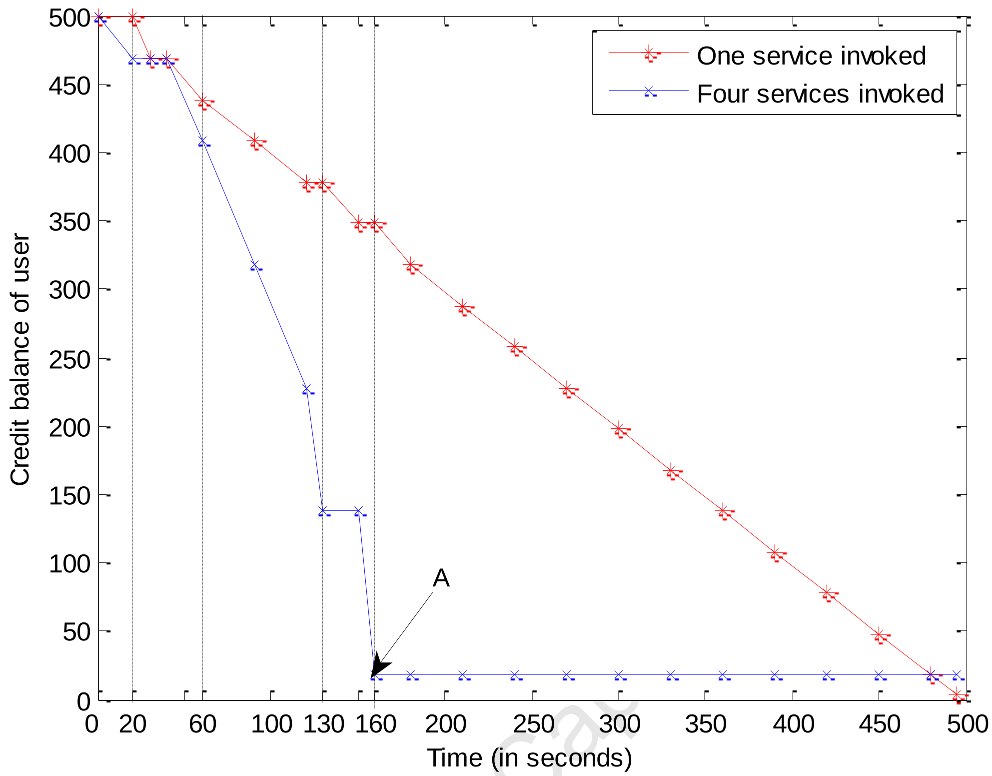


Figure 5.4: Comparison of credit consumption for services

In the second scenario the user requests an additional service at times t = 20; 60; and 130. The graph shows the user's remaining credit balance for the duration of the scenarios. For the case of multiple service invocations the user runs out of credit in a third of the time when compared to the one service scenario. With four services running the user's session is closed due to insufficient credit after 160 seconds – this is represented as point A on the graph. From point A onwards, services cannot be delivered to the user due to an insufficient credit balance.

5.2 Evaluation of the Proposed Framework

To evaluate the proposed charging framework for external domain composite services, certain metrics are measured within the developed network environment. Latencies relating to service session setup delay and service delivery are of importance. Not considered are transport plane metrics such as jitter, packet loss and network throughput or utilisation of services as these do not directly apply to this work. Furthermore, the effects of service composition are investigated in terms of:

- the session setup delay incurred by a service request
- how this delay is affected when the user is on different access networks
- the service mediator's response time as the number of service requests increases
- CPU utilisation of the service composition process as the number of requests increases
- traffic that is generated between the service mediator and the charging functions when online charging is being performed

5.2.1 Session Setup Delays

Additional signaling between the entities in the framework will have an effect on session setup times. To observe session setup delay two scenarios are evaluated. The first scenario is the reference case that implements basic IMS service session setup. In this scenario there is no additional signaling to the charging functions and no service lookup is performed as the service resides in the IMS domain. The second scenario shows the session setup of a 3rd party service. This scenario includes the service lookup in the Service Provider Database; the charging functions authorisation and session setup with the 3rd party AS. The scenarios are shown in Figure 5.5

A service request was initiated 30 times and the session setup delay was recorded for each instance. These tests were performed with the user using 100BASE-T Ethernet LAN as an access technology. For the 3rd party service scenario the lowest recorded delay was 454 milliseconds; the highest recorded delay was 2233 milliseconds, and the average delay of 1234 milliseconds. Results from the two scenarios are compared in Table 5.1 and Figure 5.6; the mean session setup delay is presented in the table and the recorded individual session setup delays are presented in the figure.

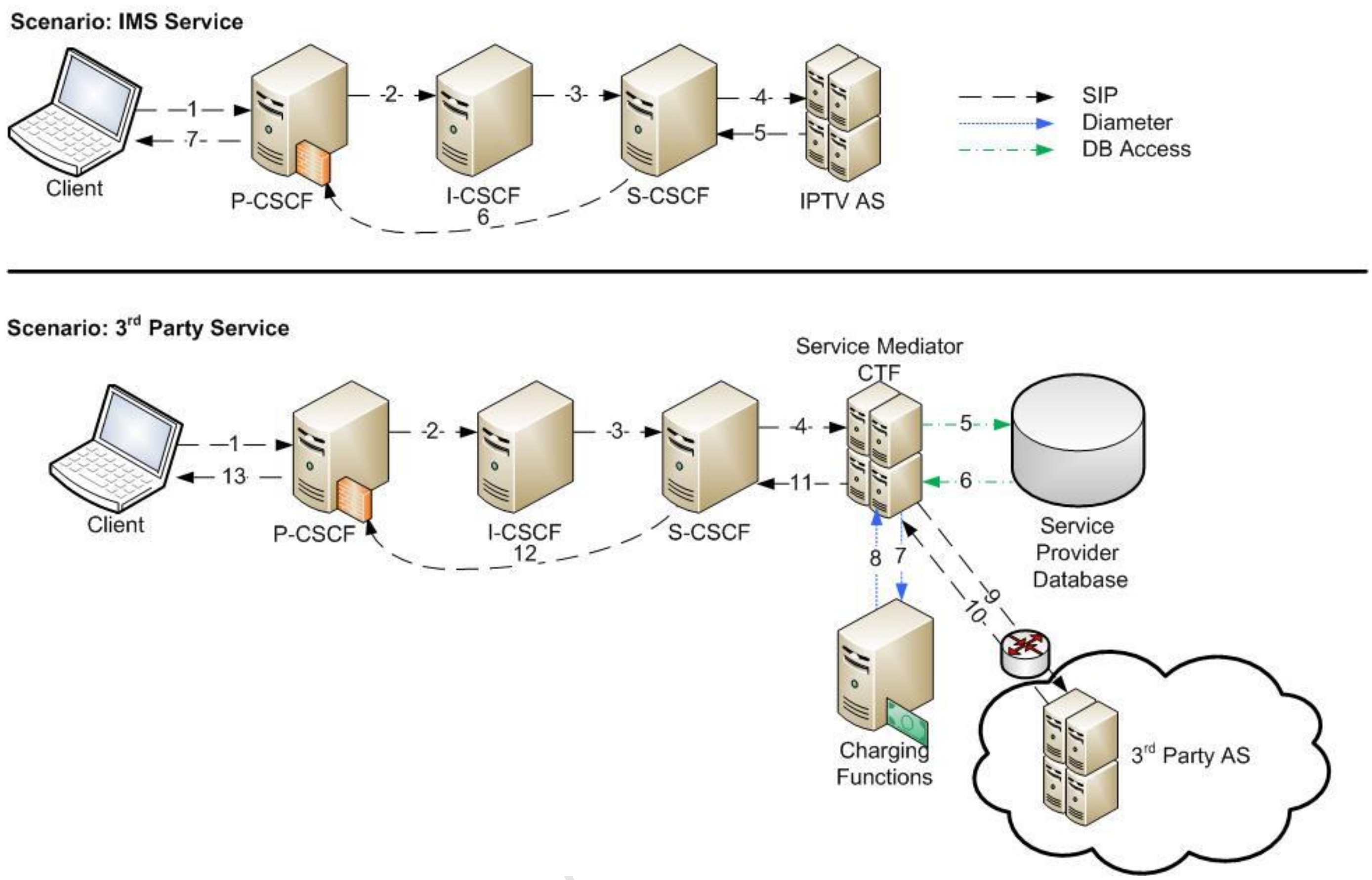


Figure 5.5: Two scenarios where session setup is evaluated

Table 5.1: Average latency results

Service type	Mean (msec)
3rd party domain service	1234
IMS domain service	657

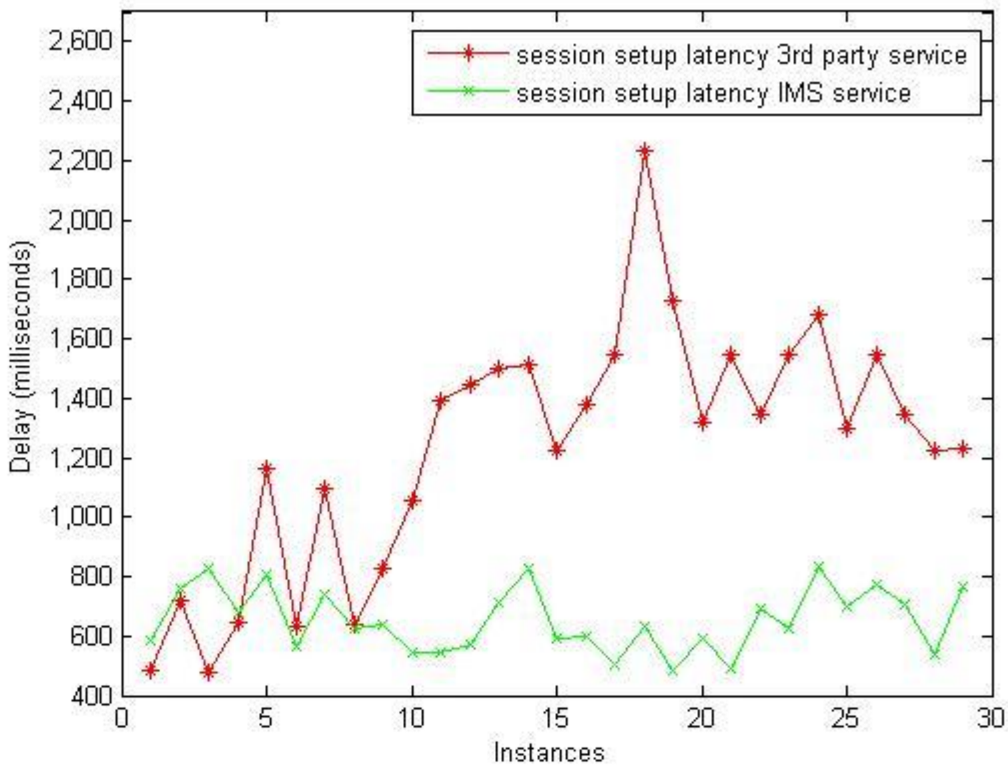


Figure 5.6: Individual session setup delays for IMS service and 3rd party service

The IMS service latencies are noticeably lower than those of the 3rd party service. This is due to the fact that the 3rd party service session setup undergoes additional signaling when compared to the IMS service.

The 3rd party service scenario was repeated over two other access networks: IEEE 802.11g (WLAN) and IEEE 802.16d (WiMax). It may be the case that the user is on a different access technology to that of the 3rd party service provider. For example the user may be a wireless user. The average session setup latencies for the different access technologies are presented in Table 5.2. The individual session setup delays are shown in Figure 5.7.

Session establishment should last no longer than 2-5 seconds to give the user a perception of almost immediate reaction [51]. For all three access technologies the average delay is below 5 seconds, however for the WLAN scenario session setup delay spikes above the acceptable values for some call instances. This can be attributed to the nature of the access technology which is prone to experience collisions and retransmission which would affect delays of session establishment. LAN access gives the best results followed by WiMax and WLAN.

Table 5.2: Access technologies comparative delays

Technology Used	Mean Delay (msec)
WLAN	2644
WIMAX	1345
LAN	1231

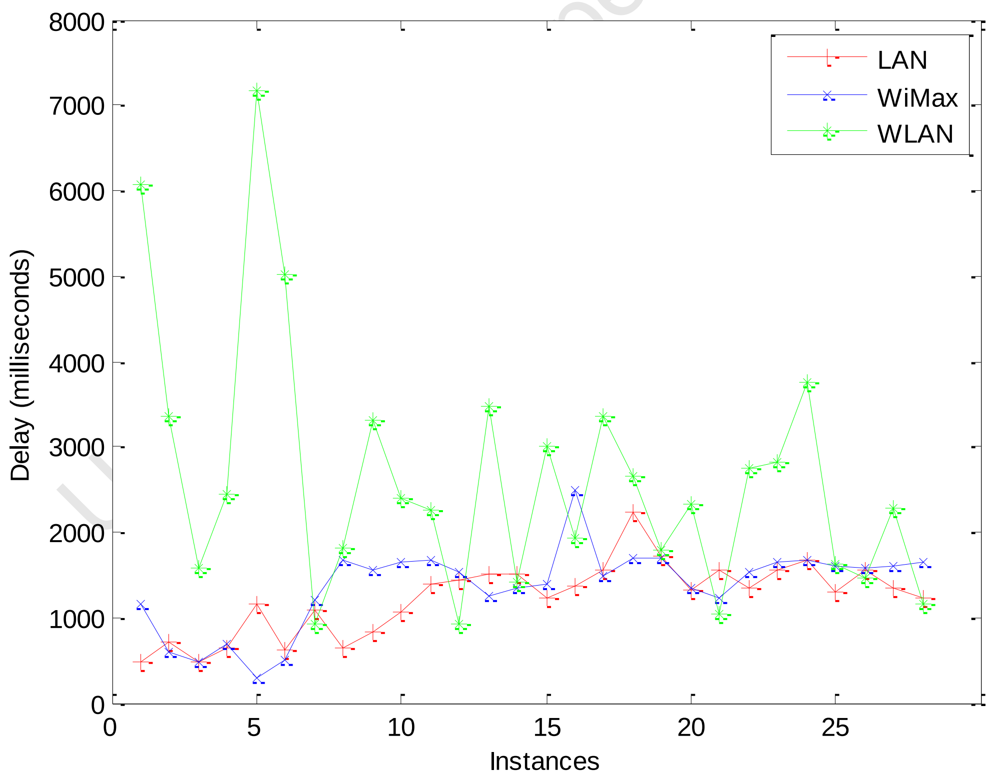


Figure 5.7: Individual session setup delays for different access technologies.

5.2.2 Composition Process Load Testing

Analysis of the service composition process involves the monitoring of the process's response time to service requests and the process's host machine resource usage as the number of requests is increased [32]. These tests are performed to gauge the performance of the system under heavy load. Every time an additional service is requested, the service mediator needs to create a new service object. This process can have an overall effect on the entire system if the number of request rises to a high level. In order to measure the effect of increased requests on the system tests were performed to measure the response time of the system as the number of request increased from 1 - 90. The response time of the service mediator is measured as the time from first receiving the SIP INVITE message from the user to the time a SIP OK message is sent back to the user for each individual request. This response time is shown as a function of the number of requests made in Figure 5.8. The time CPU utilisation of the composition process on the service mediator server machine was measured as the number of requests was increased; this is presented in Figure 5.9.

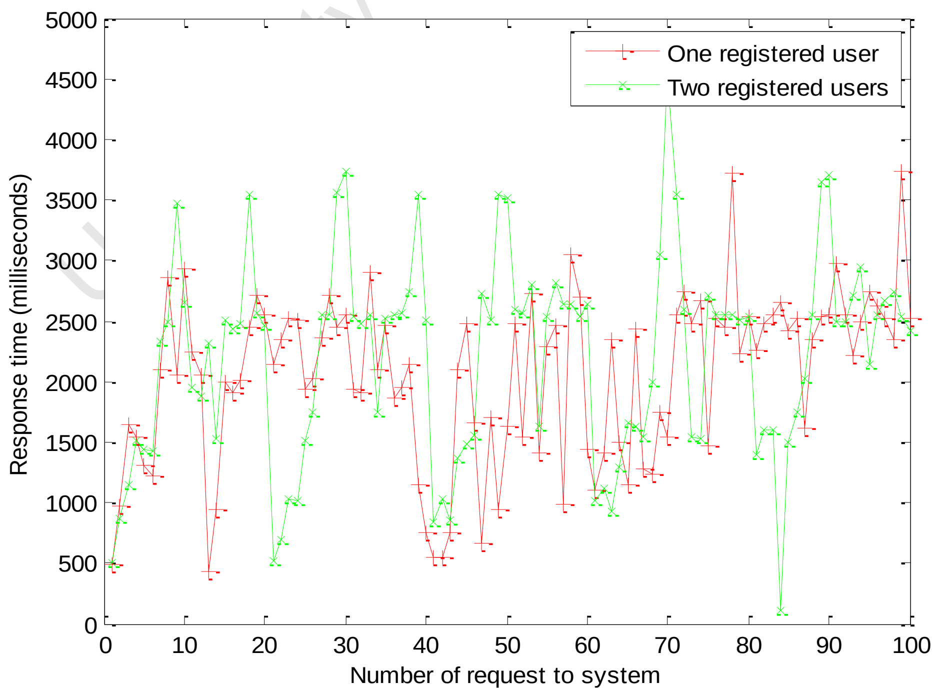


Figure 5.8: Response time of service mediator as requests increase.

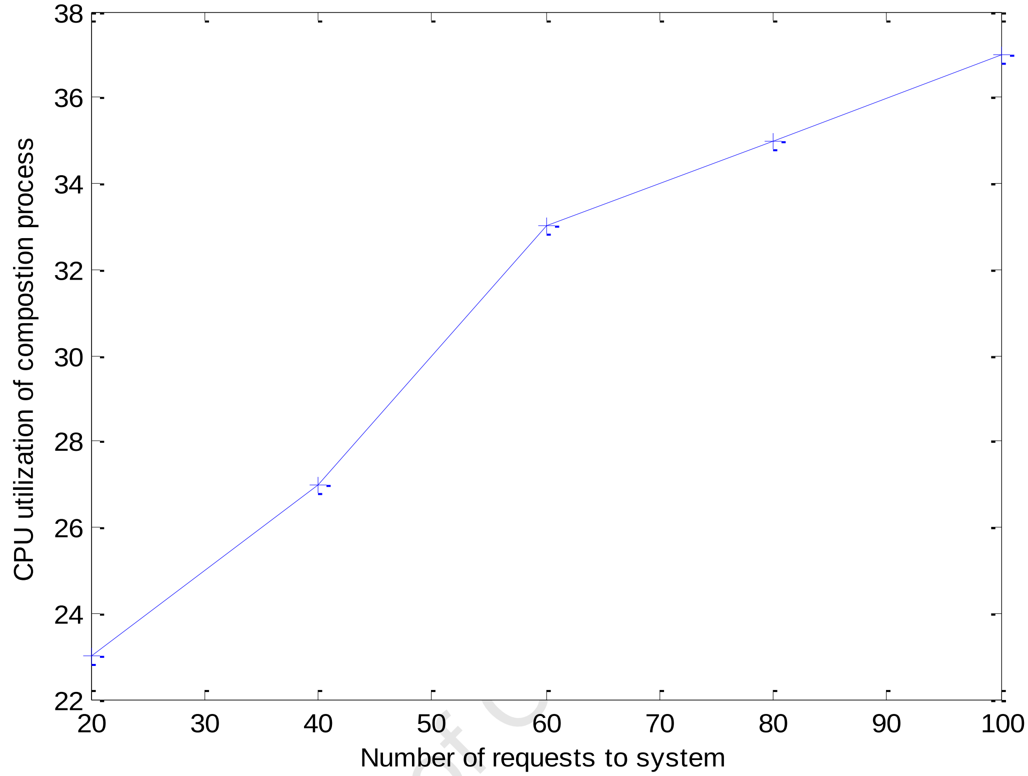


Figure 5.9: CPU utilisation (5%) of composition process

For both results, as the number of requests placed to the service mediator increased, so did the response time and the CPU utilisation of the composition process. As the number of requests increase the average response time rises above 2 seconds and spikes to 4-5 seconds on some requests. This shows the system still performing within what would be considered acceptable according to [51]. The CPU utilisation remains below 40% on the server machine running the service composition process.

These results show that the service mediator's response time remains unaffected as the number of requests increase. These results consider scalability to a limited extent however, they cannot form the basis for comparison with commercial implementations. The performance of the composition process is dependent on the host machine specifications and installed operating system. The hardware specifications and operating system used in the presented testbed is detailed in Appendix B.

5.2.3 Charging Overheard

Due to the nature of the charging functions, continuous charging Diameter messages are passed within the network from the service mediator. In Chapter 3 the operations of offline and online charging functions is explained. For the duration of an established session interim messages need to be sent from the service mediator (CTF) to the charging functions. For the case of online charging, the interim messages allow the OCS to perform credit re-authorisation to keep the session valid. If the CTF sends an interim message and receives a response from the charging function *CCR_TERMINATE*(insufficient credit) the service mediator will tear down the current session.

Each interim message contains information on all service requests currently received from the user. To be able to perform charging on more than one service in a single session the Multiple Services CC AVP needs to be added to the Diameter Credit Control message. During online charging the CCR_INITIATE, CCR_INTERIM AND CCR_TERMINATE will contain this additional AVP. Table 5.3 shows that as the number of services requests increases, this will have an effect on the size of the *Multiple Service CC* AVP. However the overall size of the Credit Control Diameter message passed remains unchanged and is fixed at 17408 bytes. This means that the addition of the AVP does not increase the amount of traffic sent to the charging functions.

These results show that the traffic generated by the charging process is minimal and would not adversely affect the network with the increased utilisation. In a 100BASE-T Ethernet LAN network where the network core elements and charging elements were located, the introduction of the additional charging messages has a negligible effect on the network. The use of interim periods to check user credit balance in conjunction with the credit reservation performed on services as detailed in Chapter 3 ensures the interval chosen for credit checks on a user's balance is irrelevant.

Table 5.3: Size of Diameter messages in charging

Number of Requests in Session	Size of Multiple Services AVP (bytes)	Size of Diameter Credit Control Message
20	732	17408
40	1452	17408
60	2172	17408
80	2892	17408

5.3 Chapter Discussions

This chapter presented the verification and evaluation of the platform presented in the previous chapters. Proof of concept tests were carried out using three 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.

Evaluation of the framework was performed by measuring the session setup delays of a third party service that undergoes charging authorisation and comparing these results to session setup delays of an IMS service. The tests showed that the framework increases the session setup delay due to the additional signaling and checks performed by the charging functions. Tests also showed that the different access technologies affected the session setup delay with 100BASE-T Ethernet LAN experiencing the lowest average delays followed by 802.16d (WiMax) and lastly 802.11g (WLAN).

Results obtained also showed that as the number of requests sent to the service mediator increased, the response time of the system and the CPU utilisation of the composition process increased slightly. The service composition process does not degrade the performance of the service mediator host machine.

Chapter 6

Conclusions

This thesis highlights the importance of deploying revenue generating services into the telecommunications marketplace with the intent of maintaining customer attention and creating revenue streams. The thesis discusses the use of interfaces that allow network operators to allow 3rd party service and content providers the ability to offer their services in partnership with network operators.

6.1 Summary

Network operators see the benefit of offering value added services to their end users because these are the services that generate revenue. Traditionally services such as voice and text messaging were the "killer applications" for the network operator; however these services are generating less income per user. With the emergence of IP based services such as VoIP, Instance Messaging, IPTV and the like, network operators end up being nothing more than a medium from which user obtain their IP services.

This thesis proposes a framework that would allow network operators to maximise on infrastructure that they possess and form business partnership with external service and content providers with the aim of tapping into lucrative revenue streams.

The key issues that that lie in network operators allowing services and content from external parties to be made available in their domain were found to be:

1. Current systems that allow for this kind of interaction are limited in the sense that they do not cater for new business models and will remain to be outdated in the Next Generation Networks context.
2. This sort of interaction produces a complexity were multiple players are involved in the value chain for a composite service. Mechanisms need to be in place to allow for the successful coordination of services to the end user.

3. The charging requirements for these kinds of services needed to be redefined and charging mechanisms that allows for multiple domain interaction needed to be in place.

This thesis proposed a framework that would allow for interworking of external service and content providers with network operators to offer services to end users. These services could be composed in such a way that the end user is unaware of the complex value chain involved in the provisioning of the service. Additionally the framework allows for the successful charging of these services, to the benefit of the end user, the network operator and the CSPs.

An evaluation platform was developed to provide a proof of concept implementation of the proposed framework. On this platform it was investigated what the expected service setup latency could be expected for an external domain service. The platform also allowed for the investigation of service interaction with the end user under different access technologies. Lastly the platform provided insight on what impact the charging for these types of services would have on the network and whether this would be an acceptable.

Based on tests run on the platform the following results were of importance:

- The coordination of multiple services that may originate from different service or content providers produces a rich service experience for the end user.
- The additional signaling introduced during service session setup that involved the user charging authorisation as well as the need to contact an external service or content provider for the service to be delivered introduced an observable delay when compared to a service that is offered within the network operator's domain that undergoes no charging authorisation. This delay however remains within the range of what would be considered acceptable for a user who establishes a service session.
- The charging that would be required for this type of service coordination introduces no additional network utilisation then charging that is performed for normal in-domain services.

6.2 Conclusions

Based on the finding of this thesis we conclude that:

- Composing or bundling of external CSPs' services will essentially create new services for the user and achieve rapid deployment of enhanced services.
- The use of a service mediator that acts as an intermediary between the network operator and the third party CSP would allow for the successful coordination of services for end user delivery. This thesis shows by proof of concept that such an architecture that conforms to 3GPP frameworks can achieve effective charging for these types of services.
- Furthermore usage based charging mechanisms can be incorporated where it was previously not seen in past systems. The architecture also allows for the incorporation of complex business models that allows for revenue sharing models to reflect in a user's credit consumption.
- The charging functions would be able to provide near real time credit monitoring of users and allow for dynamic rating of services depending on how they are invoked by the user.

6.3 Recommendations

During the course of this thesis, a number of key issues were faced in either literature or during implementation of the thesis that are not directly addressed in this work but could form a basis or starting point for future work.

The implementation of the network operator relied heavily on the use of an IMS implementation that allows for successful user registration and service coordination. If it is the case that a network operator does not deploy an IMS control layer then this work cannot validate the use of a servicer mediator to interface with the network. Future work could investigate how to implement such a system in the absence of an IMS. In fact due to the nature of the work presented in the thesis, the entity that interfaces with the external domain could be adjusted to work in future network architectures such as the Evolved Packet Core or from an Internet perspective with the use of Web 2.0 interfaces.

The scope of this thesis did not allow for the actual development of a third party service, as services were assumed to be already available. For this reason real time tariff information or changes about services was not implemented in the platform, as is proposed in the architecture. Future work would involve the creation and modification of a third party service to allow for this to take place.

Bibliography

[1] K. Järvi, L-M. Sainio, and P. Ritala, "A *Partnership Business Model: Case IP Multimedia Communication Services*", Proceedings of the Third European Conference on Management Technology (EuroMOT '08), September 2008.

[2] L. Xu and B. Jennings, "*Automating the Generation, Deployment and Application of Charging Schemes for Composed IMS Services*" Proceedings of Integrated Network Management 2007 (IM '07) the 10th IFIP/IEEE International Symposium, pp. 856 – 859, May 2007.

[3] B. Bhushan, M. Tschichhols, E. Leray, and W. Connelly, "*Federated Accounting: Service Charging and Billing in a Business to Business Environment*", Proceedings of Integrated Network Management (IM 2001) IFIP/IEEE Int'l Symposium, pp. 107-121, May 2001.

[4] M. Koutsopoulou, A. Kaloxylos, A. Alonistioti, and L. Merakos, "*A Platform for Charging, Billing & Accounting in Future Mobile Networks*", Elsevier Computer Communications, Special Issue on "Emerging Middleware for Next Generation Networks", vol. 30(3), pp. 516 - 526, February 2007.

[5] W. Ooms, "*Providing AAA with the Diameter protocol for multi-domain interacting services*", submitted Masters Thesis, University of Twente, June 2007.

[6] P. Calhoun et al., "*Diameter Base Protocol*," IETF RFC 3588, Sept. 2003.

[7] H. Khlifi and J. Grégoire. "*IMS Application Servers: Roles, Requirements and Implementation Technologies*". IEEE Internet Computing, vol. 12(3), pp.40 – 51, May 2008.

[8] 3GPP TS 32.240, "*Telecommunication management; Charging management; Charging*

Architecture and Principles," Rel. 8, June 2010.

[9] 3GPP TS 32.299, "*Telecommunication management; Charging management; Diameter Charging Applications*" Rel. 8, June 2010.

[10] 3GPP TS 32.260, "*Telecommunication management; Charging management; IP Multimedia Subsystem (IMS) charging*" Rel. 8, June 2010.

[11] M. Koutsopoulou, A. Kaloxylos, A. Alonistioti, L. Merakos, and P. Philippopoulos, "*An integrated charging, accounting and billing management platform for the support of innovative business models in mobile network*s," International Journal of Mobile Communications, vol. 2(4), pp. 418 – 434, December 2004.

[12] H. Hakala et al., "*Diameter Credit-Control Application*," IETF RFC 4006, Aug 2005.

[13] Y. Lin and S. Sou, "*Charging for Mobile All-IP Telecommunications*", ISBN 978-0-470-77565-3, September 2008.

[14] Internet World Stats, "Internet Usage Statistics – World Internet users and Population Stats," http://www.internetworldstats.com/stats.htm, June 2010.

[15] B. Jennings and P. Malone, "*Flexible charging for Multi-provider Composed Services using a Federated, Two-phase Rating Process*" Proceedings of the 10th IEEE/IFIP Network Operations and Management Symposium (NOMS 2006), pp. 13 – 23, April 2006.

[16] F. Eyerman, P. Racz, B. Stiller, C. Schaefer and T. Walter. "*Diameter-based Accounting Management for Wireless Services*", Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC 2006), pp. 2305 – 2311, April 2006.

[17] S. Q. Khan, R. Gaglianello and M. Luna. "*Experiences with Blending HTTP, RTSP, and IMS*". IEEE Communications Magazine, vol. 45(3), pp. 122 - 128, March 2007.

[18] 3GPP Version TSG, "*Overview of 3GPP Release 6*", Release 6, December 2006.

[19] 3GPP Version TSG, "*Overview of 3GPP Release 7*", Release 7, December 2008.

[20] M. Olsson, S. Sultan, S. Rommer, L. Frid and C. Mulligan. "*SAE and the Evolved Packet Core*", Elsevier Ltd ISBN 978-0-12-374826-3, August 2009

[21] 3GPP TS 32.296, "*Telecommunication Management; Charging Management; Online Charging System (OCS): Applications and Interfaces*," Rel. 8, March 2009.

[22] 3GPP TS 23.125, "*Overall High Level Functionality and Architecture Impacts of Flow Based Charging; Stage 2*," Rel. 6, March 2006.

[23] "*Trend in VoIP Markets*," Wall Street Journal, Oct 2 2007.

[24] ITU-T, "*Recommendation Y.2250 – Y.2299 NGN Framework Reference Architecture*," September 2006.

[25] ETSI TS 282 001 ver. 3.3.0 "*TISPAN, NGN Functional Architecture Release 2" Telecommunications and Internet Converged Services and Protocols for Advanced Networking (TISPAN)*, February 2009

[26] 3GPP, "*3GPP Specifications – Releases (and phases and stages),*" http://www.3gpp.org/releases, Accessed July 2010

[27] Open Mobile Alliance "*OMA Service Environment*", Approved Version 1.0.5, October 2009.

[28] R, Christian and H. Hanrahan, "*Structuring the Next Generation Network Using a Standards-based Service Delivery Platform*" Proceedings of Innovations in NGN: Future Network and Services K-INGN First ITU-T Kaleidoscope Academic Conference, pp. 33 – 40, May 2008.

[29] H. Lu, Y. Zheng and Y, Sun, "*The Next Generation SDP Architecture: Based on SOA and Integrated with IMS*" Proceedings of the 2008 Second International Symposium on

Intelligent Information Technology Application (IITA ’08), pp. 141 – 145, December 2008.

[30] S. Maes. “*Service Delivery Platform as IT Realization of OMA Service Environment: Service Oriented Architecture*” Proceedings of Wireless Communications and Networking Conference (WCNC 2007), pp 2885 - 2891. April 2007

[31] H. Ohnishi, Y. Yamato, M. Kaneko, T. Moriya, M. Hirano and H. Sunaga. “*Service Delivery Platform for Telecom-Enterprise-Internet Combined Services*” Proceeding of Global Telecommunications Conference (IEEE GLOBCOM 2007), pp 108 - 112. December 2007.

[32] T. Moriya, Y. Nakatani, H. Ohnishi, M. Yoshida and M. Hirano. “*Practical Study on Providing Event-Driven Composite Services for Telecom-Enterprise Convergence*” Proceedings of the International Symposium on Applications and the Internet (SAINT 2008), pp. 333 – 336, July 2008.

[33] N. Kryvinska and C. Strauss. “*Next Generation Service Delivery Networks: A Strategic Approach Involving Architectural Planning and Design, from a Business Perspective*”, Proceedings of the Fifth Advanced International Conference on Telecommunications (AICT ’09) pp. 410 – 415, May 2009.

[34] N. Blum, T. Magedanz and F. Schreiner. “*Management of SOA based NGN Service Exposure, Service Discovery and Service Composition*” Proceedings of the International Symposium on Integrated Network Management (IFIP/IEEE ’09), pp. 430 – 437, August 2009.

[35] N. Blum, T. Magedanz, F. Schereiner and S. Wahle. “*A Research Infrastructure for SOA-Based Service Delivery Platforms,*” Proceeding of the 5th International Conference on

Testbeds and Research Infrastructures for the Development of Networks and Communities and Workshops (TridentCom ’09), pp. 1 – 6, April 2009.

[36] L. Ren, Y. Z. Pei, Y. B. Zhang and C. Ying. “*Charging Validation for Third Party Value-Added Applications in Service Delivery Platform*” Proceedings of the Networks Operations and Management Symposium (10th IEEE IFIP/NOMS 2006), pp. 1 – 13, April 2006.

[37] L. Zhao and L. Tang. “*Service Pricing for Third Party Logistics Corporations Implementing VMI,*” Proceedings of the IEEE International Conference on Industrial Engineering and Engineering Management, pp. 1442 – 1446, December 2007.

[38] F. Anjum, F. Caruso, R. Jain, P. Missier and A. Zordan, *“ChaiTime; A system for Rapid Creation of Portable Next Generation Telephony Services Using Third-Party Software Components,*” Proceedings of the IEEE Second Conference on Open Architectures and Network Programming Proceedings (OPENARCH ’99), pp. 22 – 31, March 1999.

[39] J. Yim, T. Choi and B. Lee, “*Third Party Call Control in IMS using Parlay Web Service Gateway*” Proceedings of The 8th International Conference on Advanced Communication Technology (ICACT 2006), pp. 221 – 224, February 2006.

[40] T. Choi. “*Accounting, Charging and Billing for NGN Services and Network*”, ITU-T NGN Technical Workshop, March 2005.

[41] E. Bertin, I. Fodil and N. Crespi, “*A Business View for NGN Service Usage*” Proceedings of the Workshop on Broadband Convergence Networks. (BcN '07) 2nd IEEE/IFIP, pp. 1 – 5, May 2007.

[42] TMF Forum, "*Shared Information and Data (SID) model*", GB922 and addenda, v4.0, August 2004.

[43] TMF Forum, *"enhanced Telecom Operations Map (eTOM)*", GB921 and addenda, v6.0,

January 2006.

[44] 3GPP TS 32.820: "*Evolved Packet Core (EPC): Charging aspects*" Release 8, December 2008.

[45] T. Frisanco. "*Benchmark-Based Assessment of Out-tasking, Outsourcing and Managed Service for Mobile Network Operators*" Proceedings of the Networks Operations and Management Symposium (14th IEEE IFIP/NOMS 2010), pp. 763 – 776, April 2010.

[46] G. Huitema, R. Kuhne, U. Meyer, J. Siljee and A. Zugenmaier, "*Compensation – Dynamic Charging and Billing Relationships in Next-Generation Business Environments*," Proceedings of the Mobile and Wireless Communications Summit (16th IST '07) pp. 1 – 5, July 2007.

[47] N. Asokan, P. Janson, M. Steiner, and M. Waidner. "*State of the art in electronic payment systems*". IEEE Computer, vol. 30(9) pp. 28 - 35, September 1997.

[48] R. J. Lipton and R. Ostrovsky, "*Mircopayments via efficient coinflipping*". Proceedings of Proceedings of the Second International Conference on Financial Cryptography (FC '98), pp. 1 – 15, February 1998.

[49] P. Seltsikas and W. Currie, "*Evaluating the Application Service Provider (ASP) Business Model: The Challenge of Integration*" Proceedings of the 35th Hawaii International Conference on System Sciences, pp. 2801 – 2809, January 2002.

[50] 3GPP TS 22.115: "*Services and System Aspects: Service aspects; Charging and billing*" Release 9, April 2010.

[51] Mobicents Converged Demo, http://groups.google.com/group/mobicents-public/web/converged-application-demo, Accessed February 2010.

[52] M. Tsitsi, Z. Sintayehu, S. Ndakunda and R. Musvibe, "Video Shopping Portal",

http://hezekiah.rucus.net/converged-movie-demo/, Accessed February 2010.

[53] D. Waiting, R. Good, R. Spiers, N. Ventura, "*The UCT IMS Clien*t,"Proc. 1st Open IMS Testbeds Workshop, colocated with Tridentcom '09, 2009.

[54] P. Weik, D. Vingarzan, T. Magedanz, "*The FOKUS Open IMS Core – A Global Reference Implementation*," The IMS Handbook: Concepts, Technologies and Services, pp. 113-132, Nov. 2008.

Appendix A Shopping Demo Example

This section gives more detail about the shopping demo example that was used to achieve the converged services scenario. This application is taken from the existing Mobicents Converged Demo Application available online at [51]. The application was further developed by the Department of Computer Science Center of Excellence research group at Rhodes University in South Africa [52].

The application allows users to purchase movies online and stream trailers when desired. The basic use case is as follows:

- User visits the Online Video Sharing portal
- Selects video of interest
- Optionally chooses to watch the trailer (if so, he/she will get it on the devices he registered on IMS)
- Clicks the purchase button

The Application requires the following open source software.

1. JBOSS
2. Mobicents Media Server sources (converged demo)
3. Video streaming server of choice (the VLC streaming server is used)
4. UCT IMS Client

Once the above mentioned tools are installed and are ready to run, the following steps need to be followed.

1. Run the JBOSS server with preloaded binaries:

```
$ cd $JBOSS_HOME/bin
```

```
$ run -b mediaserver.mobicents.ac.za
```

2. Run the streaming server. For VLC:

```
$ vlc -I telnet --vlm-conf vlm.conf
```

3. Run the client; the settings on the client need to be the same as that of Mobicents Server. Open the Community Video Sharing Portal in a browser at http://mediaserver.mobicents.ac.za:8080/ShoppingDemo. Register a user whose credentials are the same as the IMS registered user.

4. Once logged in: Choose "Watch trailer" to watch trailer. Note: only logged in users may watch trailers. Choose Purchase to download trailer.

The idea is to have a converged application that shows how JEE application can leverage Mobicents to have voice, message and data transfer seamlessly. This example is built using the Seam and JAIN SLEE service deployed on Mobicents.

Appendix B Details of machines used in the test-bed

This appendix gives the details for each machine used in the test-bed architecture.

The information was obtained using the following commands in ubuntu:

1. #head /proc/cpuinfo
2. #head /proc/meminfo
3. #lsb_release -a
4. #uname -a

LAN Client Machine

- vendor_id : GenuineIntel
- cpu family : 6
- model : 15
- model name : Intel(R) Pentium(R) Dual CPU E2160 @ 1.80GHz
- stepping : 13
- cpu MHz : 1203.000
- cache size : 1024 KB
- physical id : 0
- siblings : 1
- MemTotal : 1018316 kB
- Distributor ID : Ubuntu
- Description : Ubuntu 9.04

- Release :9.04
- Codename :jaunty
- Linux 2.6.28-19-generic

JAIN SLEE machine

- vendor_id : GenuineIntel
- cpu family : 6
- model : 23
- model name : Pentium(R) Dual-Core CPU E5300 @ 2.60GHz
- stepping : 10
- cpu MHz : 1203.000
- cache size : 2048 KB
- physical id : 0
- siblings : 2
- MemTotal : 2052412 kB
- Distributor ID : Ubuntu
- Description : Ubuntu 9.04
- Release : 9.04
- Codename : jaunty
- Linux 2.6.28-19-generic

HSS & S-CSCF Machine

- processor : 0
- vendor_id : GenuineIntel

- cpu family : 15
- model : 2
- model name : Intel(R) Pentium(R) 4 CPU 3.00GHz
- stepping : 9
- cpu MHz : 2992.687
- cache size : 512 KB
- physical id : 0
- siblings : 2
- MemTotal : 1016500 kB
- Distributor ID : Ubuntu
- Description : Ubuntu 8.10
- Release : 8.10
- Codename : intrepid
- Linux 2.6.27-11-generic

OSA & Charging Functions Machine

- processor : 0
- vendor_id : GenuineIntel
- cpu family : 15
- model : 3
- model name : Intel(R) Pentium(R) 4 CPU 3.20GHz
- stepping : 4
- cpu MHz : 3191.994
- cache size : 1024 KB

- physical id : 0
- siblings : 2
- MemTotal : 1016500 kB
- Distributor ID : Ubuntu
- Description : Ubuntu 8.10
- Release : 8.10
- Codename : intrepid
- Linux 2.6.27-11-generic

P-CSCF & I-CSCF Machine

- processor : 0
- vendor_id : GenuineIntel
- cpu family : 6
- model : 23
- model name : Pentium(R) Dual-Core CPU E5300 @ 2.60GHz
- stepping : 10
- cpu MHz : 1203.000
- cache size : 2048 KB
- physical id : 0
- siblings : 2
- MemTotal :2052412 kB
- Distributor ID : Ubuntu
- Description : Ubuntu 9.04
- Release : 9.04

- Codename : jaunty
- Linux 2.6.28-19-generic

Wimax Client

- processor : 0
- vendor_id : GenuineIntel
- cpu family : 15
- model : 1
- model name : Intel(R) Celeron(R) CPU 1.70GHz
- stepping : 3
- cpu MHz : 1699.774
- cache size : 128 KB
- MemTotal : 507680 kB
- Distributor ID : Ubuntu
- Description : Ubuntu 9.04
- Release : 9.04
- Codename : jaunty
- Linux 2.6.28-19-generic

WLAN Client

- processor : 0
- vendor_id : GenuineIntel
- cpu family : 15
- model : 1

- model name : Intel(R) Celeron(R) CPU 1.70GHz
- stepping : 3
- cpu MHz : 1699.774
- cache size : 128 KB
- MemTotal : 507680 kB
- Distributor ID : Ubuntu
- Description : Ubuntu 9.04
- Release : 9.04
- Codename : jaunty
- Linux 2.6.28-19-generic

Appendix C Diameter Protocol

This thesis relies heavily on the implementation of Diameter interfaces to achieve charging functions that conform to 3GPP and ETSI specifications. The IMS uses the Diameter protocol to transport all AAA messages between the functions. Diameter is specified as a base protocol and is complemented by a set of application protocols that add on to the base protocol functionality. The base protocol is implemented at all Diameter nodes independent of the application. Applications are extensions of the base protocol and will cater to the specific needs of the node that implements the Diameter protocol.

Diameter is designed to run over a transport protocol that offers reliable connections (e.g. TCP). This is important because lost Diameter messages can be retransmitted, thus it cannot be used over a transport protocol such as UDP. The Diameter protocol can be performed on different nodes and each node can have a different Diameter function:

- Diameter Client – an entity that performs access control with the help of information obtained from a Diameter Server.
- Diameter Server – an entity that handles Authentication, Authorisation and Accounting request in a domain or realm.
- Diameter Proxy – an entity that forwards Diameter messages. It can also change the Diameter messages to implement policy decisions, such as controlling resource usage and providing admission control.
- Diameter Relay – an entity that forwards Diameter messages based on routing information and realm-routing table entries. A Relay cannot modify data in a Diameter message.
- Redirect agent – an entity that refers clients to servers so that they can communicate directly.
- Translation agent – a functionally entity that translates Diameter messages to those of other AAA protocols.

Diameter is a peer-to-peer protocol. This means that any Diameter node can send and receive Diameter messages asynchronously and out of turn, as opposed to a client-server mode where clients send request to servers and servers respond to these request. Both Diameter Clients and Servers can send requests and respond to these requests.

Diameter messages are either requests or answers. A request is almost always replied to with one answer, barring very few exceptions. This means that a sender of a Diameter request always knows the fate of the Diameter message that it sent and in the case of errors, retransmits the message. Diameter is a binary encoded protocol and unlike SIP is not human readable.

C.1 Format of a Diameter Message

A Diameter message consists of a 20-octet header and a number of Attribute Value Pairs (AVP). The length of the header is fixed for all messages. The number of AVPs is variable, depending on the particular message. An AVP is a container of AAA data. The following figure shows the format of a Diameter message.

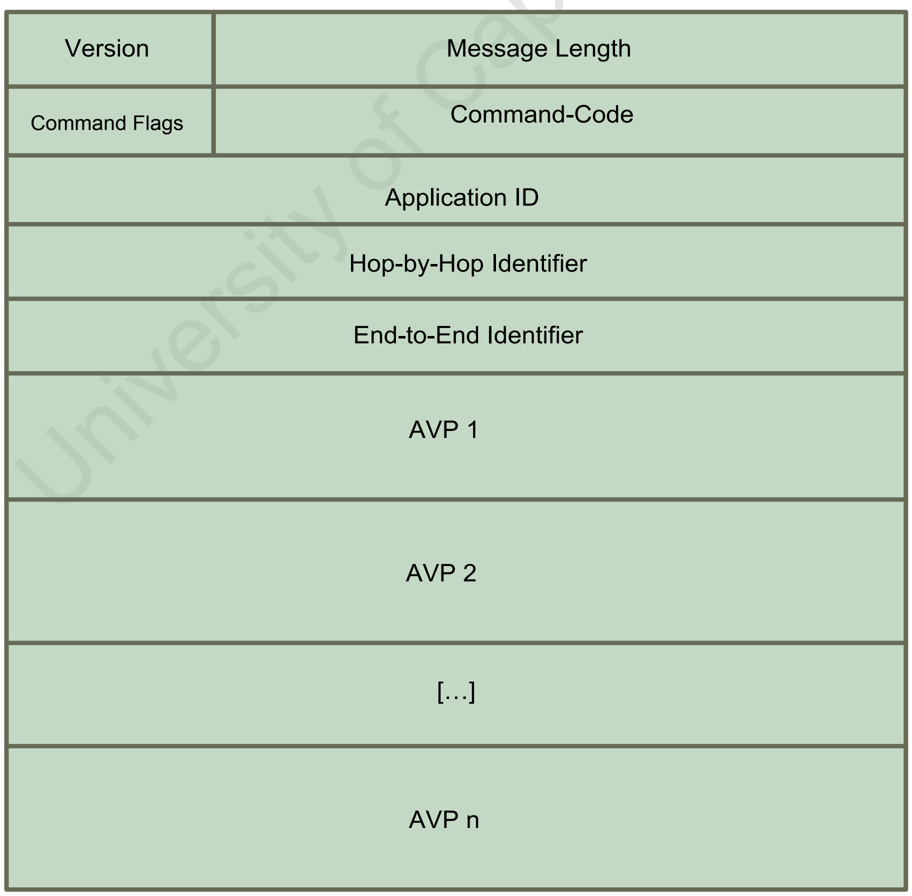


Figure C.1: Format of a Diameter Message

The header starts with a Version field. Currently there is only version 1. The Message Length field contains the length of the Diameter message including the header and following AVPs. The Command-Flags contain:

- If the message is a request or an answer
- If the message can be forwarded by a proxy
- If the message contains a protocol error in terms of its format not conforming to the Diameter protocol
- If the message is a retransmitted message

The Command Code has the value of the actually command contained in the message. Command codes for request and answers reside in the same field, the command-flags will tell if it a request or an answer. The Application-ID field indicates which Diameter Application sent the message. The hop-by-hop identifier contains a value that each hop set when sending the request. The answer will have the same identifier so that a Diameter node can easily correlate the answer to the corresponding request. The sender of the request will set a end-to-end identifier that does not change at any forwarding node. Together with the origin's host identity the end-to-end identifier can help the receiver detect duplicate requests.

C.2 Attribute Value Pairs

AVPs are containers of data. As shown in the following figure an AVP will contain an AVP code, flags, an AVP length and data. Having a vender ID is optional.

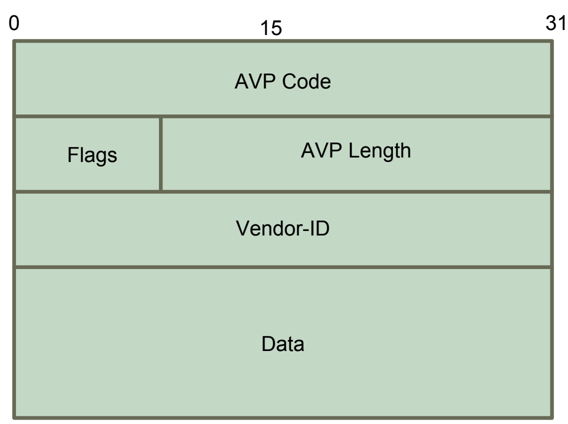


Figure C.2: Structure of an AVP

The Flags field indicates:

- the need for encryption to guarantee end-to-end security;
- whether support for the AVP is mandatory or optional. If the sender indicates that support for the AVP is mandatory and the receiver does not understand the AVP the Diameter request is rejected;
- whether the optional Vendor-ID field is present or not

C.3 The Rf interface

The Rf interface is based on the Diameter base protocol together with a vendor-specific "Diameter Application for the Rf/Ro interfaces." The Rf is specified between either an IMS-AS, MRFC, BGCF, MGCF, P-CSCF, I-CSCF or a S-CSCF and the Charging Data Function (CDF). This interface is used to report offline charging information to the CDF

C.3.1 Command Codes for the Rf Interface

Two command codes are defined for the Rf interface, namely the Accounting-Request (ACR) and Accounting-Answer (ACA) messages. The ACR and ACA messages are used to report accounting information to the CDF and can contain a number of AVPs relating to charging information. The table below shows the 3GPP defined AVPs that relate to accounting information sent over the Rf interface.

Table C.1: Mandatory AVPs defined for Rf Interface

Attribute Name	AVP Code
Session Identifier	263
Origin Host	264
Origin Realm	296
Destination Realm	283

Accounting Request Type	480
Accounting Request Number	485
Result Code (in ACA only)	268

Although there is only one type of Request message that is passed along on this interface, it can be subcategorised into four different types of Accounting request messages

- START
- INTERIM
- STOP
- EVENT

The Accounting-Record-Type AVP will hold the value of the type of accounting request the message is. The ACR types START, INTERIM and STOP are used for session based accounting messages. The ACR type EVENT is used to relay event type accounting messages.

C.3.2 Event based accounting

Event based charging is when the CTF relays charging information on an event basis, without the use of any timers. The CTF will send an ACR of type EVENT to the CDF once at when a chargeable event occurs to inform the CDF that a service is being rendered. The following diagram shows the message flows between the CFT and the CDF using event based charging.

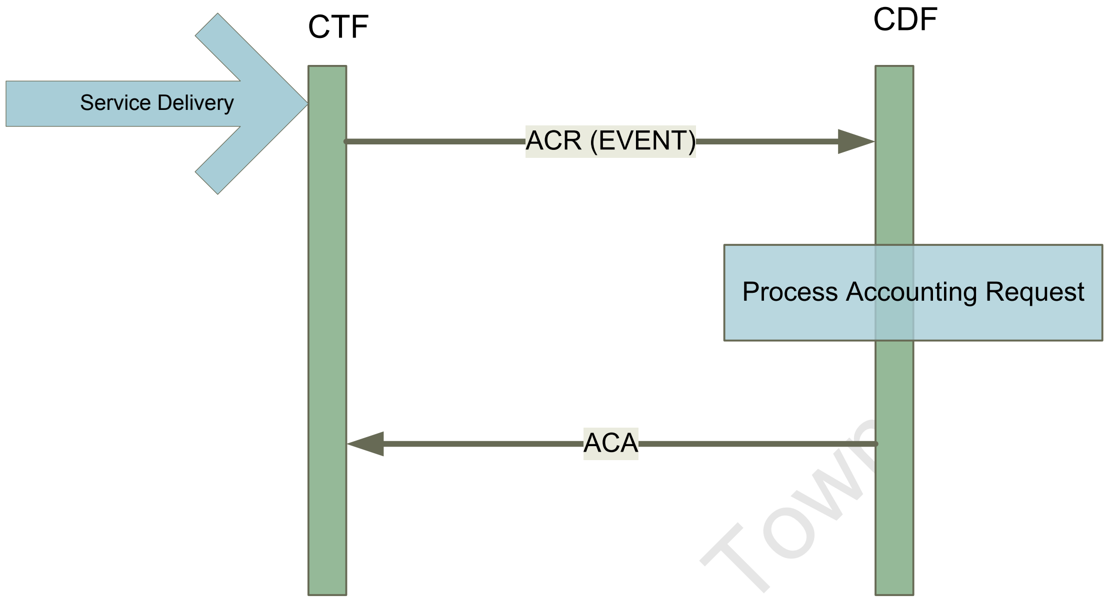


Figure C.3: Event Based Offline Charging

C.3.3 Session Based Accounting

Session based charging is the process of reporting service usage reports for a session for example streaming of media content. When the session is initialised by a user requesting a service, the CTF sends an ACR of type start to the CDF. The CDF will then start a timer relating to the user and send back an ACA. Upon the receipt on the ACA the CTF can then provide the user with the service. The CTF has to periodically send ACR messages of type INTERIM to the CDF relating to the session so that the CDF can reset the timer. If the CTF fails to send these interim messages then the CDF will assume a failure has occurred at the CTF and end the charging session for the user. When the user stops using the service the CTF will send an ACR of Type STOP to the CDF. The CDF will then stop the timer and create a CDR associated with the user to send to the billing domain. The billing domain can then bill the user at a later date. The following flow diagram depicts the interaction between a CTF and a CDF using session based accounting.

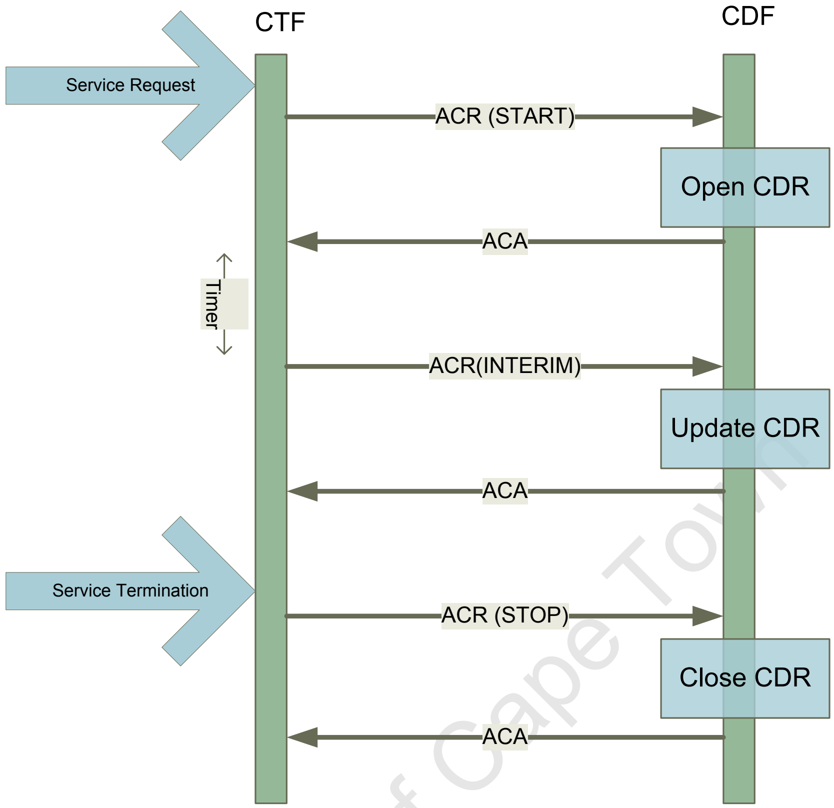


Figure C.4: Session Based Offline Charging

C.4 The Ro interface

The Ro interface is based on the Diameter base protocol together with a vendor-specific "Diameter Credit-Control application." The Ro is specified between either an IMS-AS, MRFC or an IMS-GWF and the Online Charging Function (OCF). This interface is used to send online charging information.

Two diameter command messages in this application are the Credit-Control Request (CCR) and the Credit-Control Answer (CCA). The following figures show the AVPs that are contained in these messages

Table C.2: AVPs Defined for Ro Interface

Attribute Name	AVP Code

Session Identifier	263
Origin Host	264
Origin Realm	296
Destination Realm	283
Credit Control Type	416
Credit Control Number	415
Result Code (in CCA only)	268

Once again there are four types of CCA messages that can be transferred on the Ro interface:

- INITIAL_REQUEST
- UPDATE_REQUEST
- TERMINATE_REQUEST
- EVENT_REQUEST

The Credit-Control Type AVP holds the value of what type of CCA message it is. There are three ways user credit control can be achieved in an online charging implementation: Immediate Event Charging (IEC), Event Charging with Unit Reservation (ECUR) and Session Charging with Unit Reservation (SCUR).

C.4.1 Immediate Event Charging

When the CTF receives a service request from the user it sends a CCR message of type EVENT_REQUEST to the OCS. At this point direct debiting occurs on the user's account, for a service rendering of a certain predefined period. The OCS will then send a CCA that will contain information of whether the debiting was successful or not (i.e. the user has sufficient credits for the duration of the service period). The following diagram depicts the message flows for IEC.

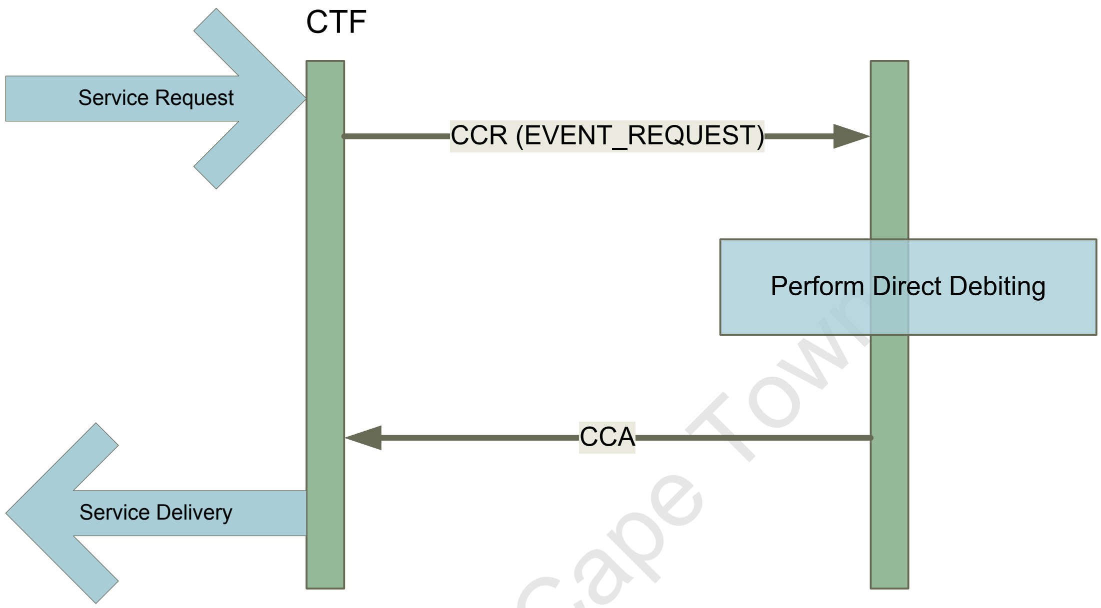


Figure C.5: IEC Direct Debiting

C.4.2 Event Charging with Unit Reservation

Before a service request can be processed the CTF first sends a CCR messaged of type INITIAL_REQUEST to the OCS. Upon the receiving of this message the OCS reserves a certain amount of credit from the user account. The OCS will then send a CCA to the CTF with information of whether the reservation was successful. The service can then be provided. Once the service session is over the CTF will send a CCR message of type TERMINATION_REQUEST to the OCS. The OCS only at this point debits the user account and releases any unused reserved credits. The message flows for ECUR is shown in the diagram below.

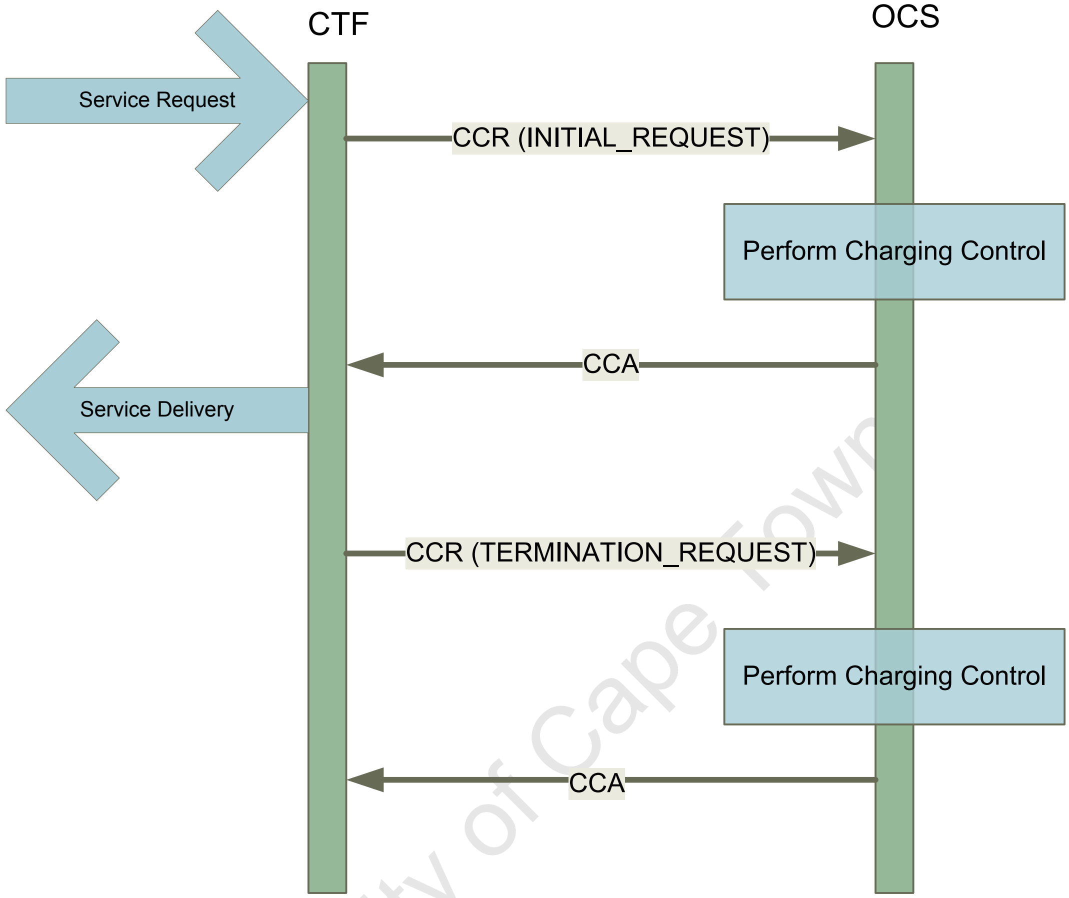


Figure C.6: ECUR for Event Based Online Charging

C.4.3 Session Charging with Unit Reservation

Before processing a service request the CTF will send a CCR message of type INITIAL_REQUEST to the OCS. The OCS will then reserve a certain amount of credit for a specified period. At this point the OCS will start a timer running and then send a CCA message to the CTF. The CTF has to periodically send CCR messages of type UPDATE_REQUEST related to the session. When the OCS gets these messages it debits the amount of credits that were used and then reserves more credits while also resetting the timer. Once the CTF stops servicing the user it will send a CCR message of type TERMINATE_REQUEST at which point the OCS will perform the final debiting on the user account and release any unused credits. If at any point in the exchange the timer on the OCS times out, then it will assume a failure and either debit or release the credits and assume the session was terminated. If the OCS received an UPDATE_REQUEST from the user and could not reserve the required credits due to insufficient funds and then sends a CCA message to the CTF with information that the reservation was unsuccessful at which point the service will immediately be terminated. The message flow for this is shown in the diagram below.

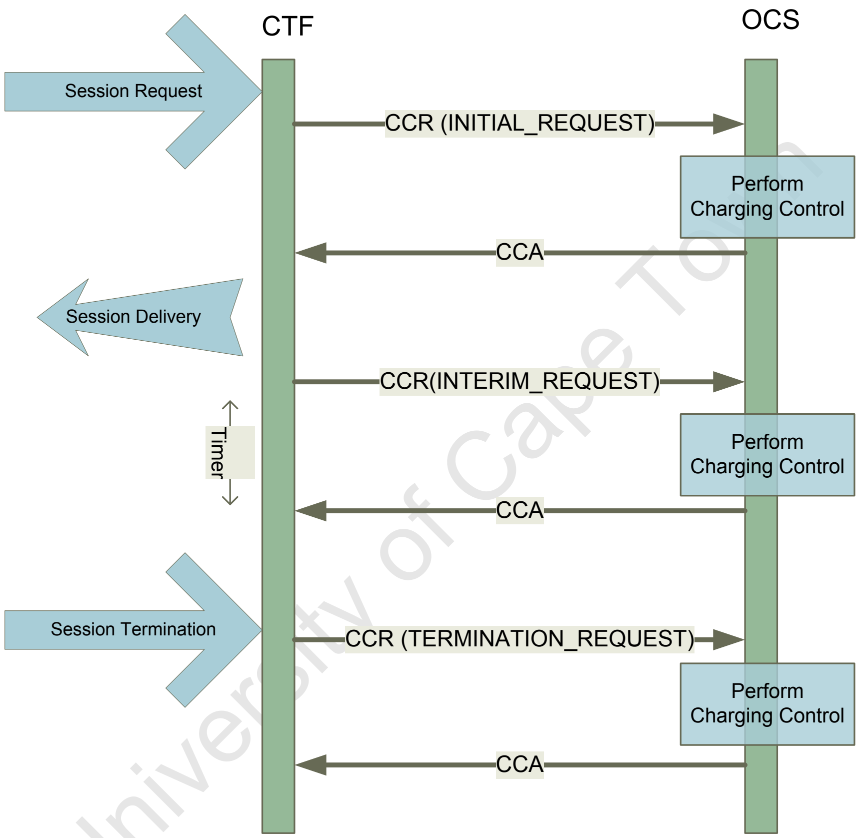


Figure C.7: SCUR for Session Based Credit Control

Appendix D Accompanying CD-ROM

The CD-ROM included with this thesis contains the following files and information:

- *Research Literature* - Electronic copies of the research papers and other literature used during the course of this research can be found in the directory labelled "Research Literature".
- *Software* - All the source code developed for the evaluation framework can be found in the directory labelled "Software".
- *Publications* - Copies of papers which have been accepted to conferences, written or co-written by the author of this thesis, can be found in the directory labelled "Publications".
- *Thesis* - An electronic copy, in PDF format, of this document can be found in the directory labelled "Thesis".
- *Results* - The results obtained during the performance tests carried out for this thesis can be found in the directory labelled "Results". This includes final and averaged results