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TOWARDS AN INTER-DOMAIN BILLING SYSTEM TO SUPPORT DYNAMIC SERVICE PROVISIONING
Van Minh Le

Today, billing is a big challenge for service providers. With a growing number of rich services such as music, mobile TV, Video-on-Demand and eHealth delivered to the mass market, service providers are missing business opportunities because current billing solutions are not fully capable. In particular, the delivery of on-the-fly composite services, composed of many service components provided by different service providers causes many complexities.

This book proposes a billing system that deals with these inter-domain complexities. Moreover, the billing system provides an interim charging mechanism that allows for monitoring and updating of customer credit balances in near real-time. The system is designed to support large-scaled transactions and can be implemented in a commercial environment.

Since billing is an expensive business process due to its complexity and high transaction volumes service providers may decide to delegate their billing processes to third parties in order to reduce operational costs. Additionally, the presented billing system can be applied to such a business model.

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Abstract

The technological advances in data-centric networks, information and communication services are pushing rich services such as music, mobile TV, Video-on-Demand and eHealth into the mainstream. Most of these services are *composite services*, composed of many service components. These service components may be provided by one or even by many service providers.

Today, the delivery of on-the-fly composite services imposes problems on the charging and billing of these services since billing information originating from various provisioning systems need to be aggregated. In fact each service component has its corresponding charge, which must be correlated according to the service composition to allow for the calculation of the total charge. An additional aspect that contributes to the billing complexity is near real-time charging, which means that the charging occurs during a service session usage or right after a service event has occurred. This is in contrast with off-line charging mechanisms where the charging for service usage occurs after a service event or service session has occurred. With the uptake of valuable composite services, most customers want to obtain near real-time charging and billing information to manage their expenses during usage. Also, service providers need near real-time management information in order to manage their financial risks. An additional complicating factor emerges when considering different third party providers participating in the service composition. Hence an inter-domain billing process asks for standardization of the billing information exchanged between domains and for open system interfaces. However, today's billing systems are not capable of dealing with near real-time composite services. Therefore, new billing architectures are needed. These needs have been recognized by standardization bodies such as the ITU, ETSI, TM Forum and 3GPP.

The objective of this thesis is to design a billing system capable of supporting inter-domain, dynamic service provisioning of composite services. In order to design such an Inter-domain Billing System, three topics will be addressed: *inter-domain billing, service composition information* and *interim accounting and charging.* This thesis proposes a billing system to support delivery of composite services. The proposed billing system is defined and specified from the business perspective, information perspective and functional perspective. The billing models define the relationships between the involved parties such as consumers, service providers and third party providers. These billing models focus on the billing aspect between a consumer and a service provider and between a service provider and a third party provider. As a result, these models constitute the end-to-end billing between the involved parties. Furthermore, a service composition information model is defined and specified supporting the correlation and aggregation of charges of composite services. This model can be applied specifically to the telecommunication and internet industry. It shows that the application of the TM Forum‘s SID framework is suitable as a basis to model billing information models for supporting composite services, especially when dealing with correlation and aggregation of charges. Finally, we define and specify an interim accounting and charging mechanism for composite services. Interim accounting and charging involves the generation of interim usage and charge records enabling the monitoring of the service charges and the updating of the customer's credit balance during service sessions.

The research contribution of the design of an inter-domain billing system is many-fold: 1. The result of this thesis is a detailed design for a billing system that addresses current billing needs of providers/operators, namely: interim accounting and charging of composite services; 2. It combines the reference model RM-ODP and the operations program NGOSS bridging the academic world and the industrial world; 3. It describes billing models that provide a solid basis for auditing purposes of billing and are constructed using the economic duality principle of REA (Resource-Event-Agent); and 4. The principle of separation of concerns is applied to the design of the proposed billing system, thus shaping a set of system components which serve as constituent building blocks. This results in a design that allows for flexible and cost effective implementation of large-scale billing systems using system components available in the market.

This thesis consists of the following parts. It begins with presenting the research context, definitions and terminology, example scenarios on eHealth service and video streaming, research challenges, objective and scope (Chapter 1). Next an overview is presented of related work in the area of billing management (Chapter 2). Furthermore, the preferred design approach is addressed from a list of potential design methodologies. The set of architectural requirements is studied that forms the basis of the design of the proposed billing system (Chapter 3). Next, the boundary for this system and relevant business roles are considered (Chapter 4). The main viewpoints of the encompassing inter-domain telematics system will guide the design of the proposed billing systems: the *Enterprise viewpoint* addresses the different participants involved in the business process to deliver services to customers and to bill the delivered services (Chapter 5); the *Information Viewpoint* describes the information the billing system manages for the purpose of service provisioning and billing. (Chapter 6); the *Computational Viewpoint* presents the functional entities of the inter-domain telematics system and their relationships. It also discusses the interfaces needed for the exchange of billing related information between the participants involved in the service provisioning to end-users (Chapter 7). Finally, the design of the proposed Inter-domain Billing System is evaluated whether the requirements from Chapter 3 are satisfied (Chapter 8). To conclude, the research contributions are summarized and in addition, directions for future research are identified (Chapter 9).

Kính dâng ba.
Kính tặng má và ba má.

to Tiên and Daphne.

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I would like to express my profound gratitude for his presence in this journey. Bert-Jan, yes we did it!

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Chapter 1 - Introduction

This chapter addresses the challenges of inter-domain billing of telematics services in dealing with the capability of billing systems to exchange billing information with third parties, the composition of the billing information and interim accounting and charging. These challenges are imposed by the dynamic service provisioning of telematics services across many domains. From it, the objectives and scope of this thesis are identified and presented.

1.1 Introduction

The liberation of the telematics market and the evolution of the Internet, together with the tremendous increase in capacity and availability of both wired and wireless broadband networks, have opened many opportunities for service providers to offer a wide range of telematics services (i.e. any kind of services that can be delivered over wired and wireless networks) such as telecommunications, eCommerce, eBusiness, eEducation and eHealth services [Goede01]. Today, many kinds of telematics services are being introduced to the consumer market, for instance, Video-on-demand (VoD), music, news, games and rich-content library [VirginMedia, MovieBeam]. Next to entertainment and educational services, medical services also show great potential in making use of the same infrastructure to provide (chronic) patients with physical condition monitoring and remote assistance [EHTEL08, Rije02, MobiHealth].

In general there are two main service provider categories. On one hand, there are connectivity providers (i.e. carriers) who concentrate on the provisioning of connectivity services. On the other hand, there are application and information service providers who provide value-added services on top of the connectivity services. Very often, services provided to the end-user are compositions of these services. Hence, we speak of *composite services*. A special situation occurs when the sub-services are provided by different service providers, from two or more distinct domains. Here, a *domain* refers to a business entity that delivers a (sub)-service in the value network [Peppard06].

In this situation where multiple service providers deliver sub-services to end-users, one needs inter-domain management processes to compose the sub-services and provide a single service. In this thesis, we specifically focus on the management of billing processes.

The provisioning of composite services in the future telematics market demands billing solutions, which account for dynamic (maybe varying between short-term and long-term) business relationships between the involved business partners. Recent surveys [Kwiatkowski08, TMFSDP08] have shown that service providers are struggling with their current billing systems. These systems are not suitable for dealing with the billing of complex, composite services. Due to time and costs constraints many service providers have continued to create additional features to their billing system to address new needs, but, the development of such “add-on” billing solutions miss an overall approach to offer flexible solutions that sustain future changes [MobileMedia04].

This thesis addresses the billing problems related to the service provisioning of composite services across multiple domains and proposes a billing system to support such a provisioning. In particular, the title of this thesis “*Towards an Inter-domain Billing System to Support Dynamic Service Provisioning*” reveals the major aspects of our research on billing: that is, “*Inter-domain*” refers to the interactions of the billing functions belonging to different administrative domains and, “*Dynamic*” refers to the temporal character of the business relationships between the business partners involved in the provisioning of service sessions to end-users.

To be more specific, the related billing problems consist of (1) the lack of a standard information model to specify service composition for billing purposes; (2) the lack of standard interfaces to support the exchange of billing related information such as service composition, usage and charge records and finally (3) the lack of control mechanisms to monitor and update customer credit balances during the usage of composite services. This thesis presents an inter-domain billing system solving these problems.

This first, introductory, chapter is organized as follows. First, it provides definitions and terminologies used in this thesis. Next, two motivating example scenarios are presented in which the billing problems are highlighted. Finally, after looking in more detail at the context of these billing problems, it describes the objective, the main research questions and the scope of this thesis.

1.2 Billing Process – Definition and Terminology

Let us consider a simplified interaction between a customer and a service provider. The *Customer* (e.g. a person, an organization, or a business partner in the value network) requests a service and the *Service Provider* delivers the requested service according to a set of rules defined in a contract, often called *Service Level Agreement* (SLA) [Keller02a]. A SLA basically defines the rights and obligations of two parties involved in a business relationship. It specifies the service requirements that the service provider must fulfill (i.e. Quality of Service), the charging settlement (i.e. service pricing, charging, discounting, etc.) and the payment obligation of the customer. Figure 1.1 illustrates the simplified interactions between the customer and the service provider.

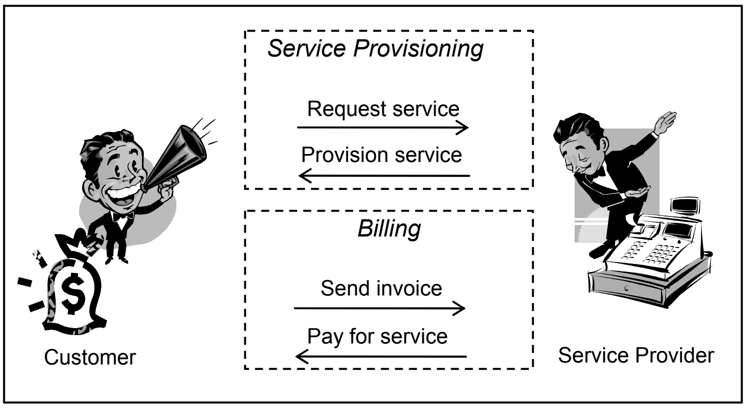


Figure 1.1. Interactions between a Customer and a Service Provider

The above example presents the business relationship between a customer and a service provider. Traditionally, business relationships are considered as static (i.e. long-term) relationships that can last for months or for years. Today, there is an emerging trend to move away from long-term relationships. The provisioning of telematics services is required to be much more dynamic and tailored to the customer's demand in time and place. It is conceivable that a customer and a service provider set up a business relationship needed for a "*once-only*" service session [Kneller02b].

The related simplified billing process, as shown in Figure 1.1, consists of a number of sub-processes. In the literature, one can find different definitions and terminologies that apply to the area of billing [TMFeTOM09, RFC2975, ETSI1001734, ITUD260, Huitema02, Stiller03]. This thesis adopts the definitions given by Huitema and Stiller [Huitema02, Stiller03]. Hence, the billing process consists of eight sub-processes, namely: *Metering*, *Mediation*, *Accounting*, *Charging*, *Invoicing*, *Payment* and *Reconciliation*.

- ***Metering*** – Metering is the process that determines the particular usage of resources within end-systems (hosts) or intermediate systems (routers) on a technical level, including Quality of Service (QoS), management and network parameters.
- ***Mediation*** – Mediation is the process that filters, aggregates and correlates raw, metered data. The Mediation process reconstructs sessions and matches e.g. measured IP addresses with users.
- ***Accounting*** – Accounting is the process that summarizes information in relation to a customer's service utilization. It is expressed in metered resource consumption, e.g., for the end-system, applications, middleware, calls, or any type of connections. The outputs of the Accounting process are *Usage Records* (URs) that include all relevant information acquired during the accounting process. In implementations, Call Detail Records (CDRs), Internet Protocol Detail Records (IPDRs), or similar standardized record formats can be applied.
- ***Charging*** – Charging is the process that calculates the charge for a given usage record by applying the appropriate tariff plan. The outputs of the Charging process are Charge Records (CRs) that include the charge of the particular service usage.
- ***Invoicing*** – Invoicing is the process that summarizes all the charges made by a customer per event or within a certain time window (e.g. month, week, day, etc.). The outputs of the Invoicing process are invoices containing all relevant information relating to the customer's service usage, the time when a service is provided, the corresponding charge, etc. Depending on the level of details that a customer requires, an invoice may present other additional information.
- ***Payment*** – Payment is the process of transferring an amount of money or economic units from a customer to a service provider.

- ***Reconciliation*** – Reconciliation is the process of updating the administration, stating that particular customers have paid for the provided service.

The above sub-processes are basically executed in sequential order. The order by which they occur depends on the payment methods used. Two well-known payment methods in the telematics market are postpaid and prepaid. *Postpaid* is the payment method that takes place *after* service consumption while the *prepaid* method takes place *before* service consumption. Figure 1.2 depicts the sequence of the billing sub-processes in case of postpaid.

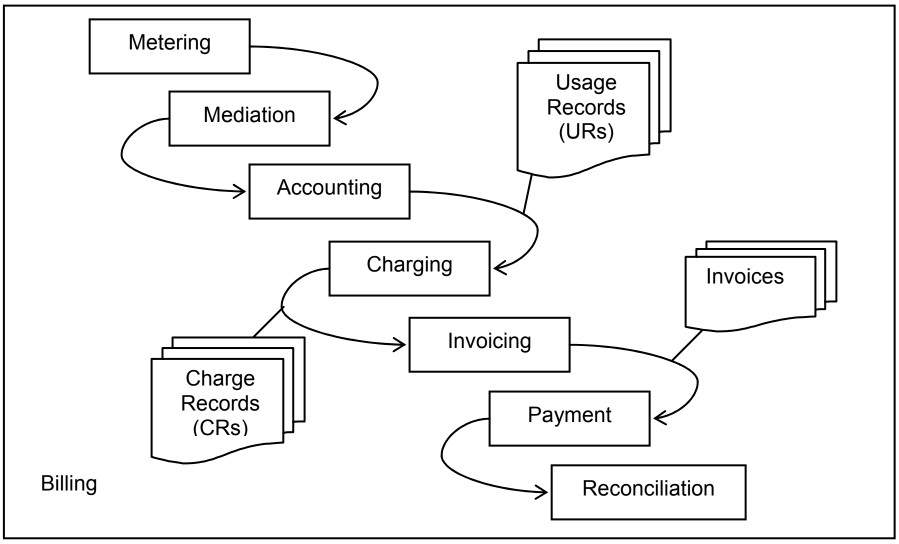


Figure 1.2. Overall Billing Process with Sub-processes (postpaid situation)

Traditionally, postpaid was the dominant payment method. The CRs are stored in a database waiting until they are periodically, say monthly, processed in a bill run. In case of prepaid, it is necessary to keep track of customers' accounts and their balances. Today, prepaid is very popular among mobile phone users. According to [Informa08], in 2008 the percentage of prepaid subscribers with respect to postpaid subscribers of wireless services reached 68% worldwide.

1.3 Example Scenarios

This section presents two cases to highlight the billing problems that are addressed in this thesis. The first case describes an eHealth service scenario which clearly shows the inter-domain billing research topics. The second case is about a real-time video service scenario revealing the need for financial controls for composite streaming services.

1.3.1 eHealth Service

Let us consider the following eHealth Service Scenario derived from the MobiHealth project [Konstantas02]. In this service scenario, a chronic Patient/User is equipped with a Body Area Network (BAN), bio-sensors and actuators that continuously monitor the physical condition of the patient and transmit the measurements to the eHealth Center via a public wireless network infrastructure. Such a measurement can be the patient's blood pressure, pulse rate, blood glucose, cholesterol, etc. The eHealth Center provides the patient with remote monitoring services. Depending on the type of treatment, feedback might be sent back to the patient's sensor/actuator to adjust or tune the medical equipment, for instance to increase the sampling frequency, or to control a pump. Occasionally, human assistance is desirable. In those cases, medical professionals can communicate with the patient through high quality live video sessions in which high-resolution digital images can also be included. The communication is based on the public Universal Mobile Telecommunications System (UMTS) networks or a combination of UMTS networks and WiFi networks that should guarantee complete freedom of movement for the patient. Figure 1.3 illustrates an eHealth service environment where different business partners are involved in the delivery of medical services to the patient.

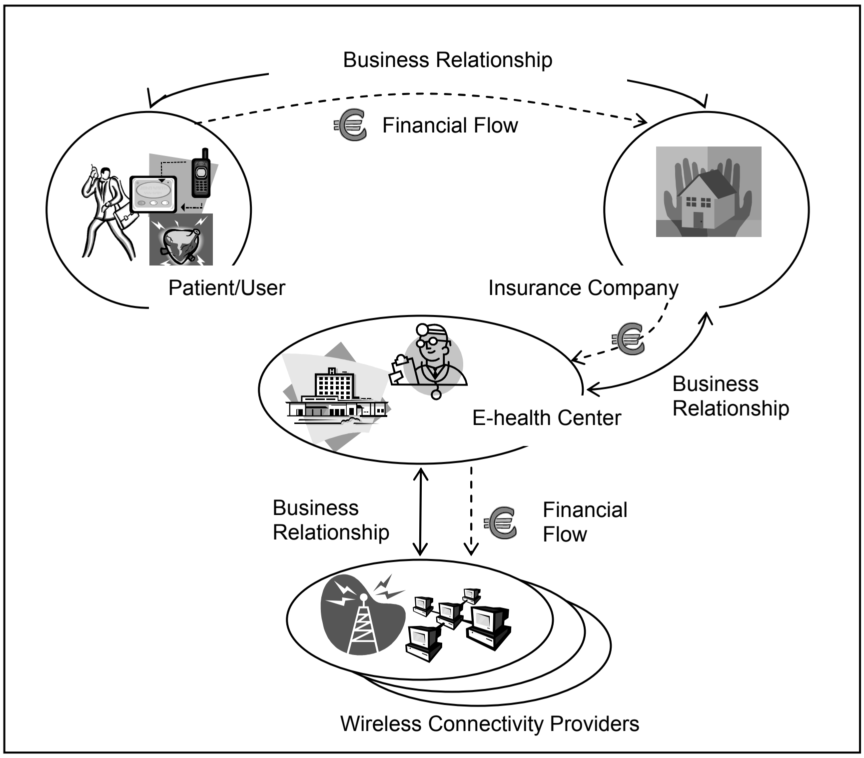


Figure 1.3. eHealth Service Scenario

From a business viewpoint, the *Patient* pays for his medical insurance to the *Insurance Company* and in return gets medical services and assistance from the *eHealth Center*. The *eHealth Center* provides eHealth services and is paid by the *Insurance Company*. To deliver medical services to the patient, the *eHealth Center* uses communication services provided by the *Wireless Connectivity Provider(s)*. Each of the business relationships is governed by a SLA that specifies the rights and obligations of the two business partners. The direction of the financial flows is the result of the financial settlement, which implies that the service requester is obliged to pay the service provider.

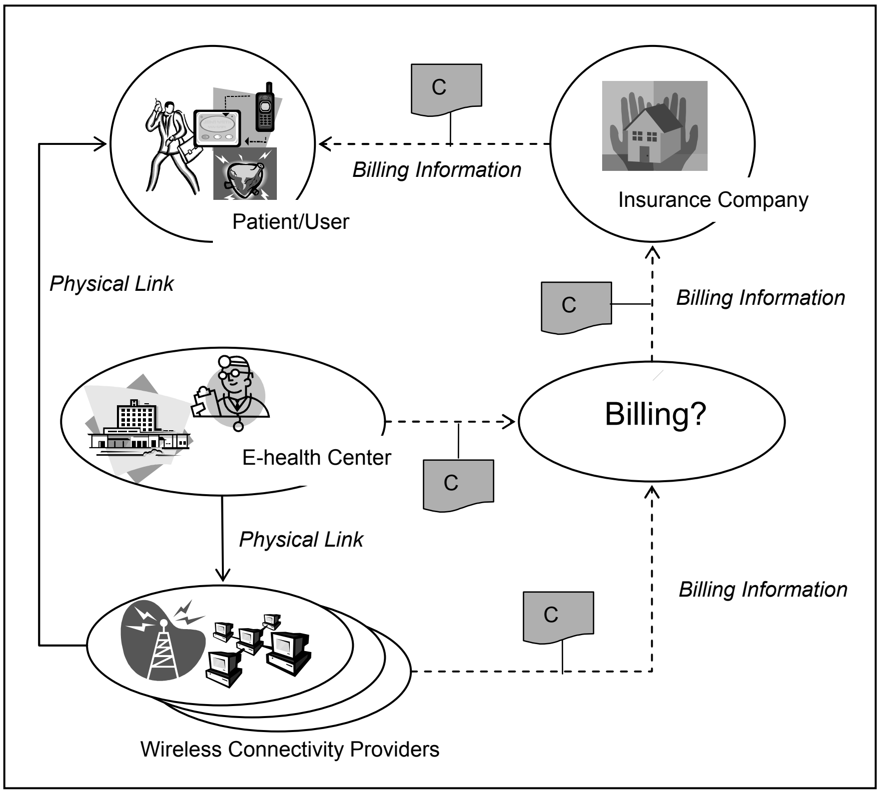


Figure 1.4. eHealth Service Provisioning and corresponding Billing Flow

Figure 1.4 presents the physical link of the service delivery from the *eHealth Center* to the *Patient* (indicated by the solid arrows). The contracts between the *eHealth Center* and different *Wireless Connectivity Providers* permit both the *eHealth Center* and the *Patient* to use connectivity services. Further, Figure 1.4 shows the possible logical link for the exchange of billing information (indicated by the dotted arrows).

From a technical viewpoint, the above service scenario poses a number of problems regarding inter-domain billing. The *first problem* concerns the exchange of billing information. That is, how should a service provider exchange its usage records and/or charge records with a so-called Billing Service Provider specialized in billing services or with another service provider? For instance, as the *Patient* travels across a number of geographical locations, it is necessary to ensure seamless roaming of the *Patient* between different wireless networks. Therefore, the *eHealth Center* needs to cooperate with different *Wireless Connectivity Providers* depending on the location of the *Patient*. To this extent, we are dealing with the open system interfaces and standardization of billing message formats.

The *second problem* concerns the one-to-one mapping of charge records onto the service session composition information. It is not trivial for a service provider like the *eHealth Center* to specify the correct service composition due to the lack of information models. The correlation of the different charge records originating from the different sub-services with the corresponding service composition is complex. In practice, incorrect correlation of charge records means revenue leakage because some charge records become unusable when they cannot be associated with the sub-services [Kabira02].

1.3.2 Video Streaming

The following is a case of real-time streaming service. In this scenario, the *Customer* requests a particular video from the *Service Broker* and the *Service Broker* provisions the requested video stream to the *Customer*. The *Service Broker* is a special kind of service provider that makes use of external services to compose its own services to the customers. More specifically, it combines a content service and a connectivity service to build up a composite service, which the *Customer* experiences as a video streaming service. The *Content Provider* and the *Connectivity Provider* are specialized in providing content and transport service, respectively. We assume that the *Customer* is a prepaid subscriber of the *Service Broker* and that the *Service Broker* conducts the billing of the video streaming service. Figure 1.5 depicts the business relationships, the financial flows between the involved business partners. Figure 1.6 presents the physical link of the service delivery (indicated by solid arrows) and the corresponding logical link for the exchange of billing information (indicated by dotted arrows).

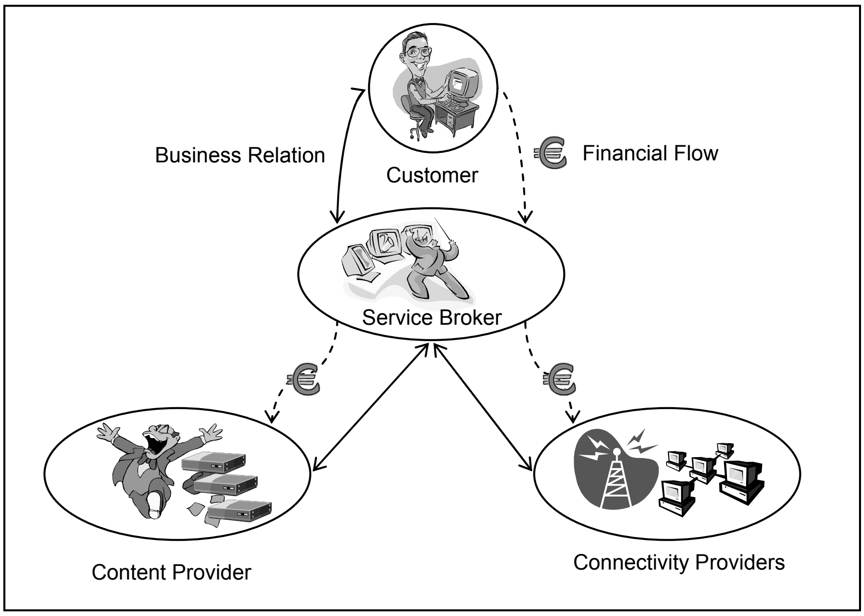


Figure 1.5. Video Streaming Service Scenario

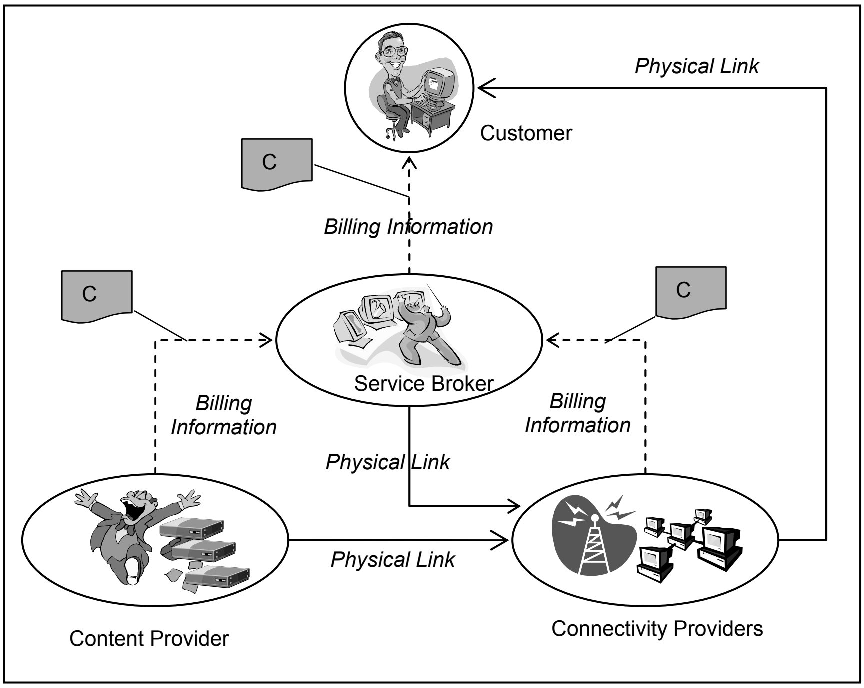


Figure 1.6. Video Streaming Service Provisioning and corresponding Billing Flow

The billing issue emphasized in this case is the financial control aspect of billing. As the video streaming service can last for hours, the risk that customers run out of credit is considerable. This raises the question about *how service providers can determine the actual charge*, *calculated during a service session*.

On one hand, the actual charge enables service providers to estimate their financial risks. On the other hand, it allows customers to control their spending pattern. Determining the actual charge during a service session is a complex matter, because most of the billing sub-processes must occur in near real-time.

1.4 Impact of Composite Service Provisioning on Billing

Up to this point, the billing problems related to the service provisioning in the telematics markets has been introduced: (1) the lack of a standard information model to specify service composition; (2) the lack of standard interfaces to support the exchange of billing related information such as service composition, usage and charge records and finally (3) the lack of financial control for composite streaming services.

Next, these above challenging billing problems will be analyzed in more detail. As stated in the introduction, many telematics services are characterized by being composed of sub-services. Therefore, this thesis will study the impact on billing of the provisioning of composite services, next to simple services. Especially, it will focus on the following aspects: *customer mobility, business relationships, domain aspects, service composition, details of billing information and financial control*.

- *Customer Mobility* – Customers today expect more and more freedom in terms of when and where to access and use a service. The mobility of a customer has a great impact on service provisioning. For example, a customer can access a network; stay there for a while and then leaving the network to access another one. In case of a simple service the customer needs to make a new request for each new network and therefore experiences different services. In case of a composite service the customer is able to roam seamlessly between the networks. This roaming behavior implies the ending of one service and at the same time the beginning of another one. From the perspective of the customer, this is still the same service. The customer has no knowledge of service components being started or ended. However, from the perspective of the service provider, the service composition changes dynamically as the customer roams. Current billing systems are incapable of supporting dynamic changes of service compositions.

- *Business Relationships* – When dealing with composite services the business relationships between customers and service providers, as well as between service providers are mostly not static but dynamic. For example, the only-once consumption of context-aware services such as location-based services in a foreign country. Two major factors that drive these dynamic business relationships are the customer's mobility and the competitive offers of service providers in the telematics market. Dynamic business relationships impose problems to current billing systems because these systems are designed to support static business relationships. Hence one here has to deal with inter-domain billing and service session billing information. Furthermore, as business relationships are dynamic service providers are more concerned about their financial risks. The availability of interim charges would enable them to monitor these risks.
- *Service Composition* – Composite services are often delivered in bundles, which are the composition of sub-services provided by different service providers. For example, a service broker can combine connectivity services with content services to deliver a bundle of services to customers. Current billing systems are incapable of supporting charging of composite services based on the actual service usage. This is due to the lack of information models that enable the one-to-one mapping between the charges and the service composition.
- *Domain aspects* – Simple services are usually provisioned from a single domain, whereas composite services concerns service provisioning across multiple domains. Inter-domain service provisioning implies inter-domain billing. This requires billing systems to exchange billing related information, open-interfaces and standards for the specification of billing related information such as service composition, usage and charge records.
- *Details of Billing Information* – Composite service provisioning results in more detailed billing related information. For example, customers want to receive converged invoices that present all details about used services and sub-services and their corresponding charges. This means that there is a need for a more detailed inter-domain billing approach, down to the level of service sessions associated with the individual customer. It is a complex process to collect relevant billing information from different domains in order to produce converged invoices for customers.
- *Financial Control* – When dealing with composite services in dynamic business relations, customers as well as providers have to deal with financial risks. Real-time or near real time billing is a way to limit

financial risks. Therefore, interim is required. That is, a frequent stream of usage and charge records *during* service sessions. From the perspective of the customer, interim accounting and charging processes allow better control on spending patterns and from the perspective of the provider or other business partners reduces the financial risks related to service misuse.

The discussion above on the impacts on billing of the provisioning of composite services leads to the three main billing issues of this thesis: *Inter-Domain Billing*, *Service Composition Information* and *Interim Accounting and Charging*. For a summary see Table 1.1 below.

	Simple Service	Composite Service	Billing Issue
Customer Mobility	Service composition does not change during a service session	Service composition changes during a service session	- Service Composition Information - Inter-Domain Billing
Business Relationships	Static relationships	Dynamic relationships	- Service Composition Information - Inter-Domain Billing - Interim Accounting and Charging
Service Composition	Limited diversity of services	Large diversity of services that consist of many sub-services	- Service Composition Information
Domain Aspects	Service delivery from a single domain	Service delivery from multiple domains	- Inter-Domain Billing
Details of Billing Information	Limited details of billing information	Extended details of billing information	- Service Composition Information - Inter-Domain Billing
Financial Control	Simple financial control imposed on a single service	Complex financial control imposed on different sub-services	- Interim Accounting and Charging

Table 1.1: Billing Challenges Related to the Provisioning of Composite Services

The next section will describe the main questions and the scope of this thesis.

1.5 Problem Statement and Scope of Thesis

Problem Statement

The main problem statement of this thesis is how to design a billing system supporting inter-domain, dynamic service provisioning. Three focus points of our problem statement are identified, namely:

a. Inter-domain billing
b. Service composition information for billing and
c. Interim accounting and charging.

Each of these focus points leads its own (sub)-research questions that contribute to the main problem statement:

(a) Inter-domain Billing

Inter-domain billing refers to the management of the sub-processes involved in the billing process, which are distributed across several domains. To this extent, it deals with the distributed constituent elements embodied within the billing systems and the relationship between these elements. The following questions will be investigated:

Q1. What are the subsystems embodied in the proposed billing system?

Q2. What are the relationships between the subsystems?

Q3. What kind of billing interfaces are needed?

(b) Service Composition Information

Service composition information is of vital importance for the one-to-one mapping between the charges and the service composition. The following question need to be answered:

Q4. What kind of service composition information must be shared between a provisioning process and the corresponding billing process, in order to correlate and aggregate charges of used service session components?

(c) Interim Accounting and Charging

Interim accounting and charging refers to the generation of interim usage and charge records enabling the monitoring of the service charges and the updating of the customer's credit balance during the service session. Currently, interim accounting and charging mechanism is limited to the transport accounting and voice over IP (VoIP) sessions as specified by the Internet Engineering Task Force (IETF) in [Calhoun03]. Consequently, in general it is not possible for service providers to monitor charges of composite services during the provisioning phase. The following question is considered:

Q5. How can an interim accounting and charging mechanism for composite services be incorporated in the proposed billing system?

Scope

From the above we have the following summary. The scope of this thesis is limited in various ways. First (i), it focuses in particular on two sub-processes of billing, the accounting process and the charging process (see Figure 1.2). Second (ii), the proposed billing system is designed to support billing of service sessions. Therefore, it emphasizes only billing aspects that are closely related to service sessions and does not cover wholesale billing between service providers. Third (iii), this thesis addresses and reasons about a high-level billing system. Hence it does not discuss the technological implementation aspects of the system such as the choice of a particular programming language. Finally (iv), however security always plays an important role in billing, here in this thesis the security aspects of inter-domain billing are left out of scope.

1.6 Outline of Thesis

This thesis is structured as follows:

- Chapter 2 – *Billing Management: An Overview* addresses related work in the area of billing management. It covers the work done by different standard organizations and relevant scientific research conducted in the area of billing. It draws conclusions about opportunities to contribute to existing solutions.
- Chapter 3 – *Design Approach and Requirements* addresses the preferred design approach from a list of potential design methodologies. Furthermore, in this chapter the collection of architectural requirements is studied that forms the basis of the design of the billing system proposed in this thesis.

- Chapter 4 – *Business Context Scope of the Design* identifies relevant business roles and defines the boundary for the Inter-domain Billing System considered in this thesis.
- Chapter 5 – *Enterprise Viewpoint of the Inter-domain Telematics System* presents the inter-domain telematics system from a business (enterprise) perspective. It addresses the different participants involved in the business process to deliver services to customers and to bill the delivered services. This chapter provides answers to questions Q1, Q2 and Q4.
- Chapter 6 – *Information Viewpoint of the Inter-domain Telematics System* presents the inter-domain telematics system from an informational perspective. It describes the information the billing system manages for the purpose of service provisioning and billing. This chapter provides answers to question Q4.
- Chapter 7 – *Computational Viewpoint of the Inter-domain Telematics System* presents the functional entities of the inter-domain telematics system and their relationships. It discuses the interfaces needed for the exchange of billing related information between the participants involved in the service provisioning to end-users. In addition, it also discusses some performance considerations for the functional entities. This chapter provides answers to questions Q3 and Q5.
- Chapter 8 – *Design Evaluation* evaluates the designed inter-domain telematics system against the requirements defined in Chapter 3.
- Chapter 9 – *Conclusions* presents the conclusion of this thesis. It evaluates the proposed billing system with respect to the objectives stated in Chapter 1. In addition, directions for future research are identified.

Figure 1.7 depicts the structure of this thesis, the relations between the chapters and the questions considered.

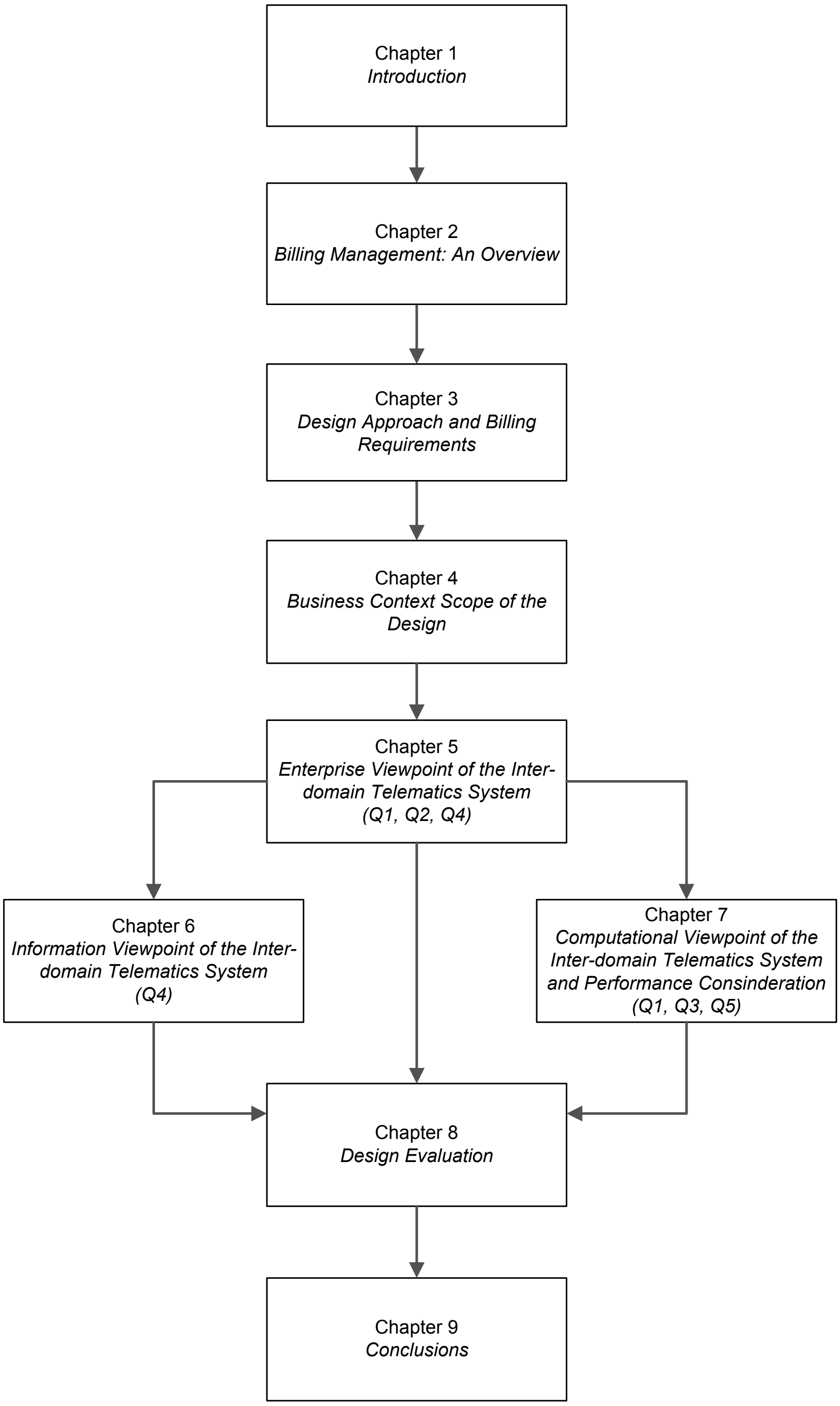


Figure 1.7. Structure of this thesis

Chapter 2 – Billing Management: An Overview

This chapter provides an overview of the scope and functionalities of the billing management areas as defined in existing management frameworks, academic research and industrial organizations. Moreover, the relationships between these management models and the work in this thesis are pointed out. This chapter ends with a conclusion summarizing all the ingredients for this thesis obtained from related work.

2.1 Billing Management in Existing Management Frameworks

In this section the scope and functionalities of the billing management area are considered as defined in well-known management frameworks like IN, WIN, TMN, TINA, IETF/IRTF and TMF.

2.1.1 Billing in IN and WIN

IN/WIN

The Intelligent Network (IN) is developed by Bell Communications Research (Bellcore) in the mid-1980s to enhance the Public Switch Telephone Network (PSTN) with additional services next to traditional call origination and call termination services. IN is an architecture that enables the real-time execution of network services and customer applications in a distributed environment consisting of interconnected computers and switches. The IN functional architecture is shown in Figure 2.1. This architecture has been presented in international standards as a set of functional entities comprising distributed functions that need to interact during call sessions [ITUQ1200,ITUQ1224]. These functions can be mapped to the physical network elements found in most of current telephone networks, namely: *Service Switching Point* (SSP), *Service Control Point* (SCP), *Intelligent Peripheral* (IP), *Service Management Point* (SMP), *Service Creation Environment Point* (SCEP) and *Service Data Point* (SDP).

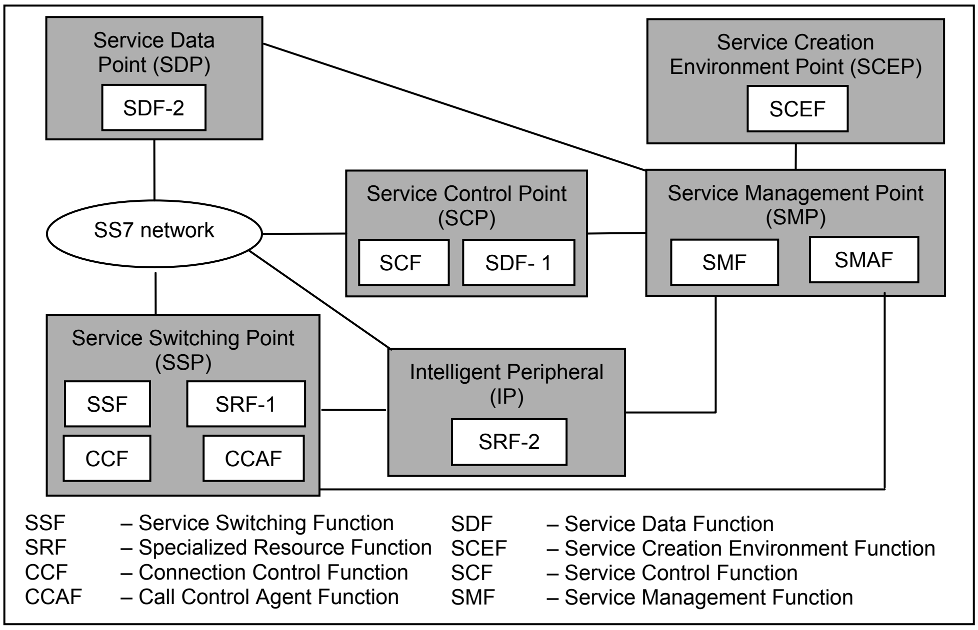


Figure 2.1. IN Functional Architecture

One of the primary goals of IN is to provide the possibility to create generic sets of reusable service components that can be used to build new services and be loaded into SCPs. These service components are called Service Independent Building Blocks (SIBs) [ITUQ1203]. In IN the SS7 (Common Channel

Signaling System Number 7) signaling network transmits management information between physical network elements, including billing information. This out-of band management signaling network provides the mechanisms to place service logic and service data into dedicated network elements that handle call control connection.

Billing

Billing in IN is strongly call-related and postpaid-oriented. The *Service Control Function* (SCF) and *Service Switching Function* (SSF) conduct basic tasks to provide billing services. Thus, the SCF issues service composition information and the associated charging characteristics to the SSF, information also known as FurnishChargeInformation. Once the SSF receives these characteristics, it generates a Call Detail Record (CDR) based on call duration. Moreover, the SCF can issue the SendChargingInformation to the SSF to enforce the SSF with some charging policies. Traditionally, CDRs are stored at the SSPs and later being collected in bulk. The collection of CDRs from the storage location to the rating engine is normally done via high-speed communication links using reliable data protocol as the X.25 [ITUX25, ITUX742]. For an overview of the billing process in IN see Figure 2.2 below.

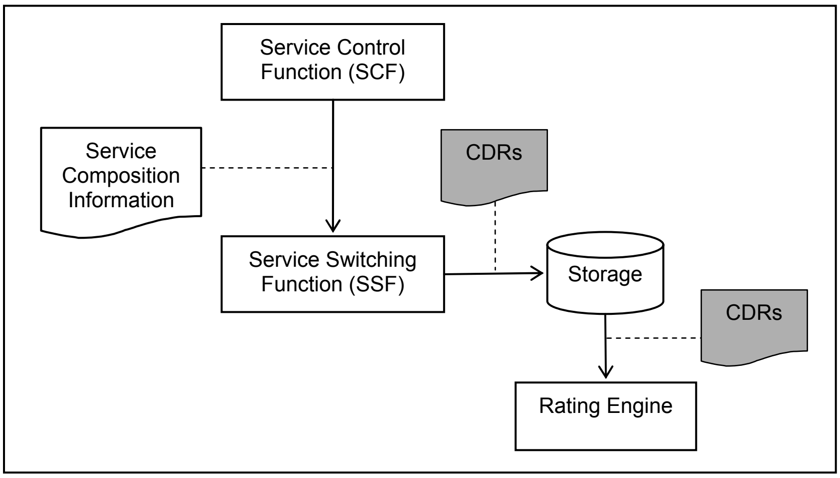


Figure 2.2. Billing Process in IN

The introduction of the digital mobile telephony standard GSM led to a sequence of next generation mobile platforms: General Packet Radio Service (GPRS), Enhanced Data Rates for Global Evolution (EDGE) and UMTS. The rapid development of mobile networks and services has been an important driver for the Telecommunications Industry Association (TIA) to bring IN strategies into the wireless mobile network [Faynberg97], known as the Wireless Intelligent Network (WIN). The TIA has not only focused on the development of wireless service creation and provisioning, but at the same time, also prepaid mobile phone service was introduced [Lin02]. Figure 2.3 depicts a simplified functional architecture of WIN for the support of prepaid services.

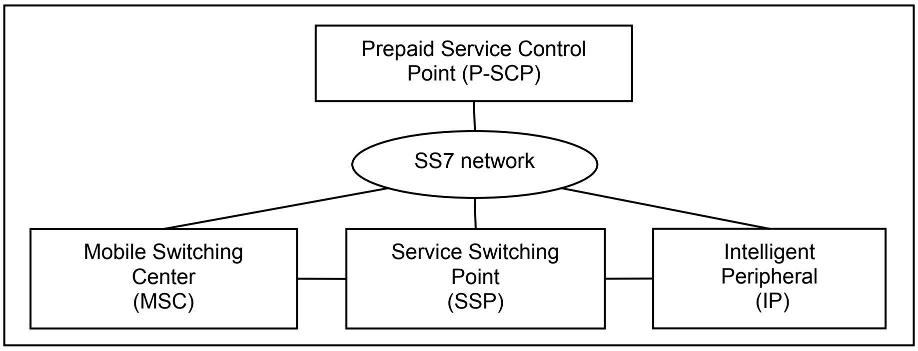


Figure 2.3. Simplified WIN Functional Architecture

In WIN the Prepaid Service Control Point (P-SCP) communicates with a Mobile Switching Center (MSC) through a SS7 signaling network. At the prepaid call setup and during the call session, the P-SCP interacts with the MSC to decide how to process the call based on prepaid applications. All billing information for a prepaid customer is stored in the P-SCP. A mobile network may need extra SS7 links to accommodate signaling traffic generated by the WIN prepaid mechanism.

The combination of WIN and the Customized Applications for Mobile network Enhanced Logic (CAMEL) protocol allows mobile operators to enhance real-time charging for roaming users. The CAMEL protocol is a network feature to provide mobile subscribers with operator specific services even when roaming in another network. CAMEL (phase 4) uses an IN SSP-SCP interface [ETSI101046]. The off-line exchange of billing information between mobile operators is done by using the so-called TAP (Transfer Account Procedure) protocol [Gullstrand01]. This protocol enables mobile operators to claim the charges for services offered to roaming customers.

IN and WIN are technology specific and most of telecommunication services provided can be considered as supplements to traditional telephony services. Although deployed worldwide, billing capacities in IN and WIN are rather primitive [Crowe98]. They are both limited in functionality to support today’s multimedia services, in particular composite services. Although many ad-hoc solutions have been proposed to “bridge” billing processes in IN/WIN with billing processes in other network types (e.g. the internet) [Koutsopoulou01, Siemens04], the tight technological coupling between service provisioning and accounting and charging in IN/WIN forms a large obstacle to integrate with billing processes of other platforms.

2.1.2 Billing in TMN

TMN

In 1988, the International Telecommunication Union (ITU) and the International Standardization Organization (ISO) have jointly defined a concept for standardizing protocols for monitoring and managing telecommunications equipment called Telecommunications Management Network (TMN). This concept encompasses a wide range of issues related to systems management of telecommunications systems. TMN uses an object-oriented approach and is based on the Open System Interconnection management framework (OSI) [ISO10165, Tanenbaum03]. The concepts of TMN are described in the ITU-T recommendations [ITUM3010, ITUX700, ITUX701].

The overall TMN architecture encompasses the following constituent architectures:

- *Functional Architecture* – This architecture defines the functional components of TMN and the reference points between these components.
- *Physical Architecture* – This architecture defines the physical components of TMN and the interfaces between these components.
- *Information Architecture* – This architecture describes an object-oriented paradigm for the exchange of information among the management functions and between the telecommunication networks and the management functions.

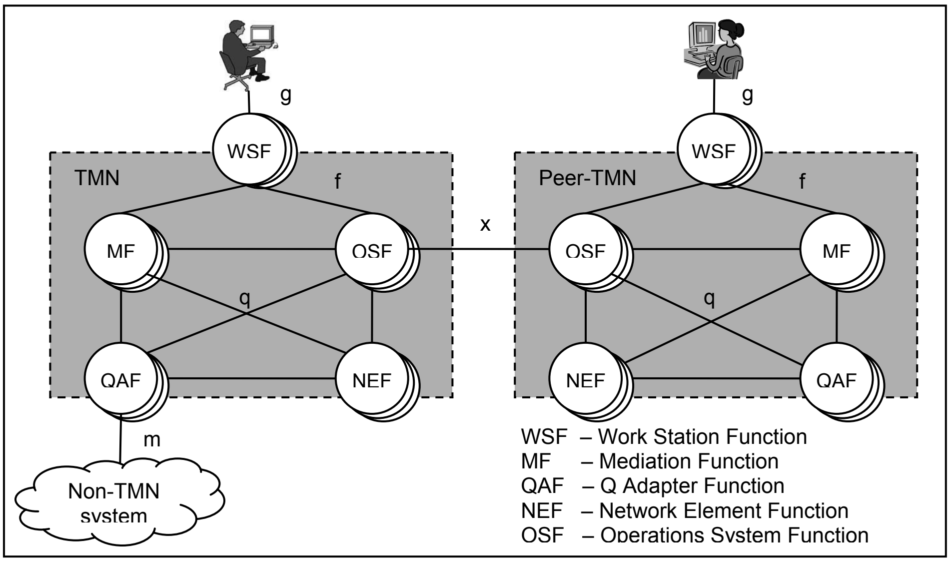


Figure 2.4. The TMN Functional Architecture

Figure 2.4 depicts the TMN functional architecture with five functional components and their relationships. These functional components are:

- *Workstation Function* (WSF) – This function supports the interactions between human users and the TMN environment.
- *Mediation Function* (MF) – This function facilitates the information exchange between Operations System Function (OSF) and Network Element Function (NEF) or Q Adapter Function (QAF). It ensures that the information, scope and functionality are presented in accordance with the expectation of other internal entities through different q interfaces.
- *Q Adapter Function* (QAF) – This function enables the TMN to manage network elements that do not have a TMN interface.
- *Network Element Function* (NEF) – This function represents the management capacities the network elements support. It provides network element level support to OSF.
- *Operation Systems Function* (OSF) – This function performs the processing of management information including operation monitoring, coordinating and controlling telecommunication operations.

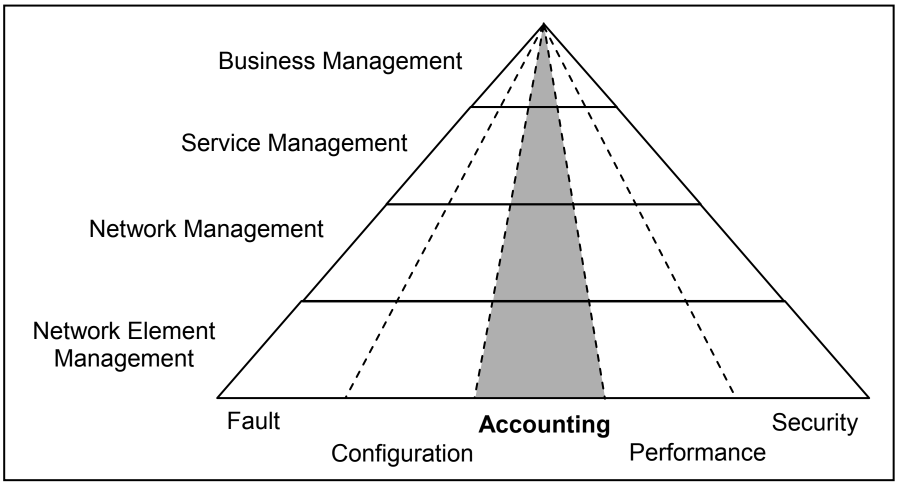


Figure 2.5. Mapping of the Management Functional Areas FCAPS on TMN Functional Layers

According to ITU-T recommendation X.700 [ITUX700], the required tasks of a management system can be categorized into five management functional areas: *Fault Management*, *Configuration Management*, *Accounting Management*, *Performance Management* and *Security Management*, often known as the FCAPS. The TMN also identifies four management layers:

Business Management, *Service Management*, *Network Management* and *Network Element Management*. In fact, FCAPS can be consistently distributed over the four management layers as suggested in [Goede01]. Figure 2.5 illustrates such a classification of FCAPS in TMN functional layers.

Billing

Billing, as defined in ITU-T recommendation X.742 [ITUX742], concerns the management functional area *Accounting*, which consists of three typical sub-processes:

- *Metering* – The process of creation of usage metering records as a result of the occurrence of accountable events in systems. The usage metering process is also responsible for logging of the usage metering records.
- *Charging* – The process of collecting the usage metering records which pertain to a particular service transaction in order to combine them into service transaction records. In addition, pricing information is added to the service transaction records. The charging process also keeps track of the service transaction records.
- *Billing* – The process of collecting the service transaction records and selecting from the ones that pertain to a particular service subscriber over a particular time-period. It includes the generation of invoices.

Figure 2.6 illustrates the sub-processes of the accounting process in TMN.

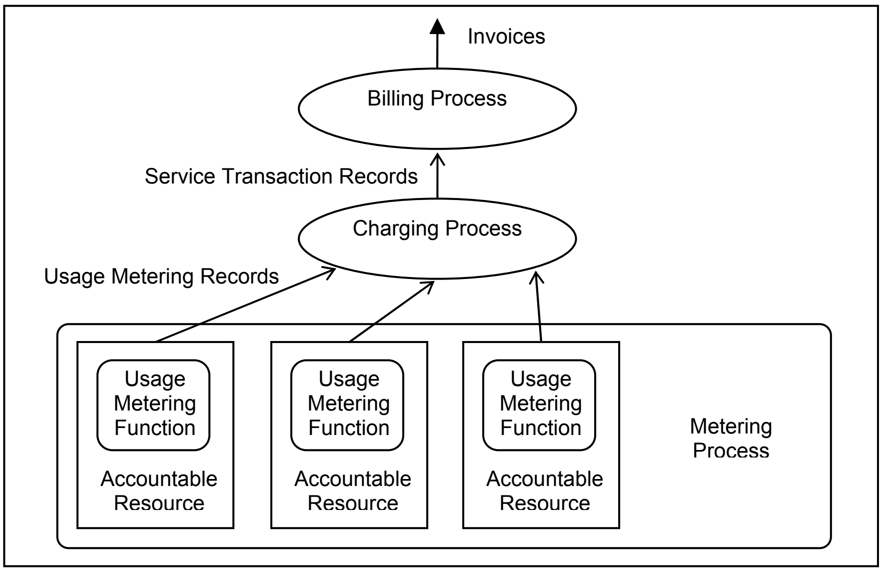


Figure 2.6. Illustration of the Accounting Process in TMN

The inter-domain billing between a TMN and a peer TMN domain is enabled over the *x-interfaces* respectively the *m-interfaces* (see Figure 2.4). Typically, inter-domain billing occurs at the service management layer and the interfaces offer the functionalities to allow so-called operations systems in the network management layer to exchange billing information.

In TMN, there is little support for the billing of non-voice services such as multimedia services and connectionless services in general. Moreover, during the period of the development of TMN, the modeling techniques to describe complex information models were immature. As a consequence, many aspects of the exchange of billing information between accounting managed objects are not supported. Nonetheless, TMN took the first step in informational modeling of telecommunications management architectures in general and billing architectures in particular.

2.1.3 Billing in TINA

TINA

TINA-C (Telecommunications Information Network Architecture Consortium) is an international collaboration of ICT (Information and Communication Technology) companies in 1990, aiming at defining and validating an open architecture and application software for information and telecommunication services based on existing ITU-recommendations. The TINA service-oriented architecture is based on distributed computing and object orientation. The information models in TINA are described according to the modeling paradigm in the Object Management Architecture of the Object Management Group (OMG) [Dupuy95, Inoue98].

The TINA framework distinguishes itself from IN and TMN by its business framework defined in [TINABMR]. The TINA business model defines business roles such as consumer, broker, retailer, third party provider and connectivity provider. Further, the model also defines specific reference points for the business roles to interact. At the business level, the model conceptually enables long-term business relationships between different business partners to provide composite services, for instant multimedia services on top of connectivity services.

Figure 2.7 depicts the TINA overall architecture, which consists of four sub-architectures, namely: *Service Architecture*, *Computing Architecture*, *Network Architecture* and *Management Architecture*. These sub-architectures rely on each other and require TINA compliant relationships to ensure the correct functioning of TINA platforms. The following briefly describes each of the TINA sub-architectures.

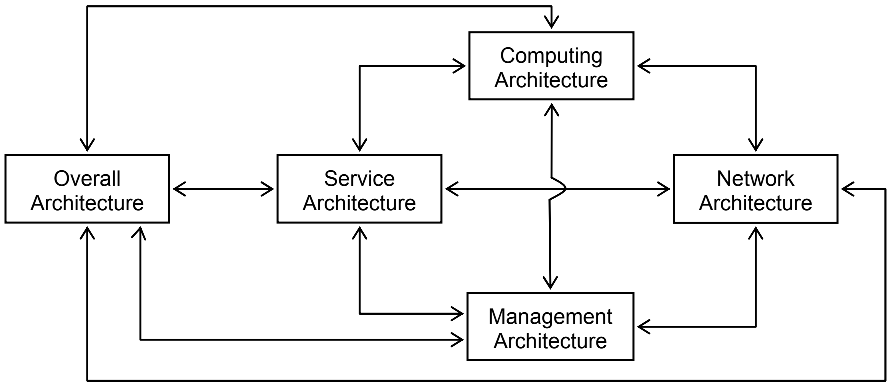


Figure 2.7. Relationships between the TINA sub-architectures

- *Service Architecture* – This architecture defines a set of concepts and principles for constructing, deploying, provisioning and withdrawing of telecommunication services. TINA services are session-oriented and are defined to be provided across multiple domains. This allows retailers and third party providers providing composite services that are composed of different sub-services. Moreover, the architecture also defines two types of sessions: access session and service session. Here access sessions concern the identification and authentication of the customers while service sessions concern the provisioning of actual services [TINASA].
- *Computing Architecture* – This architecture defines the computational specification of object-oriented software for TINA platforms. This architecture describes distributed applications in terms of computational entities (i.e. software components) that interact with each other. The architecture makes use of TINA proprietary language called Object Definition Language (ODL) for the development of computational specifications. The execution environment for the applications is called Distributed Processing Environment (DPE) [TINACA].
- *Network Architecture* – This architecture has been designed to take into account the principles of ITU recommendations M3010 [ITUM3010]. It defines a set of abstract recourses being generic descriptions of network elements. At the same time, it also offers a high-level view of network connections to services that run on top of the connections [TINANA]. The architecture also covers the management area of the FCAPS as defined in the TMN framework.
- *Management Architecture* – This architecture provides the concepts to build management systems that can manage TINA systems. Two types of management are distinguished:

- ° Computing Management, concerning the management of computers, DPE and the software that run on DPE.
- ° Telecommunications Management concerning the management of the transport network and the management of services [TINAMA].

Billing
TINA billing covers one to the five management areas of the FCAPS and consists of four sub-processes: *metering*, *classification*, *tariffing* and *billing* [TINASA]. The architecture introduces the concept of Service Transaction (ST) and Accounting Management Context (AcctMgmtCtxt) to support service session provisioning and service session billing on a customer/provider basis. The ST, on one hand, specifies service agreements between a service provider and a customer in terms of service fulfillment toward the customer. Further, it enables the service provider to ensure that all related management functions (i.e. FCAPS) incorporate correctly within its domain. On the other hand, the AcctMgmtCtxt specifies the billing information needed to charge a service session. It covers the so-called five Ws, namely: *What*, *hoW*, *When*, *Who* and *Where*. In case of inter-domain service provisioning there are the notions of "nesting Service Transaction" and the corresponding "nesting AcctMgmtCtxt" to handle inter-domain billing.

Despite its distributed character based on DPE (Distributed Processing Environment) and later on CORBA (Common Object Requesting Broker Architecture) technology, the TINA framework fails to be integrated into non-TINA service platforms. This is mainly due to the strict technical specifications between service provisioning and the associated billing.

2.1.4 Billing in IETF/IRTF

IETF/IRTF

The Internet Engineering Task Force (IETF) develops and promotes Internet standards. It cooperates closely with the World Wide Web Consortium (W3C) and ISO/IEC standard bodies and deals in particular with standards of the internet protocol suite (TCP/IP). The IETF is organized into a number of working groups and informal discussion groups, each dealing with a specific topic. As the popularity of the internet started to grow, together with the immense commercial interest around internet applications and services, the IETF started to pay more attention to billing issues in the late 1990s.

Billing
The first serious attempt of the IETF to investigate billing resulted in the specifications [RFC2924] and [RFC2975] that discuss general processes

involved in billing and billing information formats. The Internet Research Task Force (IRTF) (sponsored by the EITF) created the Authentication Authorization Accounting Architecture (AAA-ARCH) Research Group to increase research activities dealing with AAA. The AAA-ARCH Research Group has defined the AAA-architecture to support inter-domain authentication, authorization and accounting [RFC2903, RFC2904]. The defined architecture considers authentication, authorization and accounting as tightly connected services that the AAA-Server should perform. Policies [RFC3334] drive the synergy of these services. The accounting process in AAA-ARCH consists of five successive steps: *metering*, *collection*, *accounting*, *charging* and *billing*. (Note that the IETF uses the term "Accounting" where this thesis uses the term "Billing".)

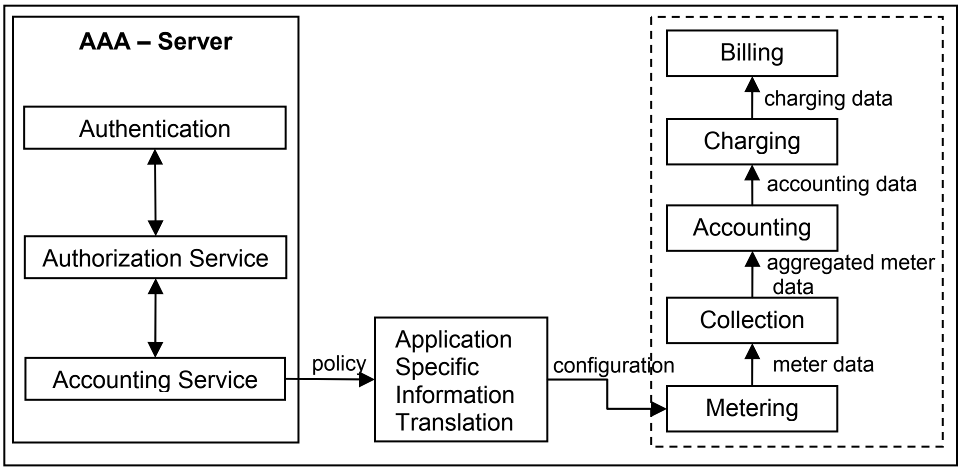


Figure 2.8. AAA Reference Model of IETF

When a user communicates with an AAA-Server, a set of rules are compiled and sent to the Application Specific Module (ASM). The task of an ASM is to translate application specific information provided by the AAA-Server to a set of configuration rules towards the meter and the meter reader. The output of a meter reader is the usage records needed for the processing of charging and billing. Figure 2.8 shows the billing sub-processes as part of the services the AAA-server provides.

The IETF has also defined a number of "accounting" protocols for carrying authentication, authorization and accounting information between the Network Access Server (NAS) and the AAA-Server, among which, RADIUS (Remote Authentication Dial-in User Service) is commonly deployed [RFC2865,RFC2866]. A RADIUS server has a central database consisting of the customer' identification, profiles and passwords to authenticate and authorize service requests from a NAS. It uses the UDP (User Datagram Protocol) transport protocol to exchange binary usage records with other

RADIUS servers. This stateless and insecure method to exchange billing information has raised a large number of questions concerning security.

The evolution of wireless access network technologies, e.g. WLAN (Wireless Local Area Network), has provided customers with mobility and freedom to move between networks, thus, possibly between domains. This evolution tends to make RADIUS obsolete due to additional requirements on mobility and security aspects that RADIUS does not cover. To support inter-domain billing requirements and to increase security, the IETF has defined *Diameter* [RFC3588] as successor of RADIUS. Unlike RADIUS, Diameter runs over reliable transport protocols such as TCP (Transmission Control Protocol) and SecureTCP. Further, Diameter communicates on a peer-to-peer basis instead of client/server to improve handling inter-domain issues. It should be noted that Diameter uses the notion of "*service session*" and "*session accounting*". The IETF has been working on the Diameter Service Session Initiation Protocol Application [IETFDraf03] to use in adjunction with the SIP (Service Initiation Protocol) [RFC3261]. This combination should be able to support accounting for internet service sessions such as VoIP (Voice-over-IP), multimedia services and such likes.

The IETF suggests using interim usage records in order to minimize possible financial risks. Diameter emphasizes this aspect even more than RADIUS. In addition, Diameter also defines mechanisms to check user credits before allowing service sessions to start.

2.1.5 Billing in TM Forum

TM Forum

The TeleManagement Forum (TM Forum) is a non-profit global consortium that focuses on Operation Support Systems (OSS) and management issues for the communications industry, including: service providers, software and hardware suppliers and systems integrators. In 1999, the TM Forum has defined the *Telecom Operations Map* (TOM) [TOM99], which describes the strategic operations management functions for supporting both service creation and management processes and the customer service support processes. As eBusines was getting increasingly important in the telecoms industry, the TM Forum released an expanded TOM version called: "*eTOM: The Business Process Framework for the Information and Communications Service Industry*" [TMFeTOM09].

The TM Forum takes a "top-down" approach to map business requirements into system requirements. The eTOM Business Process Framework serves as the blueprint to develop and integrate Business and Operations Support Systems (BSS, OSS) categorized in three process areas: *Strategy, Infrastructure & Product, Enterprise Management* and *Operations*.

- *Strategy, Infrastructure & Product* – This area includes processes that help to develop strategy, to build infrastructure, to develop and manage products and the supply chain.
- *Enterprise Management* – This area includes basic business processes that focus on enterprise-level processes, such as financial management and human resource management processes.
- *Operations* – This area includes processes that concern all operations to support customer operations and management.

The eTOM business framework can be presented at different process levels. Each level is a refinement of the previous one. Figure 2.9 depicts the *level 1* processes of eTOM. Here, the process areas *Strategy, Infrastructure & Product* and *Operations* are characterized by the so-called *vertical* and *horizontal process groupings*. The vertical process groupings represent different management functional areas, whereas the horizontal process groupings represent different management layers: *Customer Relationship Management*, *Service Management & Operations*, *Resource Management & Operations* and *Supplier/Partner Relationship Management*.

Our problem domain concerns the process area Operations, in particular, the vertical process groupings *Fulfillment*, *Assurance* and *Billing & Revenue Management* (FAB).

Billing

Up to release 7.5 [TMFeTOM08] billing in eTOM focuses mainly on accounting and charging of traditional (i.e. simple) telecommunication services. With the integration of the Revenue Management Map, formerly Global Billing Association (GBA) Map, the eTOM *Billing* process area is expanded to *Billing & Revenue Management* to cope with accounting and charging of multimedia services [TMFeTOM09]. Today, billing in eTOM concerns with the process grouping *Billing & Revenue Management* that consists of four *level 2 processes* as shown in Figure 2.10. From top down, these processes are *Billing and Collection Management*, *Service Specific Instance Rating*, *Resource Data Collection Analysis & Control* and *Supplier/Partner Settlements & Billing Management*.

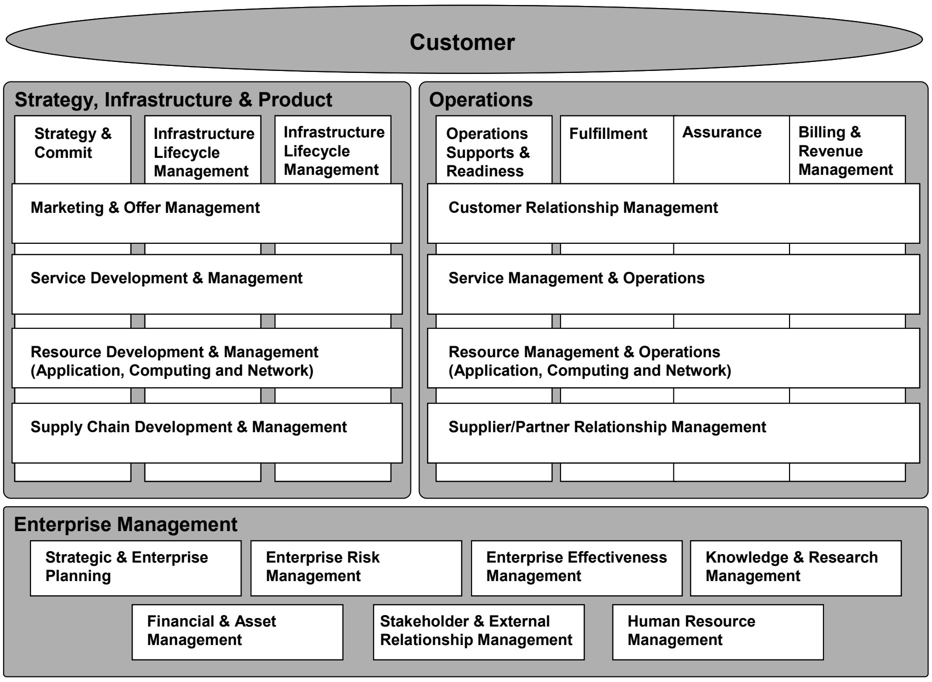


Figure 2.9. eTOM Business Process Framework – Level 1 Processes

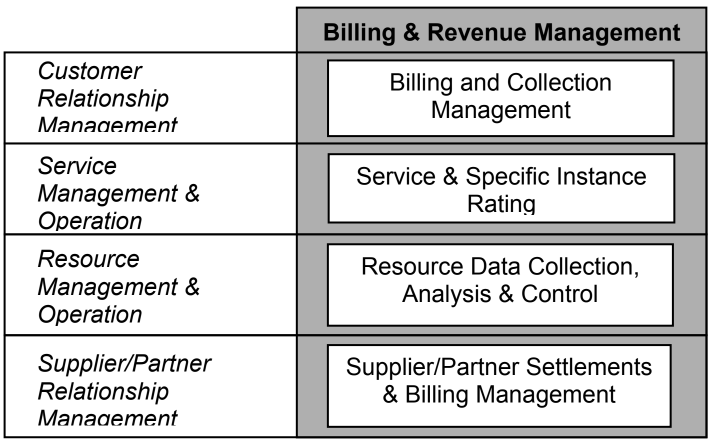


Figure 2.10. Billing & Revenue Management Process Grouping – eTOM Level 2 Processes

2.2 Billing Management in academic research

Within the academic community, many studies have been carried out to tackle the challenges of billing management from different angles. Stiller provides [Stiller03] an extended survey of charging for internet services, which stresses the importance of charging for different qualities of internet services. The survey also consolidates the terminologies related to billing, which are also used in this thesis (see §1.2).

The project ACTS project SUSIE has also applied TINA billing architectures to develop an accounting and charging framework for QoS-enhanced IP services provided over ATM at network level [Carle99].

The European funded project FORM has successfully applied the eTOM business framework to its research in the area of “co-operative inter-enterprise” billing [FORMD9, FORMD11]. This project intensively uses UML [OMGUML09] to model billing processes across multiple domains. It demonstrates that inter-domain billing can be modeled in a process-oriented manner [Bushan02].

Kneer proposes in [Kneer00, Kneer01] a business model for accounting and charging of internet services, including valued-added services such as content. The business model of Kneer considers service scenarios involving end-customers, “Electronic Commerce Service Providers” (ESPs) and Internet Service Providers (ISPs).

Radisic proposes in [Radisic02] the application of policies to manage the IT (Information Technology) services and the billing service. Here, Radisic identifies relevant billing sub-processes related to the different phases of a service life cycle as defined by Hegering [Hegering99] (see also §3.3.2). A set of policies manage these billing sub-processes. One of the main objectives of the work done by Radisic is to integrate industrial software components for billing purposes using a policy description language.

Redmond presents in [Redmond00] a service-level billing architecture based on the TINA framework, which is implemented using CORBA [OMGCorba]. This work mainly focuses on the enhancement of usage-based charging and dynamic price setting of composite telematics services. Despite its merits to demonstrate the accountability of services at the service instead of the network level, it still lacks the crucial mapping between service composition information and charging of individual sub-services in a composite session.

Sekkaki demonstrates in [Sekkaki01] demonstrate a prototype of a TINA-based billing system, which includes basic security functionalities of TINA billing. However, the developed prototype is only suitable for integration in TINA service platforms.

Koutsopoulou proposes in [Koutsopoulou03] an architecture to support billing processes which also accounts for inter-domain billing. In this architecture, the authentication, authorization and event-based billing in roaming service scenarios is well addressed. However, the charging of composite services has not been considered in detail.

Kurtansky introduces in [Kurtansky07] a concept called Time Interval Calculation Algorithm (TICA) for interim accounting and charging to deal with performance issues. That is, to avoid large overhead caused by credit checks. TICA supports flexible tariff functions to cope with sophisticated business relationships between the involved business partners. TICA and the proposed billing system in this thesis are complementary. Hence, a combination of TICA and our proposed solution helps to tackle performance issues of interim accounting and charging of inter-domain composite services.

2.3 Billing Management in Industrial Organizations

This section covers the scope and functionalities of the billing management area as defined in industrial organizations like M3I, Parlay and IPDR.org.

2.3.1 Billing in M3I

M3I

M3I (Market Managed Multi-service Internet) [M3I] (initiated in 2000) is an industrial project that aims at the design and implementation of systems enabling accounting and charging for differentiated telematics services provided over the internet. The main area of focus of M3I is IP network middleware on customer and provider systems enabling real-time price negotiation and control over application and network QoS [Briscoe03]. M3I also investigates QoS-adaptive pricing schemes as a means to manage network resources, and at the same time, to optimize revenues [M3ID8, M3ID16, Stiller01].

The M3I project defines its business framework from a different angle than that of the telecommunications industry, namely from the internet business and service provisioning viewpoint. M3I defines its internet business actors and their business roles in a similar way as the approach taken in the TINA business framework. Nonetheless, M3I introduces new specialized business roles, such as the *Connectivity Provider* and *Information Provider*. A Connectivity Provider can be for example, a last mile network provider, an access provider, a backbone provider, or a server farm provider. Whereas an Information provider can be an application service provider, a content provider, an internet retailer, or a market place provider. A stakeholder (i.e. an enterprise) may have different business roles to fulfill. Moreover, M3I also provides a generic functions set that each business role should obey.

Billing

The billing related function set includes *service provisioning functions*, *charging functions* and *business policy functions* [M3ID1]. The relation between the functions of a role and the interfaces between a role and its environment is depicted in Figure 2.11.

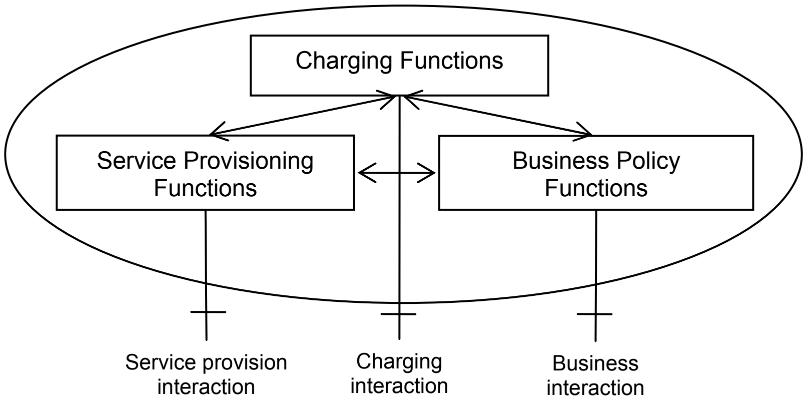


Figure 2.11. Billing related Role Functions and Interactions in M3I

2.3.2 Billing in 3GPP

3GPP

The 3rd Generation Partnership Project (3GPP) (founded in 1998) is a collaboration of a number of telecommunications standards bodies. The scope of the 3GPP is to provide global technical standards for network architecture and service architecture for the 3rd generation mobile networks (GSM, UMTS, CDMA). Part of the standards proposed the 3GPP are the IP Multimedia Subsystem (IMS) specifications [3GPPTS32.225], which are currently widely used by the telecommunications industry as de facto standards to support the design of fixed-mobile converged IP networks. The IMS uses Session Initiation Protocol (SIP) [RFC3261] to setup, maintain and terminate voice and multimedia sessions.

Billing

The 3GPP proposes three reference charging models for different service scenarios [3GGPTS32.200], namely: off-line charging model for non-roaming scenarios, off-line charging for roaming scenarios, and online charging model for both roaming and non-roaming scenarios. Note that the 3GPP uses the term “charging” where this thesis uses the term “billing”. Figure 2.12 depicts the reference charging model for online charging. This reference model covers charging of service sessions within an administrative domain. In case of roaming this implies that the service session charge is sent from the visited domain to the home domain after the service session is terminated. Hence, there is no exchange of billing related information during service sessions between two domains. As a result, the home domain would undergo financial risks in case of prepaid because the end-user might retain a service session for a long period while the credit balance has already reached the predefined threshold.

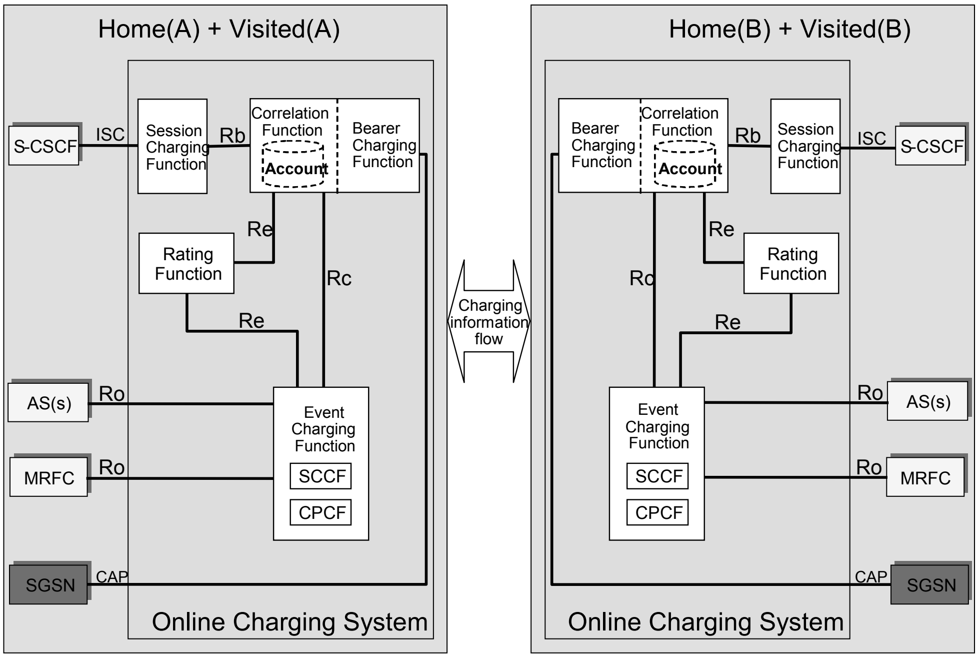


Figure 2.12. Online IMS Charging Model of 3GPP

2.3.3 Billing in PARLAY

Parlay

The Parlay group (founded in 1998) is a multi-vendor consortium that develops technology-independent application programming interfaces (APIs) enabling applications to access information from the telecommunications network infrastructure. ETSI (European Telecommunications Standards Institute) [ETSI] has standardized a number of documents released by Parlay.

The Parlay/OSA (Open Service Access) APIs allow access to telecommunications networks through a Parlay gateway, which is usually inside a telecom administrative domain [ETSI2019153]. To do so, the Parlay/OSA gateways use protocols like CS1 [ITURP30542] (under ITU-standardization process) and MAP (Mobile Application Part) [TS29002]. The framework consists of a family of interfaces that enables management functionalities such as Trust and Security Management, Registration, Service

Life Cycle Management, Service Discovery, Integrity Management, Event Notification, Contract Management and Charging [Moerdijk03]. Parlay/OSA applications run on application servers using CORBA to communicate with the Parlay gateways.

Billing

The Accounting Management Service Capacity Feature (SCF) supports accounting and charging for value-added services provided over mobile networks. This API enables charging instructions down to the network and informs the user with charging information by adding additional charging information to CDRs the network elements generate. In [ETSI20191511] the Accounting Management API of the Parlay framework is specified. Parlay uses the Unified Modeling Language (UML) to describe user account management-oriented services such as transaction history retrievals between two Account Managers, user balance requests and accounting event notifications. Further, the Accounting Management SCF can combine prepaid services available in the WIN supporting prepaid value-added services.

2.3.4 Billing in IPDR.org

The IPDR organization (founded in 1999) is working on the standardization of usage and charge records. It has adopted the eTOM framework for the purposes of motivating the functional role and interfaces of the Internet Protocol Detail Record (IPDR) specifications relative to operations support systems (OSS). The motivation of the IPDR.org's to adopt the eTOM is because it is a well-known, industry-accepted business process framework operators and service providers use today [IPDR02, IPDR03]. In 2007 the IPDR.org organization was acquired by the TM Forum.

The high-level model of IPDR.org consists of three layers, namely: network and service element layer, mediation layer and the business support systems layer. Each layer is discussed below:

- Network and Service Element (NSE) layer: The NSE layer consists of all the network and service elements required to provide an IP-based service to a given customer. For example, network elements that provide basic connectivity, application services, circuit to packet voice translation services, etc. Further, management systems are also part of the NSE layer.
- Mediation layer: Mediation systems bridge the network elements/infrastructure and the business support systems. A mediation system must determine the devices at the service element layer and interfaces with an infrastructure to collect the relevant usage information. The other role of a mediation is to pass provisioning

information from the BSS to the network elements, within the temporal constraints.

- Business Support Systems (BSS) layer: The BSS layer consists of the systems deployed by a Service Provider or Provider to support IP business operations. This layer corresponds to the Systems Development and Operation Processes and Customer Care Processes in the eTOM model. The BSS usage collection and provisioning requirements drive the mediation system and the services provided at the service element layer.

The IPDR specification defines a set of interfaces for exchanging IPDRs between IPDR-enabled devices or systems. IPDRs are packaged in protocol data units (PDUs) known as IPDR Documents (IPDRDocs). Figure 2.13 shows the key interfaces and elements of the IPDR.org reference model. Here the Service Element SE is supposed to generate proprietary usage records that the mediation system can transform into the IPDR format. The BSS receives IPDRs from the mediation system; now charges can be applied and the records can be transferred to a clearing house or the supplier/partner BSS.

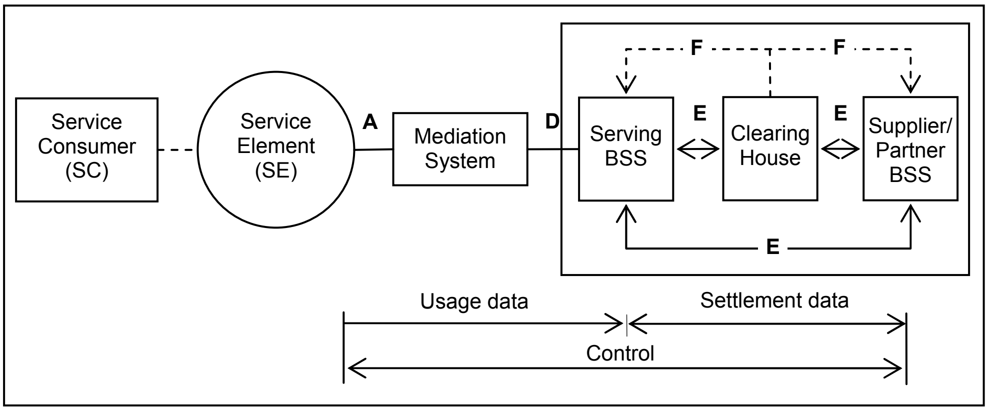


Figure 2.13. IPDR.org Reference Model

The focus of the IPRD.org is the design of XML-based IP usage records. Figure 2.14 shows the graphical presentation of the master IPDR schema, which declares elements common to all IP-based Services. An IPDR document (IPDRDoc) may contain one or more IPDRs.

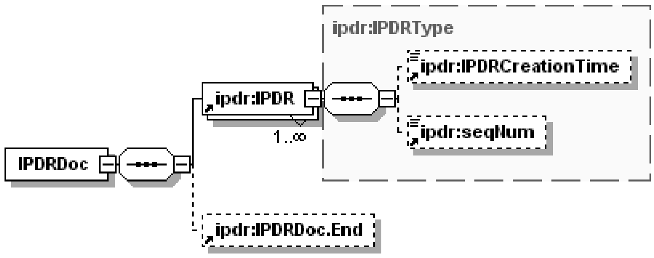


Figure 2.14. Master IPDR Schema

Among the service specific schemas the IPDR.org defines, there are specific usage record formats for email, VoIP, streaming media, DOCSIS, ASP, Public WLAN and AA services [IPDR].

2.4 Conclusion

The overview in this chapter on related work indicates the need to study inter-domain billing supporting dynamic service provisioning. As has been described in the first chapter this is mainly due to the business development of the telecommunications industry driven by internet technologies. Therefore, billing architectures need to cover current and future business scenarios and requirements. The eTOM business framework serves as an inspiration for us to achieve this goal.

As described the problems of billing involve the accounting and charging of individual services that build up composite services, provisioned across different administrative domains. Hence, a billing system should enable the accounting and charging of individual service. To achieve this goal, this thesis will provide a service composition information model enabling the correlation of charges originated from different services within a single service session.

Interim accounting and charging is becoming important to minimize financial risks for users and service providers. The IETF as well as telecommunications industrial organizations recognize the importance of the real-time aspect of accounting and charging management. This thesis will also consider billing solutions dealing with interim mechanisms.

Finally, this thesis adopts the proposal of the IPDR.org for using XML for the exchange of billing information between business support systems in multiple domains hence providing a flexible way to extend service definitions and therefore of the definition of usage and charge records.

Table 2.1 below shows a comparative summary of existing frameworks with respect to supporting Inter-domain Billing, Service Composition Information and Interim Accounting and Charging. Note that filled cells indicate that a particular framework does address the related billing problem, whereas empty cells indicate the opposite.

Framework	Inter-domain Billing	Service Composition Information	Interim Accounting and Charging
IN and WIN			
TMN	■		
TINA	■	■	
IETF/IRTF	■		■
TMForum	■	■	
M3I	■		
3GPP	■		■
PARLAY	■		
IPDR.org	■	■	

Table 2.1: Comparison of existing Management Frameworks related to the focus points of the problem statement. A filled cell denotes that the issue is mentioned.

Chapter 3 – Design Approach and Billing Requirements

This chapter presents the two main ingredients of the design of the proposed billing system. First, a suitable design methodology is considered followed by a systematic approach to derive the requirements for a billing system for composite services.

3.1 Overview of Design Methodologies

In the literature [Eden03, Halteren03] there are multiple definitions of the terms *architecture*, *system* and *model*, sometimes causing confusion about their precise meaning. In this thesis we will use the following three definitions. The definitions are adaptations of the ISO/IEC Standard 42010:2007 [ISO/IEC07].

Definition 3.1: *An architecture is the fundamental organization of a system embodied in its subsystems, their relationships to each other, and to the environment, and the principles guiding its design and evolution.*

By *design* we mean the conceptual image that a designer, the person who works with it, has in mind. A designer can develop a coarse-grain design and then create a more fine-grain design that conforms to the coarse-grain design by adding more details. The process of adding more details is called *refinement*, whereas *decomposition* is a special case of refinement. Decomposing is achieved by splitting some or all of the parts of a coarse-grain design into a more detailed design. The decomposition step from a coarse-grain to a fine-grain design is called the *design step*. A design at level N results in a design at level N+1 through decomposition. The related decomposition levels are also called *abstraction* levels. The design at level N is called the architecture of the design at level N+1 [Hateren03]. To this extent we do not have an absolute notion of the term "architecture" in our design of a billing system.

Definition 3.2: *A system is a collection of subsystems organized to accomplish a specific function or set of functions.*

A system consists of a set of subsystems; these subsystems are used to build the overall system that fulfills a set of specific functions. Moreover, a subsystem can be further decomposed into sub-subsystems, until the atomic level is reached. A system can be observed from different viewpoint depending on the interest of the designer. In general, one can study the system in question from a *structural*, *behavioral*, or *quality* viewpoint (e.g. performance, dependability, security, maintenance, etc.). In this thesis we will use the term "Inter-domain Billing System" to denote the proposed billing system. The Inter-domain Billing System consists of billing subsystems which can only be seen at the next design step through further decomposition.

Models are used to manage the complexity of a system by representing the characteristics of a system that are of interest for some specific goal. We will use the following definition for a model:

Definition 3.3: *A model represents a system in which certain aspects are considered and others are intentionally omitted.*

There are a number of standard methodologies that can be applied in the design of distributed systems such as billing systems. The following section provides a brief overview of well-known design methodologies. In particular we will discuss the Reference Model of Open Distributed Processing (RM-ODP), the Model-Driven Architecture (MDA), the Next Generation Operations Systems and Software (NGOSS) that embodies the business process framework called the enhanced Telecom Operations Map (eTOM), the design methodology proposed by Booch et al. [Booch99] and finally, the design methodology proposed by Lewis et al. [Lewis03].

3.1.1 Reference Model of Open Distributed Processing (RM-ODP)

RM-ODP is an ISO and ITU standard presenting a reference model for modeling distributed systems [ITUX901-904]. It uses five viewpoints from which a system can be observed: *Enterprise*, *Information*, *Computational*, *Engineering* and *Technology Viewpoint*. The reference model provides useful separation of platform independent modeling and technology concerns, but suffers from a lack of traceability between the viewpoint models, as pointed out in [Lewis03].

3.1.2 Model-Driven Architecture (MDA)

MDA is an architecture proposed by the Object Management Group (OMG). This architecture aims to separate business and applications logic from underlying platform technologies. The MDA uses three viewpoints on a system, a *computation independent viewpoint*, a *platform independent viewpoint* and a *platform specific viewpoint* [OMGMDA03]. Furthermore, MDA emphasizes the application of the Unified Modeling Language (UML) [OMGUML09] at different points of the software development life cycle, covering design and analysis, programming and deployment, and management.

3.1.3 Next Generation Operations Systems and Software (NGOSS)

The *NGOSS* [Reilly05] is a work program that provides an architecture for Operations Support Systems (OSS) and Business Support Systems (BSS). This program is an initiative of the TeleManagement Forum (TM Forum). NGOSS emphasizes a service-oriented approach based on integration of off-the-shelf software/hardware components having well-defined interfaces, also called “contracts”. The key feature of NGOSS is the use of process management techniques to integrate components to perform business processes. The NGOSS makes use of the concepts defined by RM-ODP and UML meta-model to represent its concepts and principles [Strassner03]. The NGOSS program currently proposes a design methodology that embodies four main aspects:

- The NGOSS Technology Neutral Architecture (TNA) which describes the architectural aspects of a distributed system.
- The enhanced Telecom Operation Map (eTOM) defines the business process framework which is a reference framework for identifying business activities of service providers.
- The Shared Information and Data model (SID) which describes the managed objects and their behavior and relationships.
- The Telecom Application Map (TAM) which describes a framework of telecom applications.

3.1.4 Booch et al.

Booch et al [Booch99] proposes five viewpoints from which a system can be observed: *Use Case*, *Design*, *Implementation*, *Process* and *Deployment Viewpoint*. Each of theses viewpoints can stand alone, so that different stakeholders (e.g. analysts, developers, system integrators, project managers, etc.) can focus on the issues that are most relevant to them. These five viewpoints also relate to one another in a consistent manner, which facilitates the traceability between the viewpoints of a system. This means that model modifications in one viewpoint that propagate to another viewpoint can be monitored.

3.1.5 Lewis et al

Lewis et al. [Lewis03] provides a reference model called Architectural Model to model management systems. The reference model aims to provide a set of modeling guidelines that supports the exchange of and comprehension of models between stakeholders involved in the development of component-based management systems and standards. It embodies a set of constituent models, each of which describes a number of aspects of the management system under development. The constituent models are the *business context model*, *domain model* and *management system model*. In addition, this reference model is accompanied with *contract set specifications*, *building block groups* and *external information models*. These elements are linked to one another, which facilitates traceability between the constituent models.

3.2 Chosen Design Approach

In the previous section an overview of existing design methodologies is presented. In practice, a preferred design methodology is often chosen on the basis of experience and preferences of the stakeholders involved. This section motivates our design approach of the billing system proposed in this thesis.

3.2.1 Design Approach

Our design approach is based on two basic ingredients: the RM-ODP [ITUX901-X904] and the eTOM business process framework.

Firstly, the RM-ODP provides a framework to develop distributed systems, operating in open, heterogeneous environments (i.e. using hardware and software from different technology standards). It supports a high-level of abstraction to hide the complexities of distribution and heterogeneity from the application level. The RM-ODP defines five complementary viewpoints. For each viewpoint a dedicated conceptual language has been defined. In particular the RM-ODP describes the “what” part of the design. That is, which constituent system elements should be modeled and the relationship between these elements. The RM-ODP approach has been successfully applied in developing telecommunications systems and middleware architectures [Leydekkers97, Kilov04, Kutvonen04]. It has served as a fundamental foundation for the development of domain-specific solutions and standards, notably the OMG’s CORBA and TINA [OMGCorba, TINA]. Recently, concrete languages have been defined for the RM-ODP conceptual languages, one for each viewpoint.

These concrete languages are based on the UML (Unified Modeling Language). More specifically, they extend the UML to capture language specific concepts. The UML extension mechanism used is that of a UML Profile [ISO/IEC19793].Today, many research groups are still developing tools and methodologies to enhance the design and modeling of complex systems, conforming to FM-ODP [Linington04, Akehurst04]. Dijkman has addressed the consistency issues between the ODP viewpoints and has proposed a way to relate enterprise and informational viewpoints [Dijkman04].

Secondly, the eTOM business process framework provides guidelines for decomposition in the various design steps. It is a widely used framework in the telecommunications industry for the integration of operations and business support services applications [Hall04]. Hence, the eTOM framework describes the "how" part of the design. That is, how to decomposed a coarse-grain design into fine-grain design conformed to the eTOM business processes. Below RM-ODP and the eTOM framework are detailed.

a. ODP Foundations

One of the most important contributions of RM-ODP is the concept of objects, which allows for precise and unambiguous object modeling of open distributed processing. Objects can represent various things of the problem domain, for instance a "real-world entity", an "idealized entity", the "subject of concern". The RM-ODP provides an object oriented concept for the modeling of precise and unambiguous object models. These object models are expressed in terms of *object, role, interface, template, factory, class, subclasses, type and subtype* [Leydekkers97] A complete presentation of these terminologies is found in [ITUX901-X904].

RM-ODP uses five viewpoints from which a system can be observed: Enterprise, Information, Computational, Engineering and Technology Viewpoint.

- The *Enterprise Viewpoint* is concerned with the purpose, scope and policies governing the activities of the specified system. It describes the business aspects and the role of the system in the business, the human user roles and business policies related to the system.
- The *Information Viewpoint* is concerned with the information that needs to be processed, exchanged and stored in the specified system. It describes the information managed by the ODP system and the structure and content of the data.
- The *Computational Viewpoint* is concerned with the functional decomposition of the system into objects that interact at the interfaces. It describes the functionalities the ODP system provides.

- The *Engineering Viewpoint* is concerned with the mechanisms and functions required to support the interactions between objects in the ODP system. It describes the distribution aspect of the processing the system performs.
- The *Technology Viewpoint* is concerned with the choice of technology to implement the ODP system. It describes the technical details of the components which construct the system.

The five viewpoints and their relationships are shown in Figure 3.1. These different viewpoints have their corresponding viewpoint language, each of which shares the general RM-ODP object modeling concepts. The relationships between two viewpoints is indicated by "derived from", which means that a system described in a particular viewpoint can be obtained via model transformation or model mapping from another viewpoint [Linington08]. The Inter-domain Billing System will be described in the first three viewpoints. This choice is made because we mainly focus on the conceptual design of the Inter-domain Billing System.

Since we do not explicitly address the deployment aspects of the Inter-domain Billing System (i.e. how distributed interaction between objects are supported by a certain infrastructure) we omit the Engineering Viewpoint. Furthermore, we do not want to suggest any choice of technology (e.g. Java, or C++, or the like) for the implementation of the Inter-domain Billing System. Therefore, the Technology Viewpoint is also omitted (see scope (iii) §1.5).

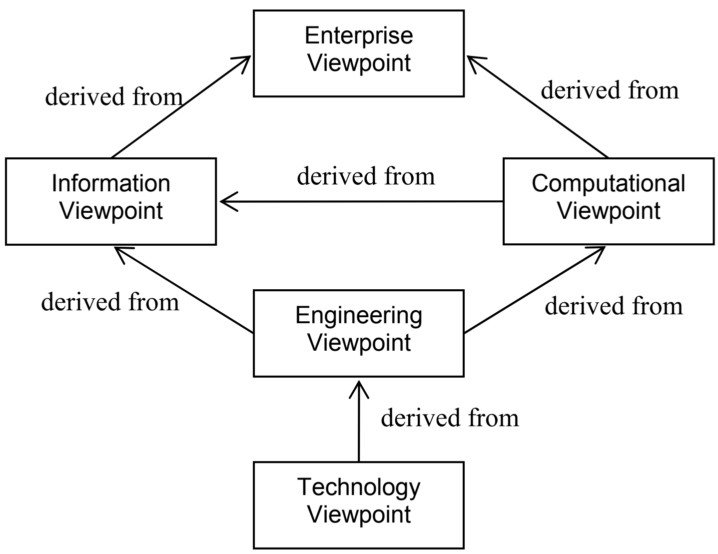


Figure 3.1. Relationship between RM-ODP Viewpoints. Engineering Viewpoint and Technology Viewpoint are out-of-scope in this thesis

Enterprise Language

The *enterprise language* provides the modeling concepts to represent an ODP system from a business perspective. The key concepts of the enterprise language are: *purpose*, *scope* and *policies*.

- The *purpose* of an ODP system refers to its objectives in an organization.
- The *scope* is expressed in terms of communities, their behavior (roles, processes, or both), policies and the relationship between these.
- The *policies* are restrictions of the behavior between the system and its environment, or between the subsystems. These policies are related to the business decisions of the system owners.

An enterprise specification represents an ODP system and its environment as a community, which is formed to meet an objective. The next concepts are relevant to our problem domain:

- *Community* – A *community* is a configuration of enterprise objects modeling a collection of entities (e.g. human being, systems, resources, etc.) that are subject of some contract. Each enterprise object plays one or more roles.
- *Enterprise object* – An *enterprise object* is a model of an entity. An object is characterized by its behavior and its state. Any change in its state can only occur as a result of an internal action or an interaction with its environment.
- *Enterprise role* – An *enterprise role* is an abstraction of the specific behavior of an *enterprise object* or an abstraction of a system behavior itself. Together, the *enterprise roles* represent an abstraction of the behavior of the *community* as a whole.
- *Enterprise process* – An *enterprise process* describes the behavior of an *enterprise role* by means of partially ordered set of steps, which are related to achieve some particular sub-objective within the *community*. In turn, steps are abstractions of actions. An *enterprise object* may participate in actions by fulfilling its role.
- *Enterprise policy* – An *enterprise policy* constrains the structure and behavior of the *community*. On the one hand, it constrains cardinalities of the relationships between an *enterprise role* and *enterprise object*. On the other hand, it can constrain an *enterprise process*. Commonly, an policy is defined separately from the model elements that it

constrains to permit modification of the behavior of the system without having to change its structure and basic elements.

Information Language

The *information language* provides the concepts for the specification of information stored within and manipulated by an ODP system, independently of the way how the information processing functions are to be implemented. Basis information elements are represented by atomic *information objects* and complex information is represented as composite information objects, each composite information object is a composition of constituent information objects.

The information specification comprises of a set of related schemata, namely: invariant schema, static schema and dynamic schema.

- An *invariant schema* expresses the relationships between information objects, which must always be true for all valid behavior of an ODP system.
- A *static schema* expresses assertions, which must be true at a single point in time. Commonly, static schemata are used to specify the initial state of an information object.
- A *dynamic schema* specifies how the information can evolve as the system operates.

Our research focuses on the relevant information objects and their content, not the behavior of the information objects themselves. Hence, we omit static and dynamic schemata in the design.

Computational Language

The *computational language* provides the concepts to describe the structure and behavior of an ODP system in terms of computational objects, interfaces and bindings between two interfaces. The following discusses briefly the basic set of concepts provided by the computational language.

- *Computational objects and interfaces* – An ODP system is composed as a configuration of interacting *computational objects*, which are abstractions of real-world entities. These computational objects contain information and perform a specific function. Computational objects have state and can interact with their environment at the *interfaces*. An interface is an abstraction of the behavior of an object that consists of a subset of interactions of that object. A computational object may have multiple interfaces.
- *Computational template* – Templates can specify computational objects and interfaces. A template is a specification of common features, which

can be used to create instances from it. An interface of a computational object is usually specified by a *computational interface template*. An interface comprises an interface signature, a behavior specification and an environment contract.

- An *interface signature* describes the type of interface, which can be a signal, operation or stream interface.
- The *behavior* of an interface template describes the allowed sequences of actions of the interface.
- The *environment contract* applies to the object as a whole. It imposes non-functional constrains upon objects. For example: security, geographical or reliability constrains.

- *Interactions* – The computational languages distinguishes three types of interactions, namely signals, operations and flows.
  - A *signal* is an atomic action between computational objects. Signals constitute the most basic type of interaction.
  - An *operation* is an interaction represented by message passing between a "client" and a "server" computational object. Such an interaction executes a function at the server object and returns a result to the client object. There exist two types of interaction: *interrogation* and *announcements*. The former is a two-way interaction, whereas the latter is a one-way interaction.
  - A *flow* is a stream of information, which represents an abstraction of a sequence of continuous data such as audio or video.

b. Enhanced Telecom Operations Map (eTOM)

The eTOM business process framework will provide us with guidelines for the decomposition in the various design steps. The eTOM business process framework has been successfully employed in the telecommunications industry as well as in research communities [AtosOrigin03, Bushan02]. The business process definition of eTOM is independent of organization, technology and type of service. The clear separation of the business *process areas* and the distinction of business *process groupings* within each process areas facilitate the development of service-oriented architectures in general and of our billing system in particular.

The eTOM business process framework [TMFeTOM09] represents the enterprise environment of service providers. At the highest conceptual level (level 0), it consists of three major business process areas:

i) *Strategy, Infrastructure & Product* – covering planning and lifecycle management

ii) *Operations* – covering the core of operation management

iii) *Enterprise Management* – covering corporate or business support management

In terms of eTOM, the billing problem domain of this thesis falls in the Operations process area. More precisely, it focuses on the three FAB process groupings of the *Operations* process area, namely *Fulfillment*, *Assurance* and *Billing & Revenue Management*:

- *Fulfillment* – This process grouping is responsible for the provisioning of the requested services to customers. The services can be delivered using internally available resources, but they can also be delivered in combination with external resources provided by a third party.
- *Assurance* – This process grouping is responsible for the execution of maintenance activities ensuring that services provided to customers are continuously available and will meet SLA and/or QoS performance levels. These processes ensure continuous monitoring of the performance of resources to detect possible failures.
- *Billing & Revenue Management* – This process grouping is responsible for the overall billing & revenue management process including production of invoices, collections and customers' payments. In addition, it handles customer dissatisfaction about invoices.

Figure 3.2 shows the FAB process groupings at the detail level 2. These level 2 processes are organized vertically within each process grouping. Further, these processes can also be organized horizontally according to the four management layers: Customer Relationship Management, Service Management & Operations, Resource Management & Operations and Supplier/Partner Relationship Management. For further details of the process level 2 we refer to [TMFeTOM09].

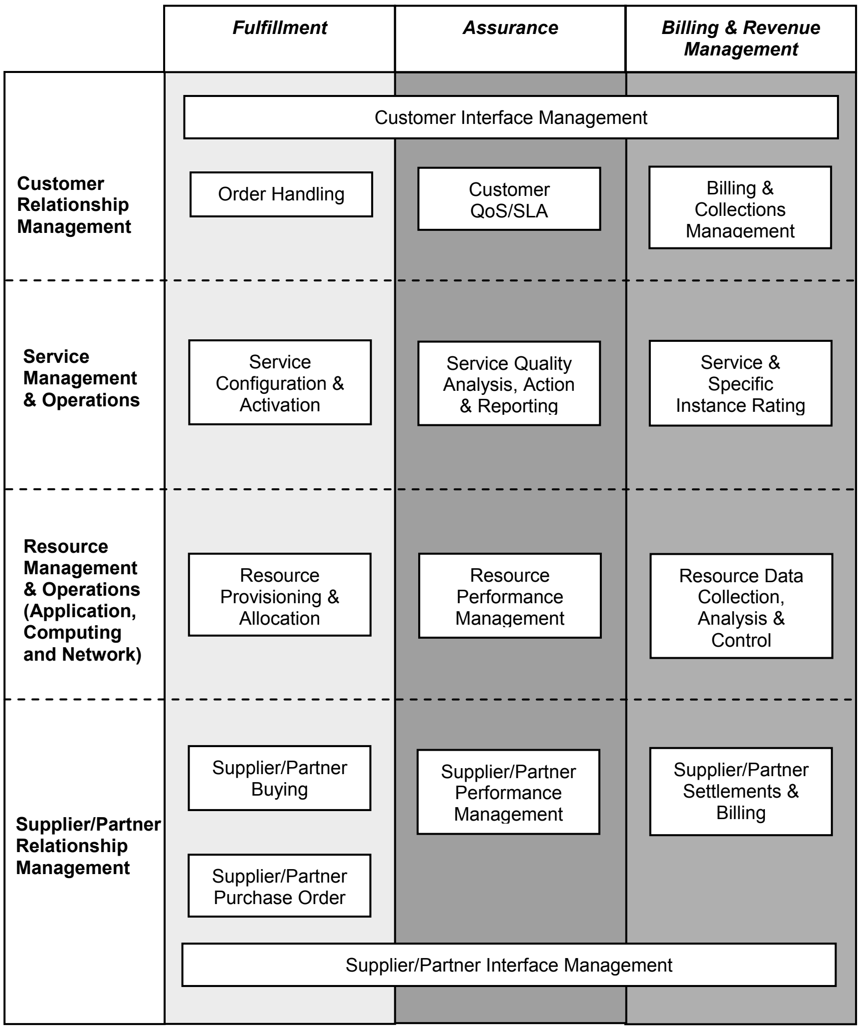


Figure 3.2. FAB Process Groupings within eTOM – Level 2 Processes

3.2.2 Application of UML Notation

The RM-ODP provides abstract languages for its concepts. However, it does not prescribe particular notations to describe ODP constructs (i.e. ODP conceptual language) in the individual viewpoints. Several notations have been proposed by different authors to describe ODP constructs. For example, formal description languages such as Z has been proposed for the enterprise and information viewpoint [Steen00]. LOTOS and Z have been proposed for the computational viewpoint [ITUX901-X904, Sinnot97]. Maude has been proposed as a formal notation for the enterprise viewpoint [Durán05, Roldán09].

System developers experience the formality of most proposed notations as difficult to learn. To this extent, UML is a promising alternative. UML is a visual language for specifying, constructing and documenting software systems. It is widely deployed by developers in the industry as well as in research communities due to the ease of learning and a great number of available UML tools. Many research groups have proposed UML to express ODP constructs in enterprise, information and computational viewpoint [Romero05, Dijkman04, Bordar02]. Notably, the ISO (International Standard Organization) and IEC (International Electrotechnical Commission) are developing standards to specify ODP systems using UML [ISO/IEC19793]. Given the successful application of UML for the specifications of ODP systems, UML will be used in this thesis to specify the proposed billing system.

3.3 Scoping of Service and Service Phases

Telematics services have a life cycle encompassing a number of phases, varying from the first step of the conception of the service to the last phase where the service is withdrawn from the market. The service life cycle is important because it permits the refinement of business processes related to the creation and management of telematics services. Moreover, a clear identification of the different phases in the service life cycle helps us to concentrate on the business processes that are most relevant to the design of the proposed billing system.

Before discussing the concept of service life cycle, we first introduce the definition of the term "service".

3.3.1 Definition of Telematics Service and Service Session

The term "service" is defined in slightly different ways in the literature. In general, service represents a set of goods or valuable functions a service provider offers to a service requester.

Gbaguidi defines service as

"*…a collection of capabilities, with each capability being a set of actions an entity performs (acting like a server) in response to a (constrained) request another entity has issued (being the client)*" [Gbaguidi96].

The ANSI consortium defines service as

"*…a set of capabilities available to a population of clients, but is conceptually distinct from whatever mechanism or configuration of parts that is used to provide it*" [ANSA95].

In TINA, service is defined as

"*...a meaningful set of capacities provided by an existing or intended system to all business roles that utilize it; each business roles sees a different perspective of the service*" [TINASA].

We note that the definition of the term "service" is only meaningful within the design scope of a specific service architecture. There exists no generic service definition, suitable for all design purposes. In this thesis we need a suitable service definition which expresses the characteristics of the business relationship between two business partners: a *service requester* and a *service provisioner*. Therefore, we will use the following definition of a service as the basis for our study on service provisioning across multiple domains and the relating billing.

Definition 3.4: *A service is a set of capacities provided by a service provisioner to a service requester according to some well-defined rules specified by Service Level Agreement (SLA).*

Next to the notion of *service*, we also use *service session* to denote the actual service provisioning of a service. A similar notion of a service session is also used in TINA [TINASA].

Definition 3.5: *A service session is a set of coherent activities carried out among service provisioning systems over a certain period.*

3.3.2 Service Life Cycle versus Service Session Life Cycle

The concept of service life cycle is extendedly studied by the TINA Consortium and also by Hegering [Hegering99]. The TINA service architecture identifies four phases in the service life cycle: *construction, deployment, utilization* and *withdrawal* [TINASA]; whereas Hegering identifies five phases in the service life cycle: *design, negotiation, provisioning, usage* and *deinstallation*. The commonality of these two identifications is that they both cover the same length of life cycle, which starts from the early service design and ends with the the service withdrawal from the market.

One of the major differences between these two identifications relates to the application domain. The TINA-Consortium defines the service life cycle for both static and dynamic business relationships, whereas Hegering only considers static business relationships. As stated in the problem statement of our study (see §1.4), one of our objectives is to take into account the dynamic aspects of business relationships between customers and service providers and between service providers themselves. The service life cycle defined in [TINASA, Le02a] is therefore the most suitable.

In the following we briefly describe the different phases of the service life cycle according to TINA:

- *Construction* – Service construction encompasses service requirements specification, service design and service testing.
- *Deployment* – Service deployment encompasses service planning, installation and activation of services.
- *Utilization* – Service utilization encompasses the activation and deactivation of services for specific users.
- *Withdrawal* – Service withdrawal encompasses the deactivation of services and eventual removal from the market.

Regarding our domain of billing, we will concentrate on the *utilization* phase of the service life cycle and assume the existence of the *construction* and *deployment* phase. In other words, it is assumed that the services are deployed and ready to be activated. Due to its irrelevance to the problem domain we further omit the *withdrawal* phase

In our point of view, the *utilization* phase can be observed from the service session perspective. A service session has its own life cycle, which consists of different phases. For each service session, there is a corresponding accounting and charging life cycle. These two distinct life cycles, one defined for the service session and the other for the corresponding accounting and charging, act like a "gearing system" where the support of one gear to the other is the driving force for the whole system. In [Le02b, Le03], this coherence of life cycles is discussed in more detail. The relationship between the service life cycle, service session life cycle and accounting and charging life cycle is shown in Figure 3.3.

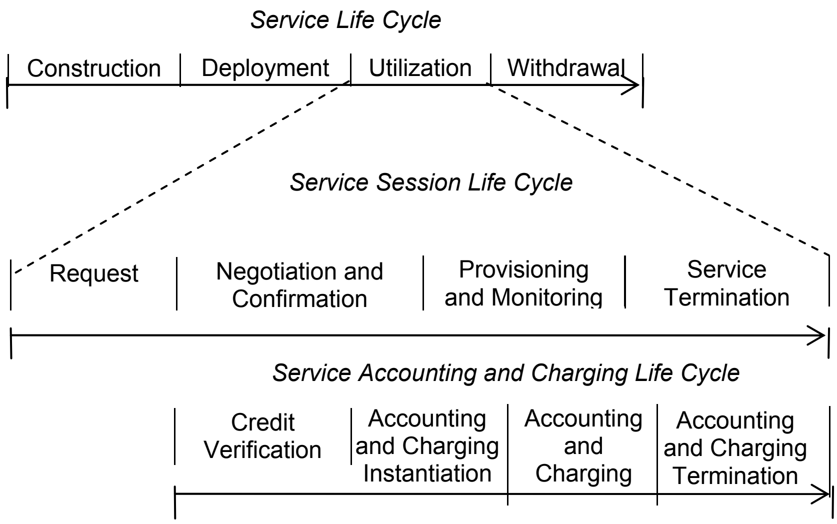


Figure 3.3. Relationship of Life Cycles

We identify four phases of the *Service Session Life Cycle* (SSLC) that are inline with the process flow of eTOM. In other words, it is possible to identify different phases of the SSLC within the FAB process groupings. The principle to group FAB-processes in different phases of the SSLC enhances both static as well dynamic business relationships. The SSLC consists of the following phases:

(1) *Request* – This phase is initiated by the customer requesting a service. The user initiates a service session by means of the Customer Interface Management process.

(2) *Negotiation and Confirmation* – In this phase, appropriate services are set up. The parameters of service specification are contained in a SLA (QoS, Price, etc.). This phase involves four FAB-processes: Order Handling, Customer QoS/SLA Management, Service Configuration & Activation. In case of composite services, additional processes are needed to enable the service negotiation with service partner(s). Therefore, the next processes are also involved: Supplier/Partner Buying, Supplier/Partner Purchase Order and Supplier/Partner Interface Management. The Service Configuration & Activation process is assumed to be capable to negotiate, choose and drop a service offered by the negotiating service providers. Further, the Service Configuration & Activation process is responsible for the confirmation of the selected services in the provisioning of a service session.

(3) *Provisioning and Monitoring* – Upon the reception of service confirmations, service instances can be set-up and provisioned. Parallel to this phase the accounting and charging is carried out for the provisioned service sessions (see Service Session Accounting and Charging Life cycle, §3.3.3). Further, service monitoring is important to determine the location of the customer in order to reconfigure the network for the purpose of seamless handovers in a multi-access technologies environment. The following processes are involved: Resource Provisioning & Allocation, Service Quality Analysis, Action & Reporting and Resource Performance Management.

(4) *Service Termination* – Service termination is the clearing of a service session. Here two FAB processes are involved: Service Configuration & Activation and Resource Provisioning & Allocation. Here, the Service Configuration & Activation process is responsible for the termination of services. The actual release of resources is done by Resource Provisioning & Allocation process.

Table 3.1 shows the execution of (level 2) *Fulfillment* processes in the distinct phases of the SSLC. The filled cells indicate the execution of the relevant FAB-processes in the various phases. When a third party provider is involved in the service provisioning, it is necessary to take into account the horizontal eTOM management area Supplier/Partner Relationship Management (see Figure 3.2). The execution of the processes in this management area ensures (among other things) appropriate *Fulfillment* and *Billing & Revenue Management* of the provided sub-service(s).

SSLC Phases / **eTOM Fulfillment and Assurance**	*Request*	*Negotiation and Confirmation*	*Provisioning and Monitoring*	*Termination*
Customer Interface Management	■			
Order Handling	■	■		
Service Configuration & Activation		■		■
Resource Provisioning & Allocation			■	■
Customer QoS/SLA Management		■		
Service Quality Analysis, Action & Reporting			■	
Resource Performance Management			■	
Supplier/Partner Buying		■		
Supplier/Partner Purchasing Order		■		
Supplier/Partner Performance Management		■		
Supplier/Partner Interface Management			■	

Table 3.1. Execution of Fulfillment and Assurance processes during the SSLC.

3.3.3 Service Accounting and Charging Life Cycle (SACLC)

The Service Accounting and Charging Life Cycle concerns the management of accounting and charging processes for service session. It consists of the following processes:

(1) *Credit Verification* – Accounting and Charging starts with the credit verification to check whether they are creditworthy to provide the requested composite service session. Here, the Customer Interface Management, Billing & Collection Management and Supplier/Partner Interface Management process are involved. Here, the Service Composition Information is used to determine the creditworthiness.

(2) *Accounting and Charging Instantiation* – This phase describes how the provided sub-services should be charged (flat rate, time-based, packet-based, value-based, etc.). Further, it also indicates the granularity of the charge increments of the incurred service session, aimed to reduce financial risks. The Billing & Collection Management and Service & Specific Instance Rating process are involved in this phase. In case of inter-domain billing, service providers make use of the Supplier/Partner Interface Management process to exchange billing information.

(3) *Accounting and Charging* – This phase measures the usage of delivered sub-services. Accounting depends on the service session declaration. In case of prepaid the credit balance needs to be monitored and be subtracted by the charge of the provisioned (end-to-end) service usage. In addition, the exchange of billing information among the involved parties is carried out. Here four FAB processes are involved: Customer Interface Management, Billing & Collections Management, Service & Specific Instance Rating and Supplier/Partner Interface Management.

(4) *Accounting and Charging Termination* – This phase takes place during the "Service Session Termination" (see Service Session Life Cycle, see §3.3.2) finalizing the accounting and charging life cycle. In a multi-domain environment, the accumulation of charge records from different service providers may take place to determine the total cost of the service session. Finally, the customer is informed with the final total cost of the service session. Eventually, the actual credit information can also be included. Here four *Billing & Revenue Management* processes are involved: Customer Interface Management, Billing & Collections Management, Service & Specific Instance Rating and Resource Data Collection, Analysis & Control.

Table 3.2 shows the execution of (level 2) Billing processes in the distinct phases of the SACLC.

SACLC Phases / eTOM Billing & Revenue Management	*Credit Verification*	*Accounting and Charging Instantiation*	*Accounting and Charging*	*Accounting and Charging Termination*
Customer Interface Management				
Billing & Collection Management				
Service & Specific Instance Rating				
Resource Data Collection, Analysis & Control				
Supplier/Partner Settlements & Billing				
Supplier/Partner Interface Management				

Table 3.2. Execution of Billing processes during the SACLC

3.4 Requirements Statements

A requirement is a criterion by which a system under design must conform in order to satisfy what is required and a requirement statement is a form of expressing the requirement. In fact, requirements statements are a set of "rules" that a design must satisfy. Our approach taken for the design of the Inter-domain Billing System will be "business driven". That is, we want to ensure the application of the Inter-domain Billing System in a relevant business context. Therefore, the requirements statements concern a categorized collection of requirements imposed on the billing system considered in this thesis. The specification of the requirements statements addresses two levels of concern:

1. Business Requirements – The business requirements are derived from the analysis about the billing challenges made in Chapter 1 (see Table 1.1). They address the constraints imposed on the business environment of the billing system under design.
2. Billing System Requirements – The billing system requirements are based on the relevant FAB processes identified within the SSLC and the SACLC. They address the constraints the environment imposes on the billing system.

The above two levels of requirements do not cover an universal collection of requirements that can be considered for the design of a billing system. For example, one could also take into account other kinds of requirements such as social requirements (e.g. it must be possible to provide free services to certain people). However, this kind of requirements goes beyond the scope of this thesis.

3.4.1 Business Requirements

Business requirements are high-level requirements imposed on the business context in which different business actors (i.e. business parties) are participating. The business context encompasses relevant roles fulfilled by the business actors present in the market and the relationships between these roles. In Chapter 4, the business requirements will be used to develop a business reference model, which serves as a basis for the design of the proposed billing system. This section provides the business requirements considered in the design. These business requirements are derived from the impact of composite service provisioning on billing as discussed in Chapter 1, §1.4.

- BR1 – *It must be possible to support both static and dynamic business relationships between customers and service providers.*
  - The fulfillment of this requirement enables the customers to obtain services from a wide range of service providers. The nature of the business relationship between customers and service providers can be static (i.e. long-term) or dynamic (i.e. short-term), depending on the customers' need.
- BR2 – *It must be possible to support business relationships between service providers and third party providers.*
  - The fulfillment of this requirement enables service providers to provide composite services to the customers using external services provided by third parties. The service provisioning from third party providers towards consumers can be static (i.e. long-term) or dynamic (i.e. short-term), depending on the service provider's need.
- BR3 – *It must be possible for service providers to outsource billing to other business partners.*
  - Billing services related to the provisioning of composite services are complex, which requires in-depth knowledge and understanding of the billing process. The fulfillment of this requirement enables service providers to delegate their billing processes to a business partner specialized in billing, so they can concentrate on their core business. In turn, business partners that are specialized in billing can make a profit providing billing services to service providers.

- BR4 – *It must be possible for a third-party business partners (e.g. payment service provider also called "customer account provider") to pay service providers on behalf of the customers.*
    - Business partners specialized in payment services are emerging in e-commerce and in telematics services thanks to the versatility of the Internet. These business partners are considered to be relevant in current and future businesses in offering customers and service providers a wide range of payment methods. The fulfillment of this requirement enables customers to increase the flexibility of paying for the requested services [Nieuwenhuis03, Le08b].

3.4.2 Billing System Requirements

The next step in system design is the specification of system requirements. In software engineering, many methods and styles have been proposed for the elicitation, analysis and documentation of system requirements [IEEE830, ISO9126, Sommerville97]. In general, one can distinguish three categories: *Functional Requirements, Data Requirements* and *Quality Requirements*. Lauesen defines these categories of requirements as follows [Lauesen02]:

- *Functional Requirements* – Functional Requirements (FRs) specify the functions of the system, how it records, computes, transforms and transmits data.
- *Data Requirements* – Data requirements (DRs) specify the data stored internally in the system and the input and output data of the system. Further, they also specify the formats of the input and output data through the various interfaces.
- *Quality Requirements* – Quality Requirements (QRs) specify how well the system performs its intended functions. They cover the so-called "quality factors" of the system, which are performance (e.g. efficiency of the system), usability (e.g. ease to use) and maintainability (e.g. ease to repair defect).

In Chapter 1 we presented the problem domain and the scope of our research. We identified three points of focus, which are *Service Composition Information*, *Inter-domain Billing* and *Interim Accounting and Charging*. Table 3.3 shows a template in which the system requirements are organized per point of focus. Moreover, the table will serve later on as a guideline to verify whether the proposed billing system fulfils all the requirements.

	Functional Requirements (FRs)	*Data Requirements (DRs)*	*Quality Requirements (QRs)*
Service Composition Information	FR1, FR2, …	DR1, DR2, …	QR1, QR2, …
Inter-domain Billing	FRn, FRn+1, …	DRn, DRn+1, …	QRn, QRn+1, …
Interim Accounting and Charging	FRm, FRm+1, …	DRm, DRm+1, …	QRm, QRm+1, …

Table 3.3.List of Billing System Requirements

The specification of the system requirements depends on the system aspects. It is essential to identify the system aspects of the requirements to ensure the scope, clarity and consistency of the design. We adopt the proposal of Lauesen and identify three main system aspects: *Domain Aspect*, *Product Aspect* and *Design Aspect*.

- *Domain Aspect* – This aspect concerns the requirements which fulfill the business goals of the problem domain. Typically, the domain aspect requirements specify what should be done to solve the problems identified in the domain of concern. For example, a functional requirement within the Domain Aspect would be: “the system under design must support the following user activities”.
- *Product Aspect* – This aspect concerns the requirements of concrete software systems. Typically, the product aspect requirements specify what should come in and come out of the software system. For example, a functional requirement within the Product Aspect would be: “the system under design must accept the following input”
- *Design Aspect* – This aspect concerns the client task support. Typically, the design aspect requirements specify how the user interfaces should look like. For example, a functional requirement within the Design Aspect would be: “the system under design must support user with visibility problem”.

Figure 3.4 shows the relations between the three main system aspects and the three distinct categories of system requirements. We note that our problem domain only concerns the *Domain Aspect* because it mainly deals with the conceptual design of the Inter-domain Billing System to solve the objectives stated in Chapter 1. We do not propose any data standards that should go in/out the system. Neither do we suggest how the user interface should look like.

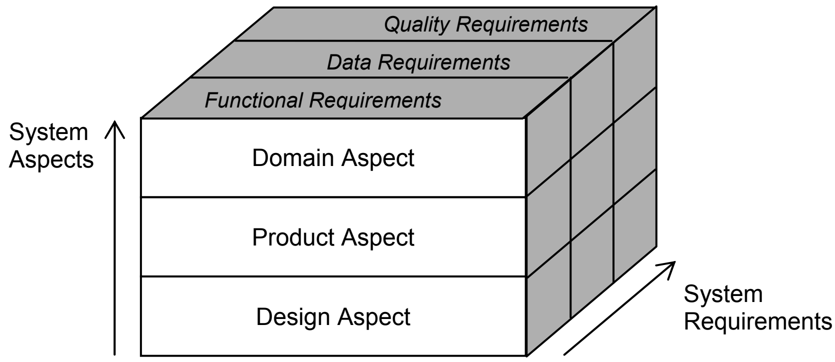


Figure 3.4. System Aspects versus System Requirements

3.4.3 Billing System Boundary

The specification of requirements depends strongly on the boundary of the billing system under design, which separates the system from its environment. The external factors that interact with the billing system through its boundary are called *roles*. In our design, two categories of roles are considered, namely: *Customers*, *Service Providers*. Figure 3.5 illustrates the fact that each category of roles has a set of requirements upon the design of the billing system.

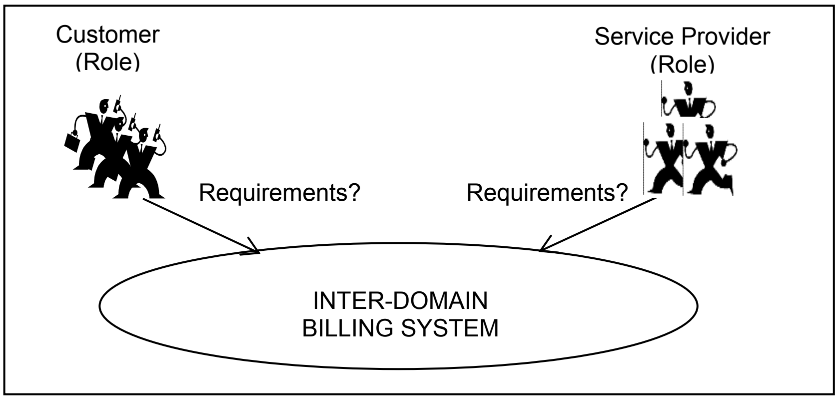


Figure 3.5. Boundary of the Inter-domain Billing System

For each of the two groups of roles, we systematically follow the SSLC and the SACLC to specify the requirements. Within each individual phase of these life cycles, we have a set of requirements as given in Table 3.3. Moreover, the requirements specified within each phase of both life cycles are guided by the eTOM business processes, which have been identified in Table 3.1 and 3.2. In other words, the billing system is required to fulfill a set of requirements that directly relates to the eTOM business processes.

3.4.4 Functional Requirements

The functional requirements specify the functionalities of the Inter-domain Billing System, which are essential to support the dynamic provisioning of composite services. This section provides a list of functional requirements that we consider in the design to address these billing problems.

Inter-domain Billing

- FR1 – *The billing system must be capable to verify the balances of all customers and offer this as a service to the provisioning system.*
  - This requirement is specified from the perspective of the customers. The fulfillment of this requirement enables the customers to obtain services from different service providers.
- FR2 – *The billing system must support the exchange of billing related information between different domains of the service providers. The billing related information concerns service composition information, usage- and charge records.*
  - This requirement is specified from the perspective of the service providers. The fulfillment of this requirement enables inter-domain exchange of billing related information.

Service Composition Information

- FR3 – *The billing system must be capable to correlate and to merge the charges belonging to the composite service provided by the various service providers.*
  - This requirement is specified from the perspective of the service providers. The fulfillment of this requirement enables the correlation of different charge records of a service session, so that the total charge of the service session can be determined.

Interim Accounting and Charging

- FR4 – *The billing system must be capable to present and to update incurred service session charges of the service session currently in progress.*
  - This requirement is specified from the perspective of the customer. The fulfillment of this requirement provides the customer with information about the service session charges in progress.
- FR5 – *The billing system must be capable to present to each customer an overview of incurred service session charges of the recently terminated service sessions.*
  - This requirement is specified from the perspective of the customer. The fulfillment of this requirement provides the

customers with information about service session charge of the requested and terminated service sessions.

- FR6 – *The billing system must be capable to present an overview of current customer balance.*
  - This requirement is specified from the perspective of the customer. The fulfillment of this requirement provides the customers with information about their current balance.

- FR7 – *It must be possible to set and to adjust in the billing system the granularity of incurred service session charge increments at run time.*
  - This requirement is specified from the perspective of the service provider. The fulfillment of this requirement enables service providers to control possible financial risks. The setting of the granularity may be time-based or charge-based increments, a combination of both, or some other policies.

- FR8 – *The billing system must inform the provisioning system whenever the customer's balance has exceeded a maximum or minimum threshold and whenever a service session charge has reached a certain limit.*
  - This requirement is specified from the perspective of the customers as well as the service providers. The fulfillment of this requirements enables the financial control of service providers over the provisioning of services at the same time it is a means for the customers to control service expenses.

3.4.5 Data Requirements

The data requirements concern the information needed for the billing processes. The key aspect of data requirements is the service composition information, which is essential for billing of composite services to correlate different charge records to a service. Next to the service composition, the billing system also needs other ingredients like resource usage information, charge information, customers' IDs, service providers' IDs, information about the credit balance and other billing related information. In the following, we specify the data requirements considered in the design of the proposed billing system.

Inter-domain Billing

- DR1 – *Customer – The billing system must store the information that represents real world customers.*
  - This requirement is specified from the perspective of the service providers. The fulfillment of this requirement enables the identification of customers.

- DR2 – *Service Provider – The billing system must store the information that represents real world service providers.*

    - This requirement is specified from the perspective of the service providers. The fulfillment of this requirement enables the identification of service providers and third-party business partners such as payment service providers.

- DR3 – *Balances – The billing system must store the information about the balance of a customer. Each balance is associated with a representation of a real world customer.*
    - This requirement is specified from the perspective of the service providers. The fulfillment of this requirement enables the relation between a representation of a customer and the corresponding balance so that service charges can be claimed.

Service Composition Information

- DR4 – *Service Session – The billing system must store the information that represents service sessions. Service sessions are representations of the "product" typically provided by one or more service providers to a single customer who requested that particular service session.*
    - This requirement is specified from the perspective of the service providers. The fulfillment of this requirement enables usage based billing, coupled to a particular service session.

Interim Accounting and Charging

- DR5 – *Service Session Charge – The billing system must store the information about the charges of a service session to be paid by the customer who requested the service session and to be received by the service providers who took the responsibility for provisioning that service session.*
    - This requirement is specified from the perspective of the customer as well as the service providers. The fulfillment of this requirement makes it possible to capture charge induced so far for a service session in progress and the total service session charge of a finished service session.

- DR6 – *Resource Usage Charge – The billing system must store the information about a resource charge.*
    - This requirement is specified from the perspective of the service providers. The fulfillment of this requirement enables the projection of an identifiable real world resource to a corresponding charge. The service session charges may be derived directly from the resource usage.

3.4.6 Quality Requirements

The quality requirements concerns three major categories: *Operation* (e.g. security, correctness, reliability, usability, performance), *Revision* (e.g. maintainability, testability, flexibility) and *Transition* (e.g. portability, interoperability, reusability, install ability) [Lauesen02]. Since we focus on the high-level functional design (see §1.5), most of these aspects go beyond the scope of the thesis. Nonetheless, we recognize the importance of quality requirements regarding the *performance* aspect of billing. Such requirements refer to the timeliness of the generation and processing of usage and the charge records depending on the granularity of the charge increments corresponding to an incurred service session. The mechanism to adjust the granularity of the charge increments is a means for a service provider to control their financial risks.

In this thesis, we aim at the design of a high-level billing system, which serves as the first step towards the realization of operational billing systems in the real world. We do not specify any quality requirements in terms of absolute performance parameters.

3.5 Conclusion

In this chapter, we have discussed the two main ingredients of the design of our proposed billing system: a suitable design methodology and the set of requirements that we will take into account during the design of the Inter-domain Billing System.

The design methodology we have chosen is based on two basic theories: the RM-ODP and the eTOM business process framework. In particular the RM-ODP describes the "what" part: which constituent system elements should be modeled and the relationships between these elements. The eTOM framework provides generic definitions of business processes and a clear categorization of process groupings. In particular the eTOM framework describes the "how" part: how should a coarse-grain model be decomposed into a fine-grain model. It is therefore favorable to be used as a guideline to define business processes in the enterprise viewpoint.

The set of system requirements that we consider in the design of the billing system proposed in this thesis belong to the Domain Aspect. These requirements address the three points of focus of the billing problem of this thesis: *Inter-domain Billing*, *Service Composition Information* and *Interim Accounting and Charging*.

Chapter 4 – Business Context Scope of the Design

The purpose of this chapter is to define a clear boundary for the Inter-domain Billing System to be designed in the following Chapters 5, 6 and 7. The discussion in this chapter is twofold. First, the business context of the telematics market, expressed by the Reference Business Role Model, is discussed. Second, this chapter provides an analysis of the business scenarios that need to be supported by the Inter-domain Billing System.

4.1 Identification of Business Roles

4.1.1 Parties and Roles in a Value Network

The provisioning of composite telematics services requires the participation of multiple parties (i.e. business actors, see also Chapter 1, §1.3). These parties form a value network [Peppard06] in which each of them delivers a sub-service and the integration of all sub-services results in composite services toward the end-users. In the context of telematics market, a *party* is an organization or a person that plays a specific business role. A *business role* is an abstraction of the specific behavior of a *party*. In a value network, a *party* can play one or more business roles at the same time. Figure 4.1 illustrates an example of the relationships between *party*, *business role* and *business relationship* in a generic manner. Strictly speaking, a business relationship between a pair of parties is realized via the business roles that they play.

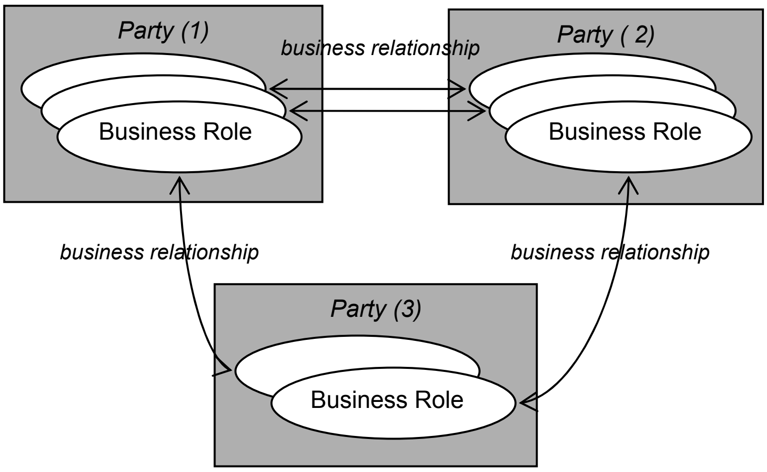


Figure 4.1. Relationships between Party, Business Role and Business Relationship

4.1.2 Reference Business Role Model

A Reference Business Role Model defines the relevant business roles and their relationships within a problem domain. It is used as a starting point to develop systems in order to ensure the business relevance of the developed solutions. In the literature, there is little consensus about the fundamental business roles. The reason is that business roles depend strongly on the domain of interest. For example, TINA distinguishes five fundamental business roles: consumer, broker, retailer, third-party provider and connectivity provider [TINABMR], whereas M3I distinguishes eleven fundamental business roles: end-user, network provider, access provider, backbone provider, server farm provider, content provider, internet retailer, communication service provider, market place provider, network component provider, financial provider and billing service provider [M3ID102]. The eTOM defines eight fundamental business roles: subscriber, end-user, service provider, third party provider, function or process supplier, hardware and software solution vendor, intermediary and complementary provider [TMFeTOM09]. Similar definitions of business roles can be found in [Fowler96].

With regard to our billing domain we need a reference business model that covers all business requirements that has been specified in Chapter 3. To this extent, the Business Relationship Context Models proposed by eTOM is the most suitable due to a number of reasons. First, it is suitable for developing eBusiness and other application areas over telecommunications networks (both telephony and the internet). Telematics services belong to these areas of application. Second, it provides a set of business roles, which is fairly generic to develop a wide range of business/service scenarios. Third, it is broadly being deployed in the telecommunications industry.

The following business roles are relevant for our billing problem domain. These roles are based on the eTOM Business Relationship Context Model, but are tailored to cope with our set of business requirements (see §3.4.1).

- *Subscriber* – The *subscriber* role is responsible for conducting contracts for the services provided by the service provider and the payment of these services.
- *End-user* - The *end-user* role actually makes use of the services delivered by the *service provider* or the *third party provider*.

The *subscriber* and *end-user* role refer to the business requirements BR1 specified in Chapter 3. In a simplest case, these two business roles can be played by a single party. Hence, there exists no business relationship between the *subscriber* and the *end-user* role. For instance, a person can subscribe to a service, pay for it and use the service. However, there can be a case where these above two roles are played by two different parties. For instance, a company (playing the *subscriber* role) can subscribe to a service and an employee (playing the *end-user* role) is allowed to use the subscribed service. In this case, there exists a business relationship between the *subscriber* and the *end-user* role.

- *Service Provider* – On the one hand, the *service provider* role is responsible for maintaining a business relationship with the *subscriber*. It sells services to the *subscriber* and bills the *subscriber* for the service usage. On the other hand, the *service provid*er role is also responsible for composing and delivering services to the *end-user*. The *service provider* can deliver proprietary services to the *subscriber*, or it might use sub-services delivered by *third party provider*(s) to deliver composite services. This business role refers to the business requirements BR2 specified in Chapter 3.
- *Third Party Provider* – The *third party provider* role has a business relationship with the *service provider*. For example, when a *service provider* delivers an eHealth service to the *end-user*, it can engage in a business relationship with a connectivity provider acting as a *third party*

provider. There is no business relationship between the *end-user* and the *third party provider*. This business role refers to the business requirement BR3 specified in Chapter 3.

Figure 4.3 shows the Reference Business Role Model with the relevant business roles and their relationships.

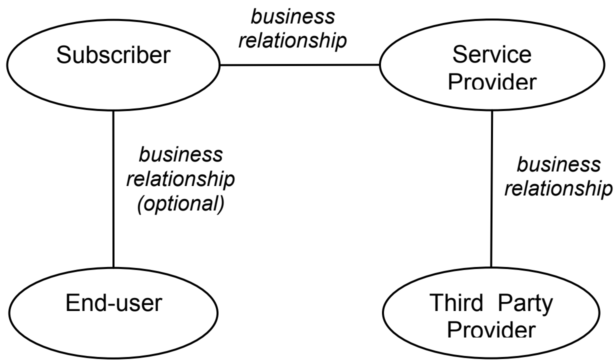


Figure 4.3. The Reference Business Role Model

4.1.3 Convention for Modeling Business Scenarios

The Reference Business Role Model lays a basis for the modeling of business scenarios. A business scenario is an instance of the Reference Business Role Model, which can expressed by graphical representation. A graph represents the parties involved in the service scenario, the business roles these parties play and the relationships between business roles. At the business level, the types of relationships considered relevant are:

- *Contract relationship* (or Service Level Agreement) expresses the formal, negotiated and agreed contract between parties (via the roles they play) defining the terms and conditions for the delivery of specified service(s). It is assumed that a *contract relationship* specifies the service, to whom the service will be provided and the payment relationship.
- *Payment relationship*: this relationship expresses the payment (either prepaid or postpaid) for the service usage.
- *Usage relationship*: this relationship expresses the usage of a service (or services) as defined by the contract relationship.

The above convention considers a business relationship as a trichotomy of *contract*, *usage* and *payment* relationships. By means of this trichotomy, it becomes possible to define realistic, complex value networks in which more than two parties (via the business roles they play) are involved. The various graphical symbols used for the design of a value network are listed in Table 4.1.

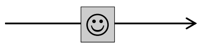
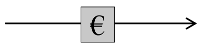
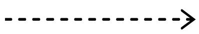
“party name”	*Party*
“business role”	*business role*
	*contract relationship* (the documented contract, i.e. SLA). The dot signifies the *subscriber* role in the contract, the diamond signifies the *service provider* role in the contract.
	*usage relationship* (the happy service user). The arrow-head signifies the receiver of the service (hence it can be read as: the service is delivered to)
	*payment relationship* (the flow of money). The arrow-head signifies the receiver of the money (hence this relationship can be read as: the payment is done to)
	*relationship dependency* The arrow-head signifies the “dependee”.

Table 4.1. Symbols Used for the Modeling of Business Scenarios

In the following, we apply the above convention to model various business scenarios. The business scenarios presented may reflect only fragments of yet even more complex value networks. However, using these examples, the general idea should become clear.

4.2 Analysis of Business Scenarios

In this section we analyze different business scenarios derived from the Reference Business Role Model in order to highlight the billing issues stated in Chapter 1. The analysis of the selected business scenarios provided in this section leads to a well-defined boundary and scope of the Inter-domain Billing

System. The business scenarios illustrated in this section are specific, but the solution the Inter-domain Billing System offers is generic. By generic we mean the ability to support billing for all business scenarios that are derived from the Reference Business Role Model.

The business scenarios assume that both *service provider* and *third party provider* are responsible for their own FAB processes, namely: *Fulfillment*, *Assurance* and *Billing & Revenue Management* (see also Chapter 3).

4.2.1 Business Scenario 1 – Single-domain Billing

The simplest business scenario is the traditional business setting where we have, say, individual *Jim* in the role of *subscriber* and *end-user* and an organization *AccessCo* in the role of *service provider*. There exists three relationships between the *business roles* fulfilled by these two *parties*. The detailed model is shown in Figure 4.4. The entities of this scenario can be mapped to the *roles* of the Reference Business Role Model as follow:

- *Jim* plays the *subscriber* role, where the *subscriber* is involved in a *contract relationship* and a *payment relationship* with the *service provider*
- *Jim* plays the *end-user* role, where the *end-user* is involved in an *usage relationship* with the *service provider*
- *AccessCo* plays the *service provider* role. It is responsible for the fulfillment of the services to the *end-user* accordingly to the SLA (defined by the *contract relationship*). *AccessCo* it is also responsible for the billing corresponding to the service usage used by *Jim*.

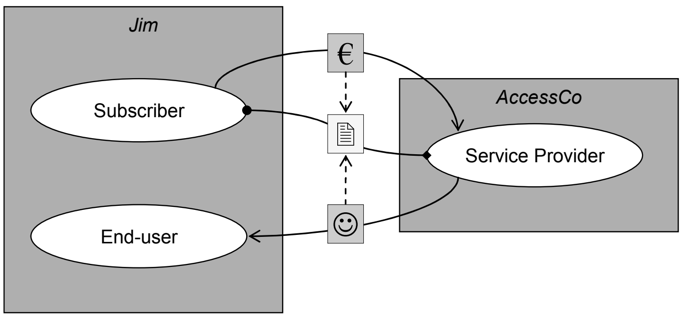


Figure 4.4. Business Scenario 1 – Single-domain Billing

This business scenario is the common case in current telematics market. As long as *Jim* stays in the area of coverage (i.e. no roaming), *AccessCo* only needs to deal with billing within its domain. Here, the billing process is concerned with primitive (i.e. simple) services such as e.g. VoIP, SMS or MMS service.

4.2.2 Business Scenario 2 – Inter-domain Billing

A more complex business scenario compared to the previous simple scenario is the video streaming service of §1.4.5, which involves inter-domain billing issues. As depicted in Figure 4.5, *Jim* is again in the role of *subscriber* and *end-user* of a video streaming service provided by *BrokerCo*. *BrokerCo* is an organization in the role of *service provider* that provides video streaming services. In order to deliver its services to *Jim*, *BrokerCo* has made arrangements with *ContentCo* and *ConnectCo*. *ContentCo* is an organization in the role of *third party provider* that provides digital movies and *ConnectCo* is an organization in the role of *third party provider* that provides connectivity services (e.g. wireless/wired broadband services). The arrangement made between *BrokerCo* and *ConnectCo* enables the streaming of digital movies from *ContentCo* to *Jim*. The entities of this scenario can be mapped to the *roles* of the Reference Business Role Model as follow:

- *Jim* plays the *subscriber* role, where the *subscriber* is involved in a *contract relationship* and a *payment relationship* with the *service provider*.
- *Jim* plays the *end-user* role, where the *end-user* is involved in an *usage relationship* with the *third party providers*
- *BrokerCo* plays the *service provider* role. It is responsible for the fulfillment and billing of the video streaming service used by *Jim* accordingly to the SLA. Further, *BrokerCo* is also involved in a *contract relationship* and a *payment relationship* with *ContentCo* and *ConnectCo*, respectively.
- *ContentCo* plays the *third party provider* role. *ContentCo* is involved in a *contract relationship* with *BrokerCo*. It is responsible for the fulfillment and billing of the content service usage. In turn, it gets paid from *BrokerCo*. Technically speaking, the digital movie is being streamed from *ContentCo* to *Jim*.
- *ConnectCo* plays the *third party provider* role. *ConnectCo* is involved in a *contract relationship* with *BrokerCo*. It is responsible for the fulfillment and billing of the connectivity service usage. In turn, it gets paid from *BrokerCo*. Technically speaking, the connectivity service is delivered from *ContentCo* to *Jim*.

This business scenario involves inter-domain billing issues because it deals with the interaction between organizations. Here, *BrokerCo* plays a center role in composing services for the *end-user* and in billing the *subscriber* for the service usage. On the one hand, *BrokerCo* needs to generate the service composition information of a particular (video streaming) service. That is, from which sub-services a video streaming service is made of. On the other hand, it needs to handle billing related information. For instance, charge records coming from *ContentCo* and *ConnectCo* and charge records related to the brokerage service need to be correlated and aggregated to determine the charge of the video streaming service.

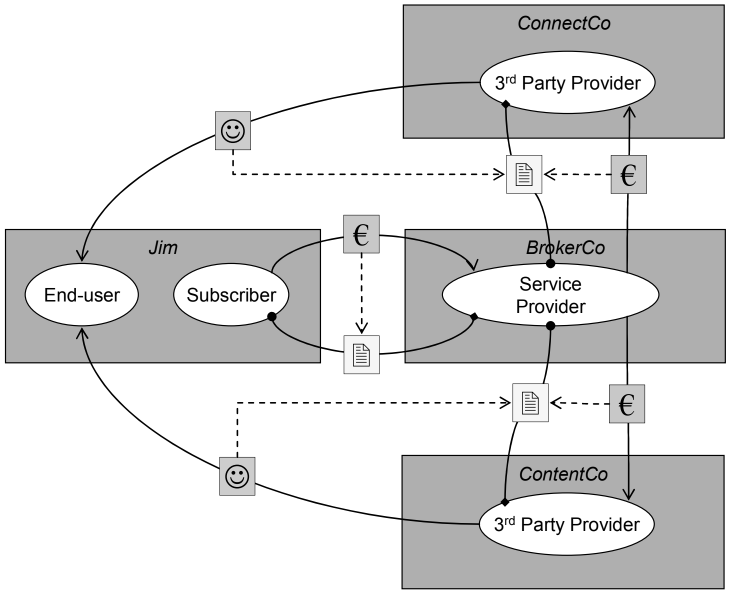


Figure 4.5. Scenario 2 – Inter-domain Billing

4.2.3 Business Scenario 3 – Complex Inter-domain Billing

This business scenario addresses billing issues involved with user mobility. The patient *Sue* is in this case a "mobile" user, who occasionally gets eHealth services from eHealth centers. With "mobile" we mean that the patient can requests medical services from different eHealth centers depending on the patient's need. The patient is not bound to a single eHealth center. This scenario assumes that the patient has acquired an insurance policy at an insurance company called *InsuranceCo* and that *InsuranceCo* pays for all eHealth services used by the patient. *InsuranceCo* has arrangements with a number of eHealth centers and *eHealthCo* belongs to one of these eHealth centers. In turn, *eHealthCo* has an arrangement with a wireless connectivity provider called *MobileCo*, which ensures the communication between *eHealthCo* and the patient. Figure 4.6 depicts the entities involved in the eHealth scenario, which can be mapped into the *roles* of the Reference Business Role Model as follows:

- The patient *Sue* plays the *end-user* role. *Sue* is involved in a *contract relationship* and a *payment relationship* with the insurance company *InsuranceCo*. Therefore, Sue is obliged to pay for the chosen polis. Further, *Sue* is also involved in a usage relationship with *eHealthCo*.
- *InsuranceCo* plays the *subscriber* role. *InsuranceCo* is involved in a *contract relationship* and *payment relationship* with the eHealth center *eHealthCo*. It is therefore obliged to pay *eHealthCo* for services used by the patient. The *contract relationship* between InsucranceCo and *eHealthCo* ensures the patient to get eHealth services from a number of eHealth centers. *InsuranceCo* is responsible for the fulfillment of insurance services that covers all medical services the patient uses, including eHealth services.
- *eHealthCo* plays the *service provider* role. *eHealthCo* is involved in a *contract relationship* and a *payment relationship* with the wireless connectivity provider *MobileCo*. Therefore, it obliged to pay *MobileCo* for the connectivity service the patient uses in the composition of the eHealth service.
- *MobileCo* plays the *third party provider* role. *MobileCo* is involved in an *usage relationship* with the patient. It is responsible for the fulfillment and billing of the connectivity service provided to the patient.

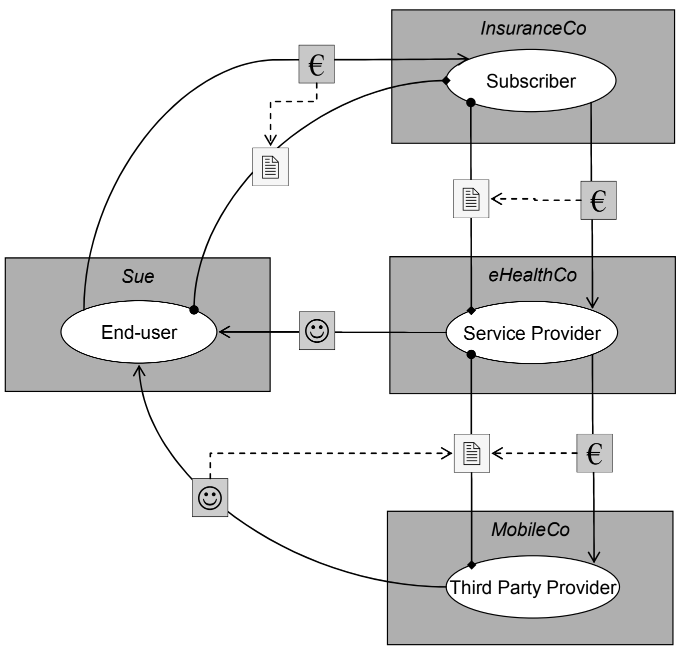


Figure 4.6. Scenario 3 – Inter-domain Billing with User Mobility

The main difference between this business scenario and the previous one is that an organization (i.e. *InsuranceCo*) pays another organization (i.e. *eHealthCo*) on behalf of its *end-user* (i.e *Sue*) for the service usage. Concerning the billing related to the provided eHealth service, *eHealthCo* is dealing with billing of a composite service, consisting of a sub-service provided by *eHealthCo* and a sub-service provided by *MobileCo*. Therefore, *MobileCo* is required to send charge records to *eHealthCo*, such that correlation and aggregation of charges can be done. Another important issue is the service authorization. Since the patient does not play the *subscriber role*, the authorization process takes place between *eHealthCo* and *InsuranceCo*. The provisioning of eHealth service to the patient is only possible if the result of authorization is positive.

4.3 Definition of the Design Scope

This thesis focuses on an inter-domain billing system from the perspective of the *service provider*. This implies that the *service provider* is responsible for the service fulfillment to the end-user and billing to the corresponding *subscriber*. The proposed Inter-domain Billing System copes with the following business context:

- The *subscriber* subscribes to a *service provider* that has a *contract relationship* and a *payment relationship* with the *service provider*.
- The *subscriber* pays the *service provider* for all services used by the *user*.
- The *service provider* delivers composite services consisting of one or more sub-services.
- The *service provider* has a contract relationship and a payment relationship with one or more *third party providers*.
- The sub-services are delivered by one or more *third party providers*.

The eTOM *Assurance* process group will be left out in further discussion because it goes beyond the scope of our work. Nonetheless, we recognize the importance of the *Assurance* process which certainly influences the *Fulfillment* and *Billing & Revenue Management* process. For instance, the eTOM sub-process *resource performance management*, which is a level 2 *Assurance* process, gathers performance information of the service provisioning. This information can be used to verify whether the service delivery has happened according to the QoS defined in a SLA. If a service provider does not met its obligations, a discount may apply for the service delivered.

4.4 Conclusion

In this chapter the Reference Business Role Model is defined, which serves in the next chapter as the basis to model the Inter-domain Billing System. In order to illustrate the relevant inter-domain billing issues of this thesis three business scenarios within the business context of this reference model are described.

The scope of the Inter-domain Billing System is limited to the billing process of the *service provider* providing composite services to the *end-users*. Finally, it is shown that the inter-domain billing issues are related to the provisioning of sub-services from one or more *third party providers*. As a consequence the exchange of billing related information between service providers and the *third party provider*(s) is necessary.

Chapter 5 – Enterprise Viewpoint of the Inter-domain Telematics System

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This chapter presents the design of the inter-domain telematics system from the enterprise perspective. It defines at the highest level of abstraction the proposed inter-domain telematics system and the surrounding entities such as human actors, organizations. The relationships between the inter-domain telematics system and these entities are also discussed. This enterprise perspective lays the basis for further design of the inter-domain telematics system in the other perspectives, i.e. the information viewpoint and the computational viewpoint, which are discussed respectively in the next Chapter 6 and 7. This chapter provides answers to research questions Q1, Q2 and Q4.

5.1 Introduction

In the context of this thesis, billing is seen from the perspective of the service provider, whose responsibility is to deliver composite telematics services to end-users and to bill subscribers accordingly. The delivery of composite services, however, involves various participants like people, companies and (computerized) supporting systems (i.e. inter-domain telematics system). We call the collection of all relevant entities: the *inter-domain telematics community*. The existence of the *inter-domain telematics community* is justified by its objective, that is to provision and to bill the usage of (composite) telematics services and to keep track of user credit/debit balance during service provisioning [Le04, Le08a].

This chapter presents the design of an *inter-domain telematics system* and the surrounding entities. The collection of entities presented here is a simplification of the real world. However, it consists of entities that are relevant to the scope of this thesis (see §4.4).

5.2 Inter-domain Telematics Community

The *inter-domain telematics community* comprises enterprise objects. These objects can play one or more enterprise roles. In this section, objects and roles and their relationships relevant for the community are identified, described and modeled.

5.2.1 Relevant Entities

According to the description of the Inter-domain Billing System boundary (see §3.4.3) and based on the Reference Business Role Model (see §4.1.2), the following entities which the *inter-domain telematics community* encompasses:

- `Person` – The `Person` represents a human being who interacts with computerized systems. For example, a human being can interact with a mobile device to receive and read some medical instruction. Furthermore, a human being may be held responsible for paying for service usage. We note that the person who uses the service is not necessarily the person who is responsible for payment.
- `Organization` – The `Organization` represents a legal business entity, which is responsible for the service provisioning or/and the corresponding billing. In some cases, a legal business entity may be responsible for the payment of service consumed by a person. For instance, a company may pay for services its employees consume.
- `Inter-domain Telematics System` – The `Inter-domain Telematics System` represents a computerized information system, which supports the provisioning and billing of telematics services.

Figure 5.1 depicts the `Inter-domain Telematics Community`, which comprises zero or more `Person(s)`, one or more `Organization`(s) and one `Inter-domain Telematics System`. `Person` and

Organization are indicated as <<EV_Party>>, which is a special kind of enterprise object (indicated as <<EV_Object>>).

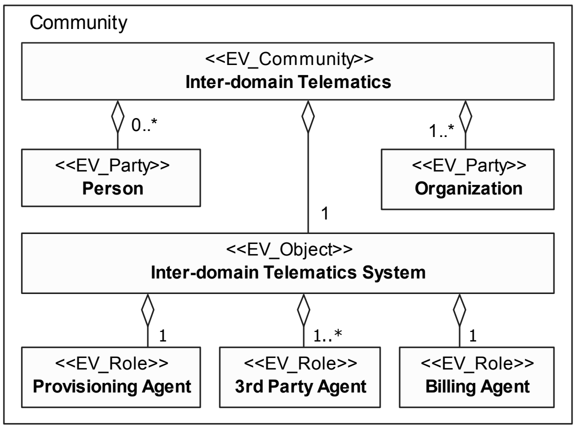

Figure 5.1. Inter-domain Telematics Community

5.2.2 Enterprise Roles Assignment

The main purpose of role assignment is to describe the relationships between an organization, a system and some particular business role. For example, an organization, e.g. a large telecommunication company can play the business role of service provider. The relationships between parties and roles can be expressed in terms of role assignment. The party model is shown in Figure 5.2.

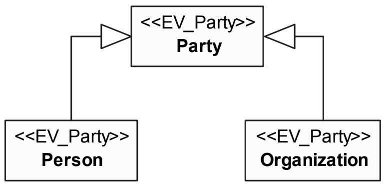

Figure 5.2. Party Model

Parties refer to legal entities that interact directly or indirectly with the Inter-domain Telematics System. Parties exhibit behavior through the party roles they fulfill. The relationship between a Party and Party Role is specified by the PartyPlaysPartyRole association. It must be noted that additional restrictions apply but are not shown in the above figure. Two examples of these additional rules are:

- A Party cannot fulfill the role of Subscriber and Service Provider at the same time in a service contract.

- A Service Provider cannot fulfill the role of Service Provider and 3rd Party Provider at the same time in a partner service contract or partner service usage.

In order to fulfill this role, this organization can make use of an automatic (provisioning) system. The next enterprise roles are identified as relevant within the design scope:

- End-user – The End-user is responsible for requesting and using the service.
- Subscriber – The Subscriber is obliged to pay the Service Provider for the service delivered to the End-user. The Subscriber can be fulfilled by a Person or an Organization.
- Service Provider – The Service Provider is responsible for the fulfillment of services to the End-user and the corresponding billing of the Subscriber. The Service Provider may have a business relationship with the 3rd Party Provider. Hence, it is obliged to pay the 3rd Party Provider for the usage of sub-services.
- 3rd Party Provider – The 3rd Party Provider enterprise role provides sub-services to and receives payments from the Service Provider.

The roles assignment for an Organization seen from the perspective of the service provider is shown in Figure 5.3. An organization may fulfill a combination of roles, namely: Service Provider, 3rd Party Provider, Subscriber. Similar to the role assignment for an organization, a natural person can fulfill the roles Subscriber and End-user. Figure 5.3 also shows the roles assignment for a Person.

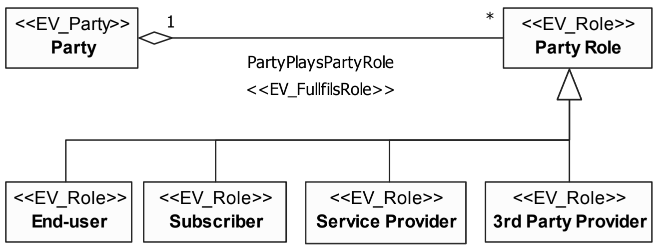

Figure 5.3. Roles Assignment for Organization and Person

5.2.3 System and System Agent

The second group of enterprise objects we introduce specifies systems (i.e. a computerized system) that can perform tasks. The main idea of this enterprise object is to represent those systems that interact with each other within the `Inter-domain Telematics Community`. We do not give an elaborate discourse on the object `System`. Relative to the Share Information/Data (SID) model [TMFGB922] we consider a `System` to be some physical (i.e. tangible) resource that can communicate with other physical resources. For the purpose of illustration, Figure 5.4 includes a non-exhaustive refinement of `System`.

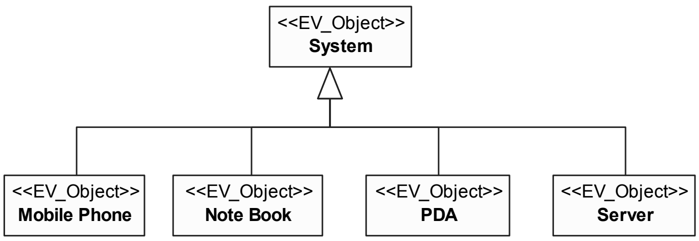

Figure 5.4. A Simple System Hierarchy

Systems interact indirectly via the roles these systems fulfill. A role that can be fulfilled by a `System` is called a `System Agent`. The following system roles are introduced:

- `System Agent` - An abstract enterprise role, from which concrete system roles can be derived.
- `End-user Agent` - A `System` in this role can mediate between an `End-user` and the `Provisioning System`. That is, it can request, modify and terminate services on behalf of the `End-user`.
- `Subscriber Agent` - A `System` fulfilling this role can mediate between a `Subscriber` and a `Billing Agent`.
- `Provisioning Agent` - A `System` in this role can deliver services to an `End-user Agent`. This service may be a composite service, incorporating services from partners.
- `Billing Agent` - A `System` in this role is responsible for the accounting, charging and billing of (composite) services delivered to an `End-user Agent` or services acquired from a 3rd `Party Agent`. In addition it provides support to the `Provisioning Agent` for granting services requested by an `End-user Agent`.

- 3rd Party Agent – A System fulfilling this role can deliver services to a Provisioning Agent for the purpose of delivering (composite) services to an End-User Agent. In addition, it can interact with the Billing Agent to support the accounting and charging of such services.

The role hierarchy and their relationship with System are shown in Figure 5.5. Here also additional restrictions on the role assignment apply. For instance: in the context of a particular (composite) service, a Provisioning Agent and a Subscriber Agent may not be assigned to the same System. A similar constraints hold for the 3rd Party Agent and Billing Agent and for the Provisioning Agent and 3rd Party Agent. These constraints are specified as OCL (Object Constraint Language) constraints [Giese04] in the enterprise specification.

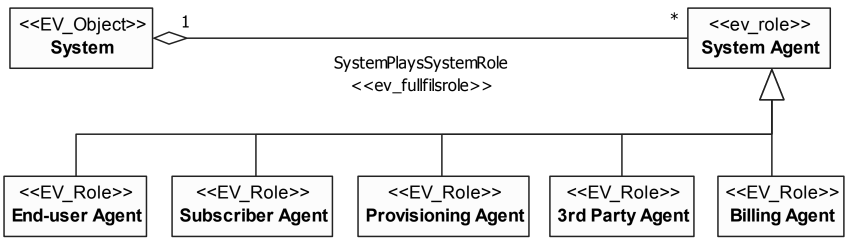

Figure 5.5. Roles Assignment for Agents

5.2.4 Role Delegation

From the specification of the roles it follows that no role has been introduced that unifies those of End-user and Subscriber. In our model, usage of a service is delegated to the End-user role by the Subscriber role. In addition, End-user and Subscriber do not directly interact with the Provisioning Agent and Billing Agent respectively. These interactions are facilitated by the End-user Agent and Subscriber Agent roles. This capability is modeled as delegation form respective party roles to system roles. The delegation model is shown in Figure 5.6. In a similar way, the Service Provider and 3rd Party Provider responsibilities are delegated to their agent role counterparts as shown in Figure 5.7.

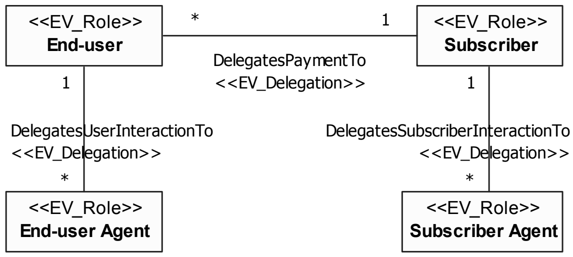

Figure 5.6. Delegation Relationship between Subscriber, End-user and their Agents

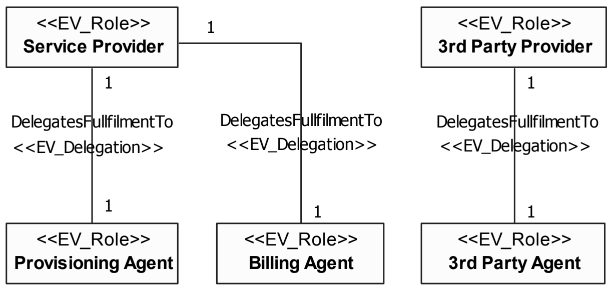

Figure 5.7. Delegation Relationship between Service Provider, 3rd Party Provider and their Agents

What is not discussed in the above roles assignment models are the billing relationship between the Service Provider and the End-user/Subscriber on the one hand and the relationship between the Service Provider and the 3rd Party Provider on the other hand. Regarding to the former relationship (i.e. service delivery), we have the Service Provider that "gives" services to the End-user and "takes" payments from the Subscriber that is associated with the End-user. When looking at the later relationship (service acquisition), we have the Service Provider that "takes" services from and "gives" payments to the 3rd Party Provider. Hence, there is a *give* and *take* duality for each of these relationships which constitute the corner stone for billing models. This duality relationship has been also been proposed in the by the Resource-Event-Agent (REA) framework by McCarthy [McCarthy82] to define the semantics of accounting information for physical goods. Recently, van Beijnum [Beijnum05] has also proposed to apply McCrathy's approach to accounting information for telematics services. In the next section, we will address the billing relationships between the enterprise objects and enterprise roles.

5.3 Inter-Domain Billing

In the previous section relevant entities and their roles have been identified. Also, the relationships regarding to roles assignment and role delegation have been defined. In this section we address the relationships between entities and role from the billing perspective. We present two billing specifications that constitute the end-to-end billing within the `Inter-domain Telematics Community`. The first specification is the "subscriber-facing billing", which deals with the billing between the `Subscriber` and the `Service Provider`. The second specification is the "partner-facing billing", which deals with the billing between the `Service Provider` and the `3rd Party Provider`.

5.3.2 Subscriber-facing Billing

The simplest billing case is illustrated in Business Scenario 1 of Chapter 4, where *Jim* (in the role of `End-user` and `Subscriber`) receives and pays for a requested service from *AccessCo* (in the role of `Service Provider` and `Billing Provider`). We use this business scenario to explain the relationships between the entities involved in the corresponding subscriber/provider billing. Although this business scenario is simple, the corresponding billing model explained here is the fundament and generic to support most subscriber/provider telematics service provisioning. Figure 5.8 depicts the subscriber-facing billing model.

- `Service Usage` – The `Service Usage` represents the service used by the `End-user Agent`. The `Service Usage` is an "information object" used as evidence to proof the subscriber service consumption.
- `Service Payment` – The `Service Payment` represents the total amount of charge (corresponding to the `Service Usage`) given by the `Subscriber` to the `Service Provider`. For example, in case of prepaid this would means that an amount of x Euro is taken from the subscriber account and is added to the service provider's account.
- `End-user-facing Service` – The `End-user-facing Service` represents the (composite) services provided by the `Provisioning Agent` to the `End-user Agent`. Examples of such services are: eHealth service, video streaming service, multimedia conference service, etc.

- Provider Cash – The Provider Cash represents the total amount of revenue of the Service Provider, generated by services provided to the End-user.

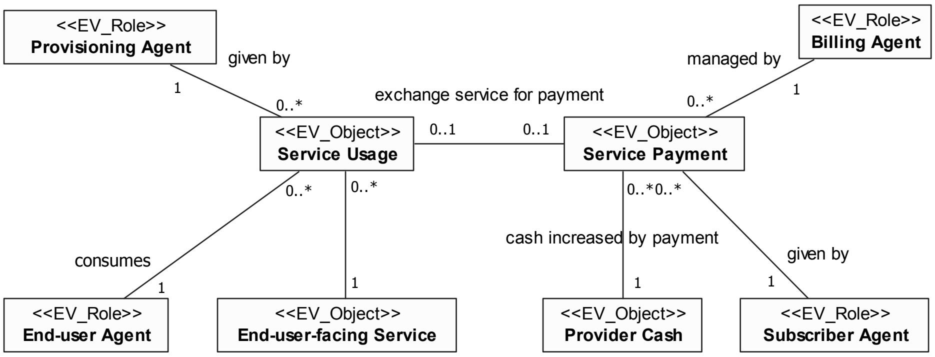

Figure 5.8. Subscriber-facing Billing

On the one hand, when the service is provisioned by the Provisioning Agent to the End-user Agent, there exists a Service Usage. This Service Usage is considered as evidence of the service provided to the End-user Agent. The Service Usage exists by providing internal End-user-facing Service (i.e. resource). In order for an "economic event" to occur (i.e. an event which can be captured and charged), resources are required. These resources are represented by End-user-facing Service.

On the other hand, the Subscriber Agent is responsible (given by) for the payment of the service usage used by the End-user Agent; whereas the Billing Agent is responsible for the billing.

Finally, the Service Payment is involved with monetary resources, which are presented by the Provider Cash. This implies that whenever a Service Payment takes place, the total amount of monetary resources of the Service Provider must increase. The duality relationship of the subscriber-facing billing model is represented by the relationship between the Service Usage and its "mirror-image" the Service Payment.

5.3.3 Partner-facing Billing

As discussed in Business Scenario 2 of Chapter 4, the service broker (i.e. a special kind of service provider) needs to acquire external services from third party providers (e.g. content provider) in order to deliver the requested customer service. Here, there is a party that uses and pays for the requested service and the other party provisions and receives payment for the provided service. The partner-facing billing model expresses the billing between a requesting service provider (e.g. service broker) and a providing service provider (e.g. content provider), which is shown in Figure 5.9.

- `Partner Service Usage` – The `Partner Service Usage` represents the service used by the `Provisioning Agent`. The `Partner Service Usage` is an "information object" used as evidence to proof the partner service consumption (i.e. usage record).
- `Partner Service Payment` – The `Partner Service Payment` represents the total amount of charge (corresponding to the `Partner Service Usage`) given by the `Service Provider` to the `3rd Party Provider`.
- `Partner-facing Service` – The `Partner-facing Service` represents the services provided by the `3rd Party Agent` to the `Provisioning Agent`. Examples of such services are: video services, music services (mp3), news, etc., which can be combined with a connectivity service (provided by the service provider).

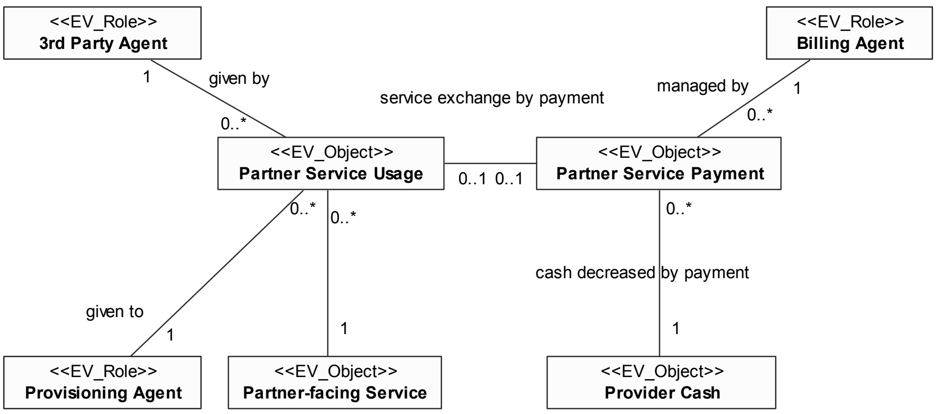

Figure 5.9. Partner-facing Billing

When a service is provisioned by the `3rd Party Agent` to the `Provisioning Agent`, there exists a `Partner Service Usage`. In turn, the `Partner Service Usage` exists by providing `Partner-facing Service`. In order for the "economic event" to occur, resources are required. These resources are modeled by `Partner-facing Service`.

The `Service Provider` is responsible for the payment of the `Partner Service Usage`; whereas the `Billing Agent` is responsible for the partner billing. In turn, the `Partner Service Payment` is involved with monetary resources, which are represented by the `Provider Cash`. Unlike the previous billing model, the `Provider Cash` in this case decreases instead of increases due to financial compensation towards the `3rd Party Provider`.

The duality relationship of the partner-facing billing is modeled by the relationship between the `Partner Service Usage` and the `Partner Service Payment.`

5.3.4 Service Composition

Telematics services often undergo an extensive transformation process in order to arrive at the end-user as a service session (i.e. the final product). For composite services, the service provider sometimes needs to acquire external services from a third party provider to compose the requested service for the end-user. A service session model therefore must express the relationship between the constituent elements in order to reveal the end-to-end value-chain.

The TeleManagement Forum (TM Forum) has been working on the Shared Information/Data (SID) model [TMFGB922], which provides guidelines for the modeling of information/data for the purpose of product design, service construct and service provisioning. Currently, the SID model is widely accepted as standard in the industries [AtosOrigin06]. Among many aspects, the SID model addresses the basic entities: `Product`, `Service`, `End-user-facing Service` and `Provider-facing Service` and their relationships. A `Product` is a particular "item" that the `End-user` can buy. For example, the `End-user` can browse through a list of products (e.g. videos) and pick out a preferred one. A `Service` is part of a `Product`. A `Service` cannot exist by itself, but is bound to a `Product`. The `End-user` can only buy a product, not a service. For example, the `End-user` buys an online video as a product and gets a video streaming as a `Service`. A `Service` represents the service, which is visible to the `End-user`. A `Provider-facing Service` represents the resources which are needed to support the `End-user-facing Service`, which is visible to the `Service Provider` but invisible to the `End-user`.

The separation between the `End-user-facing Service` and `Provider-facing Service` is one of the strengths of the SID model. This separation makes it possible to construct service session compositions which contain detailed information about *how* a service session is built and *what* service components are used in a service session. The *how* and the *what* are expressed by `Provider-facing Service`. What an `End-user` "sees" is the End-user-facing Service, which is transparent and abstracted from detailed business information intended only for the Service Provider.

Figure 5.10 depicts a service composition model. The heart of the service composition is the Service, which consists of an End-user-facing Service and a Provider-facing Service. The End-user-facing Service is linked to Product, which the End-user can choose. The Provider-facing Service consists of one or more Atomic Services, which can be Provider Services (i.e. internal services) or Partner-facing services (i.e. external services) or both. The relationship between the Provider-facing Service and the Atomic Service is a *transformation duality* relationship. Hence, in order to arrive at a Provider-facing Service, the Service Provider needs to compose a service session usage from different service components.

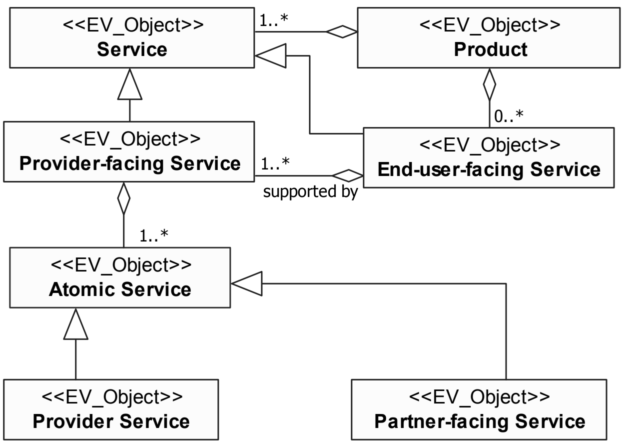

Figure 5.10. Service Composition Model

The above model represents the structure of the service and service session composition. It lays the basis structure for the service session information model, which will be presented in more detail in Chapter 6.

Up to this point, we have defined the relevant entities, roles and their relationships within the Inter-domain Telematics Community. The defined roles and their relationships describe the structural aspect of the community. In the following, we discuss the behavioral aspect of the Inter-domain Telematics Community in terms of processes.

5.4 Inter-domain Telematics Community Behavior

While the `Inter-domain Telematics Community` focuses on the provisioning and billing of service sessions, this section mainly addresses the billing processes that express the behavior of the `Inter-domain Telematics Community` within the boundary of the Service Accounting and Charging Life Cycle (SACLC). According to the definition given in §3.3.3, the SACLC consists of four process flows, namely:

- *Credit Verification* – The objective of this process flow is to verify whether the `Subscriber` credit is sufficient for the consumption of the requested service. Using the Service Composition Information, the `Billing Agent` can determine the expected total charge of the service session and verify this against the `Subscriber` credit balance.
- *Accounting and Charging Instantiation* – The objective of this process flow is to authorize accounting and charging for individual service components that are involved in the service session. As a result, the provisioning of individuals service components can be initiated.
- *Accounting and Charging* – The objective of this process flow is to reauthorize the provisioning of individual service components during the service session usage. As a result, the `Subscriber` credit balance is updated accordingly.
- *Accounting and Charging Termination* – The objective of this process flow is to terminate the accounting and charging process of the service session and to update the `Subscriber` credit balance accordingly.

The description of these processes is conducted in two steps: *First*, each of the above process flows will be presented in terms of relevant eTOM level-3 processes, showing which eTOM processes are involved and under the responsibility of which role. *Second*, each eTOM process flow will be further refined into an (enterprise) process, which shows the behavior of the `Billing Agent` and its interaction with the `Provisioning Agent` and `3`rd `Party Agent`, respectively.

5.4.1 Credit Verification

The purpose of the *Credit Verification* process flow is to verify whether or not the requested service session can be granted to the `End-user`. This process flow assumes a number of pre-conditions, which are listed below.

Pre-conditions

- A Subscriber is known by the Service Provider.
- There exists a unique relationship between an End-user and a Subscriber.
- A Subscriber has a unique account which the Provisioning Agent can identify.
- The service the End-user Agent requests is a composite service, which is composed of a Provider Service and a Partner Service.
- The Provisioning Agent can interact with the 3rd Party Agent to ensure the availability of the requested service.

In order to achieve the stated objective, the Provisioning Agent must conduct the following tasks:

1. Receive the service request from an End-user Agent.
2. Generate Service Composition Information.
3. Ask the Billing Agent to verify the creditworthiness of the associated Subscriber.
4. Let the End-user Agent know if the request is accepted or refused.

There are several reasons for a service refusal. For example: there are no resources available, or the Billing Agent reports that the associated Subscriber is not credit worthy. Here, the "associated" Subscriber is the one who is responsible for the payment of the service usage.

The Billing Agent verifies the credit worthiness of the Subscriber by checking the account of the subscriber. In order to do so, the Billing Agent conducts the following tasks:

1. Determine the charge of the requested composite service based on the received Service Composition Information.
2. Identify the End-user and his associated Subscriber.
3. Verify the creditworthiness of the Subscriber.
4. Provide the Provisioning Agent with the answer regarding credit verification.

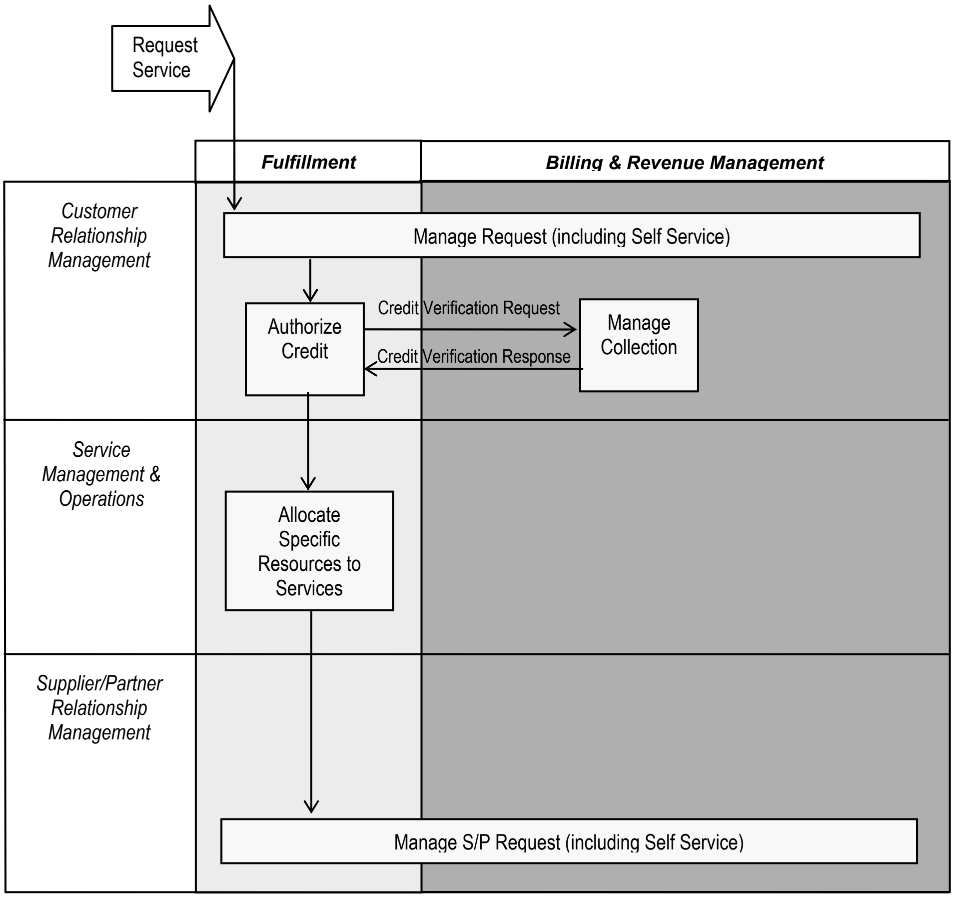

Figure 5.11. Credit Verification Process Flow

Figure 5.11 depicts the *Credit Verification* process flow where five eTOM (level 3) processes are involved: Manage Request, Authorize Credit, Allocate Specific Resources to Services, Manage Collection and Manage S/P Requests.

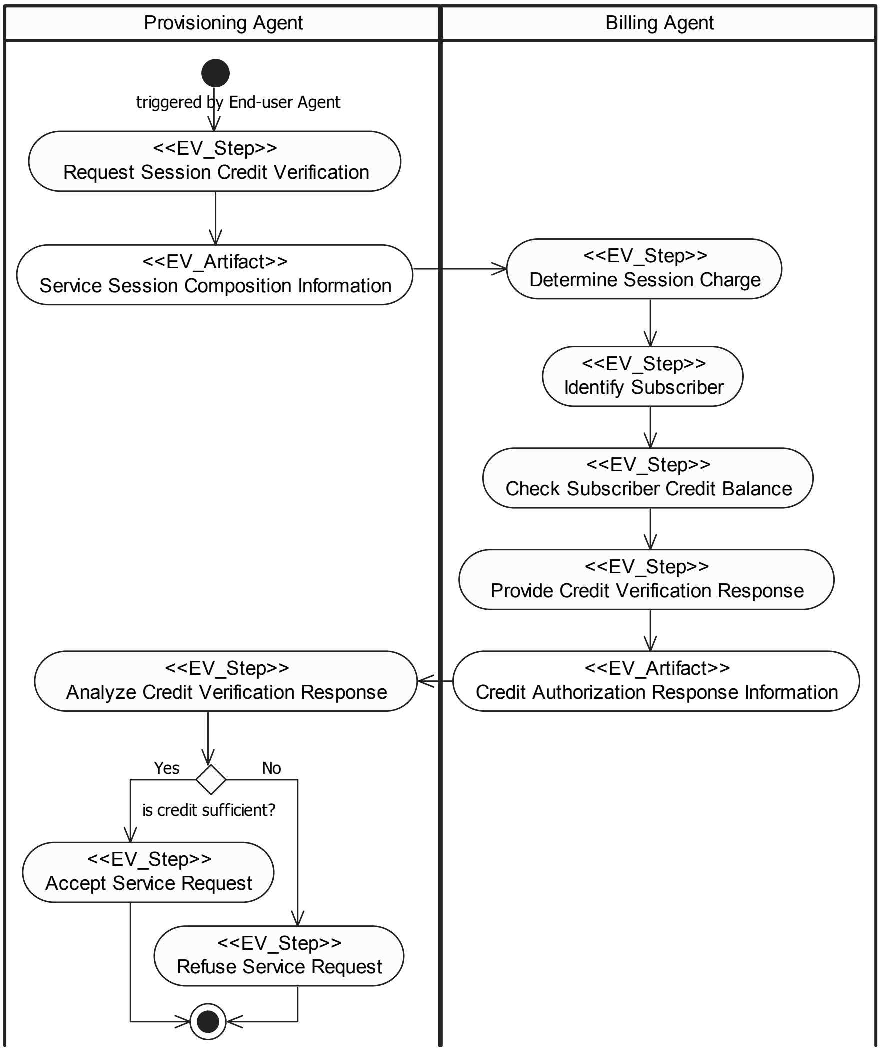

Figure 5.12. Steps in the Credit Verification Process

Figure 5.12 shows the *Credit Verification* process flow in terms of partially ordered *steps*. The behaviors of the `Provisioning Agent` and the `Billing Agent` are represented as two separate process flows with their own starting and ending point. This technique favors the modularity of the process flow, which in turn decreases the complexity of the behavior of the `Billing Agent`. Although the process flow of the `Provisioning Agent` and the `Billing Agent` can act independently, they are loosely coupled due to their interactions. In this process flow, we have omitted the interaction between the `Provisioning Agent` and the 3rd `Party Agent`. At this level of detail, it is acceptable to do so because this process flow focuses on the credit verification, not on the service provisioning.

5.4.2 Accounting and Charging Instantiation

The purpose of the *Accounting and Charging Instantiation* process flow is to authorize the individual service components so that service provisioning of these components can be initiated. This process flow assumes the pre-conditions listed below.

Pre-conditions

- The associated `Subscriber` responsible for the payment of the requested service has been identified.
- The credit balance is sufficient to allow for service session usage.
- The necessary resources are available.

During this process flow, the `Provisioning Agent` needs to conduct the following tasks:

1. Request credit authorization for individual service components.
2. Analyze credit authorization received from the `Billing Agent`.
3. Instantiate service provisioning of the involved service components.

In turn, the `Billing Agent` needs to conduct the following tasks:

1. Identify the corresponding charging session for each service component. This is necessary to ensure that usages records (e.g. credit authorization request messages) are rated appropriately and the charges are mapped to the service composition.
2. Determine the charge for each service component.
3. Create credit reservation (i.e. claim) for each service component.
4. Report the credit authorization to the `Provisioning Agent` that provisioning of the requested service component is allowed.

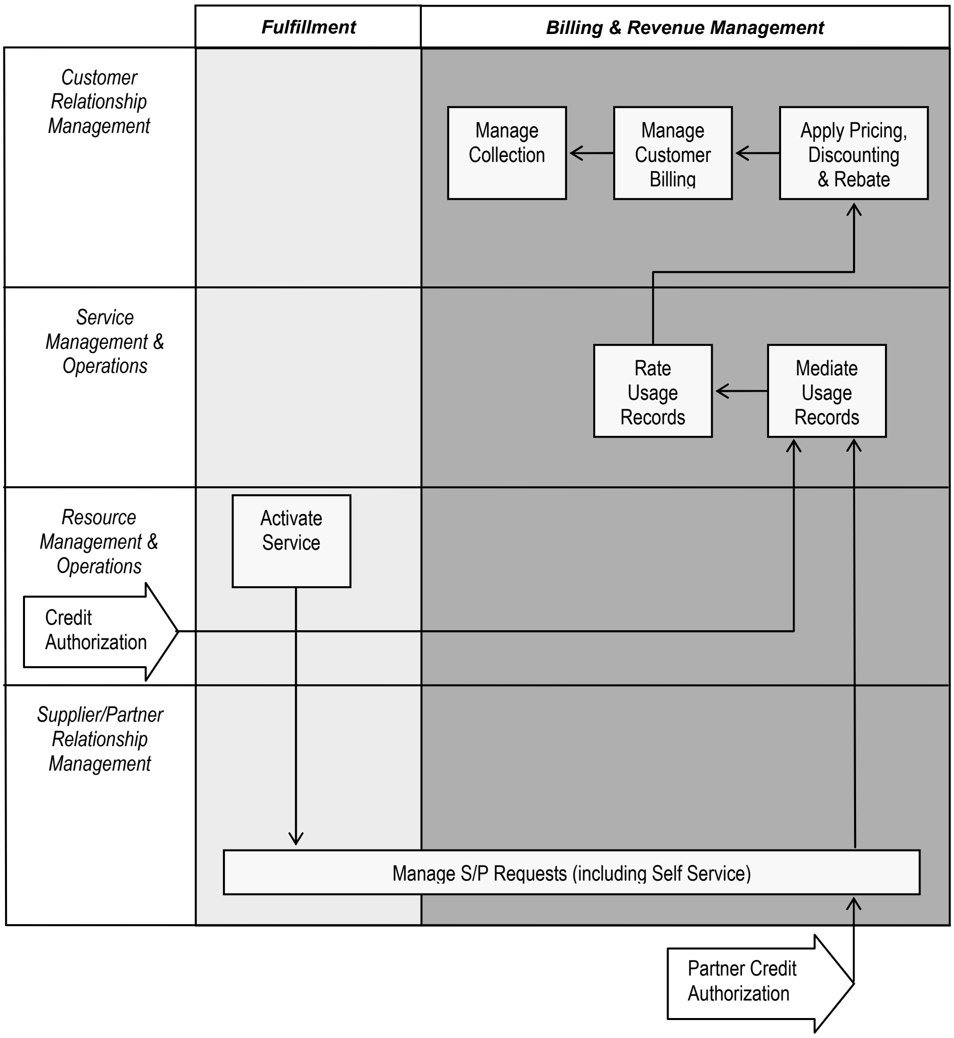

Figure 5.13. Accounting and Charging Instantiation Process flow

Figure 5.13 depicts the *Accounting and Charging Instantiation* process flow where the following four eTOM (level 3) processes are involved: Manage Collection, Manage Customer Billing, Activate Service and Manage S/P Requests.

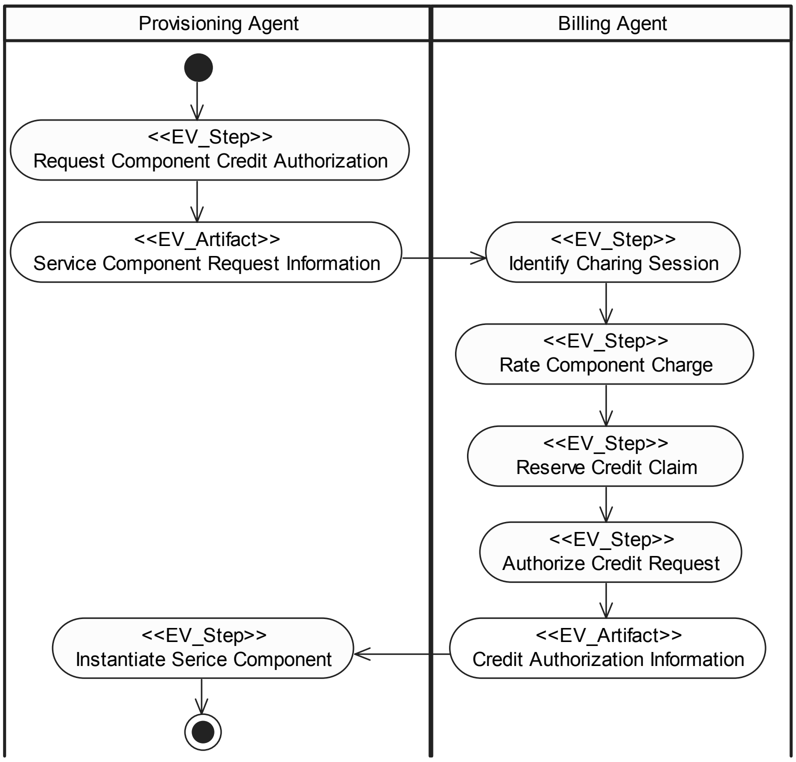

Figure 5.14. Steps in the Accounting and Charging Instantiation Process between Provisioning Agent and Billing Agent

Figure 5.14 shows the *Accounting and Charging Instantiation* process for the `Provisioning Agent` and `Billing Agent` in terms of partially ordered *steps*. The above process shows the interaction between the `Provisioning` and the `Billing Agent`. The same interactions also occur between the `3rd Party Agent` and the `Billing Agent`, which are shown in Figure 5.15.

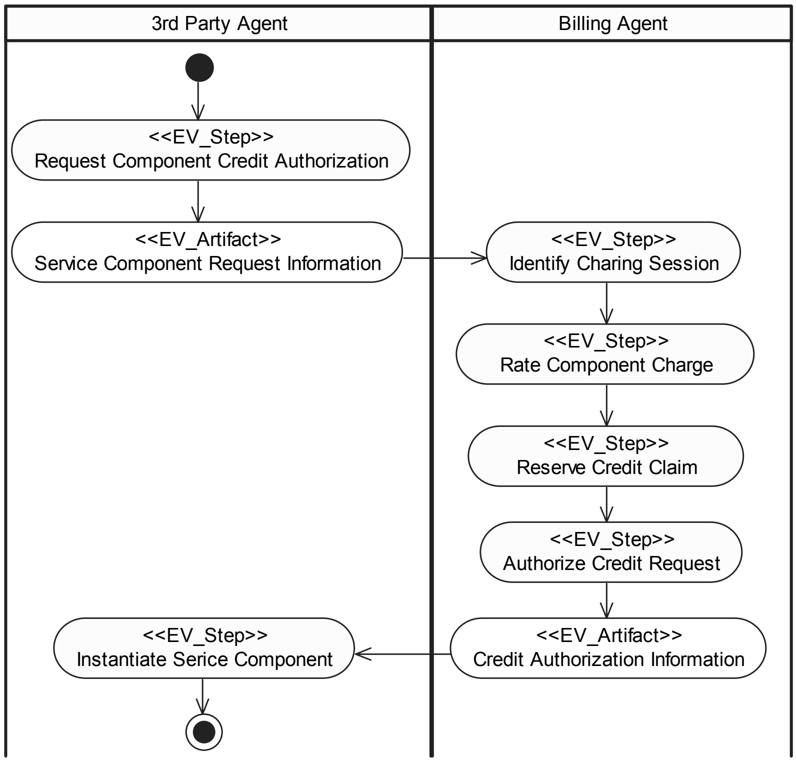

Figure 5.15. Steps in the Accounting and Charging Instantiation Enterprise Process between 3rd Party Agent and Billing Agent

5.4.3 Accounting and Charging

The purpose of the *Accounting and Charging* process flow is to account and charge the service usage and to update the subscriber's credit balance accordingly in real-time. By real-time, we mean during the service session. This process flow assumes the pre-conditions listed below.

Pre-conditions

- The contracts between the `Service Provider` and the `3rd Party Provider` have been signed, which allows for the service provisioning from the `3rd Party Provider` to the `Service Provider`.
- The (interim) usage records generated by the service usage is available from the `Provisioning Agent` and are ready for the `Billing Agent` to mediate.

- The (interim) usage records generated by the service usage is available from the `3rd Party Agent` and are ready for the `Billing Agent` to mediate.
- The requested service component usage is registered in interim usage records, which are generated during the service session with a pre-defined frequency. The frequency to generate interim usage records depends for example on the financial risks that the service provider prefers to avoid. An interim usage record contains the "credit reauthorization request" to proceed with the ongoing service provisioning of a particular service component.

During this process flow, the `Provisioning Agent` needs to conduct the following tasks:

1. Distribute the interim usage records to the `Billing Agent`. This can be done with a push mechanism (by the `Provisioning Agent`) or a pull mechanism (by the `Billing Agent`). The choice for this mechanism will be explained in Chapter 7, which will address the interfaces between the `Provisioning Agent` and the `Billing Agent`.
2. Handle "credit reauthorization" response from the `Billing Agent` whenever this message arrives. Depending on the `End-user's` profile and the associated `Subscriber's` profile, the `Provisioning Agent` can decide to let the service session continue or to terminate it immediately. This is the matter of how much the `Service Provider` can trust the `Subscriber` to pay for the `Service Usage` even though the credit balance has already reached a pre-defined threshold.

In turn, the `Billing Agent` needs to conduct the following tasks:

1. Mediate interim usage records received from the `Provisioning Agent` and the `3rd Party Agent`. The interim usage records need to be matched with the corresponding service session.
2. Rate the usage records according to the tariff agreed with the `Subscriber`.
3. Determine the increment or cumulative charge (depending on the charging policy) and reserve credit claim.
4. Apply discounting to the charge according to the appropriate discounting policy, which depends for example on the time of the day, subscriber's profile, etc.
5. Update the credit balance of the `Subscriber`.

6. Provide the `Provisioning Agent` with "credit reauthorization" response. In case the credit balance of the `Subscriber` credit reaches the pre-defined threshold, the credit reauthorization response contains an "out-of-credit" notification.

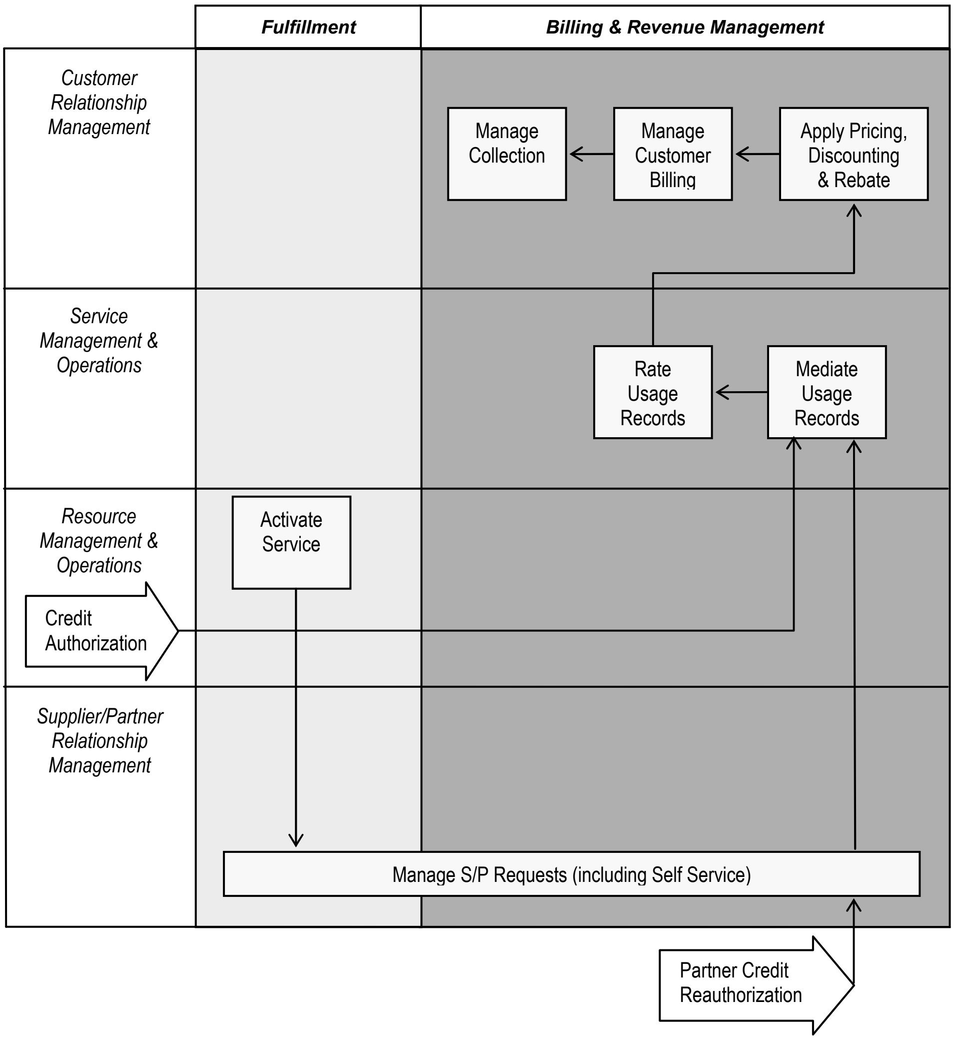

Figure 5.16. Accounting and Charging Process flow

Figure 5.16 depicts the *Accounting and Charging* process flow where the eTOM (level 3) processes are involved: Manage S/P Request, Mediate Usage Records, Rate Usage Records, Apply Pricing, Discounting & Rebate, Manage Customer Billing and Manage Collection.

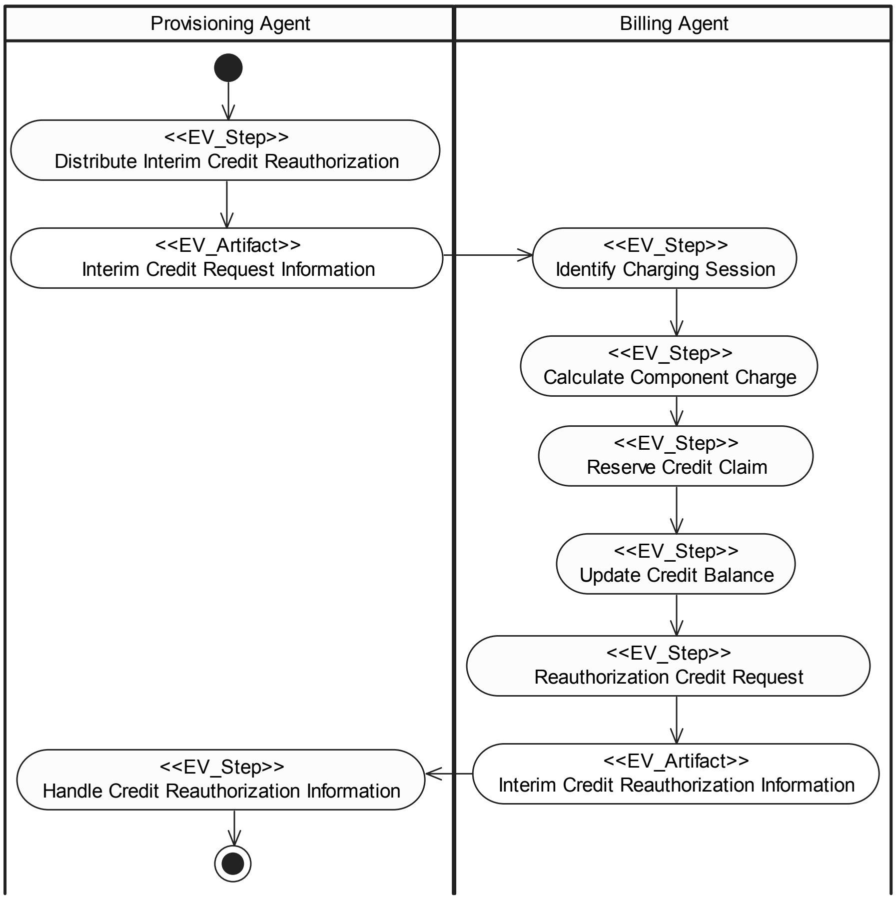

Figure 5.17. Steps in the Accounting and Charging Process for Subscriber-facing Billing

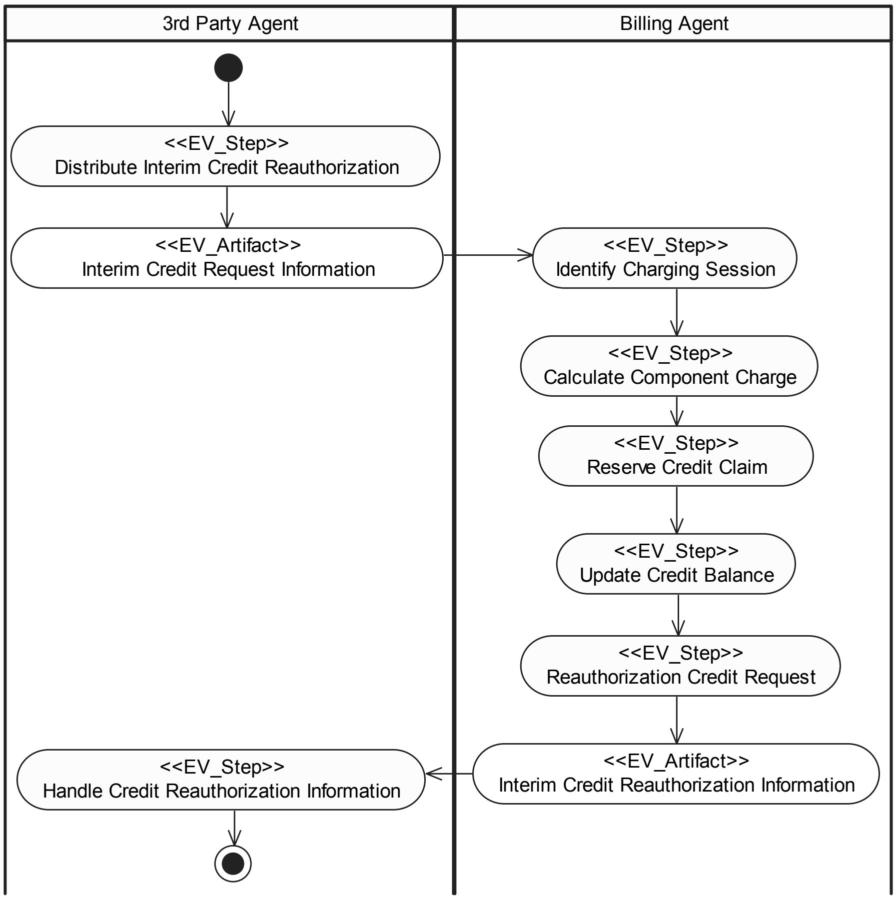

Figure 5.18. Steps in the Accounting and Charging Process for Partner-facing Billing

Figure 5.17 and 5.18 show the *Accounting and Charging* process in terms of partially ordered *steps*. The transfer of interim usage records from the `3rd Party Agent` to the `Billing Agent` is considered in this flow as to highlight the inter-domain billing aspect. This implies that the usage records from the `3rd Party Agent` need to be acquired through a billing interface (see §7.3).

5.4.4 Accounting and Charging Termination

The *Accounting & Charging Termination* process flow presented here is specific for interim accounting and charging. The purpose of it is to terminate the accounting and charging process at the end of the service usage. This process flow assumes the precondition listed below.

Precondition

- At the end of the service session usage, final usage records are generated by the `Provisioning Agent` and the `3rd Party Agent`.

The *Accounting and Charging Termination* process flow looks very similar to the previous process flow. The only difference is the usage record type received from the `Provisioning Agent` and the `3rd Party Agent` (final instead of interim). Here, the same eTOM (level 3) processes are involved (i.e. Manage S/P Request, Mediate Usage Records, Rate Usage Record, Activate Service, Apply Pricing, Discounting & Rebate, Manage Customer Billing and Manage Collection).

When both the final usage records from the `Provisioning Agent` as well as from the `3rd Party Agent` have gone through the whole accounting and charging process and the credit balance has been updated, the `Billing Agent` reports to the `Provisioning Agent` about the completion of the accounting and charging process. It is then up to the `Provisioning Agent` to inform the `3rd Party Agent` about the status of the accounting and charging process.

Figure 5.19 and 5.20 show the *Accounting and Charging Termination* process in terms of partially ordered *steps* for subscriber-facing and partner-facing billing, respectively.

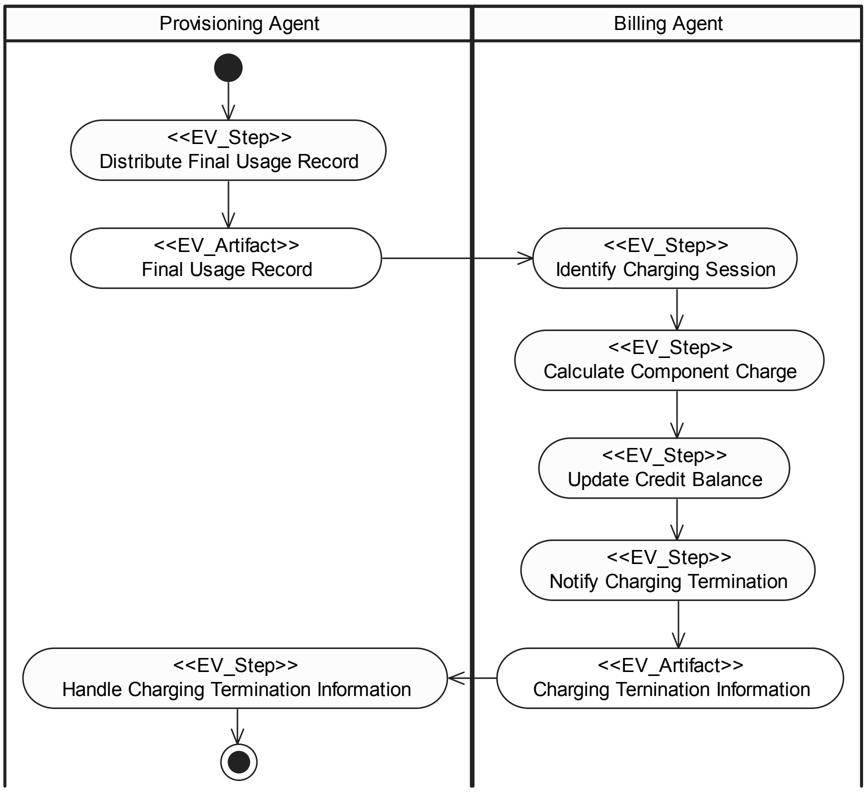

Figure 5.19. Accounting and Charging Termination Enterprise Process for Subcriber-facing Billing

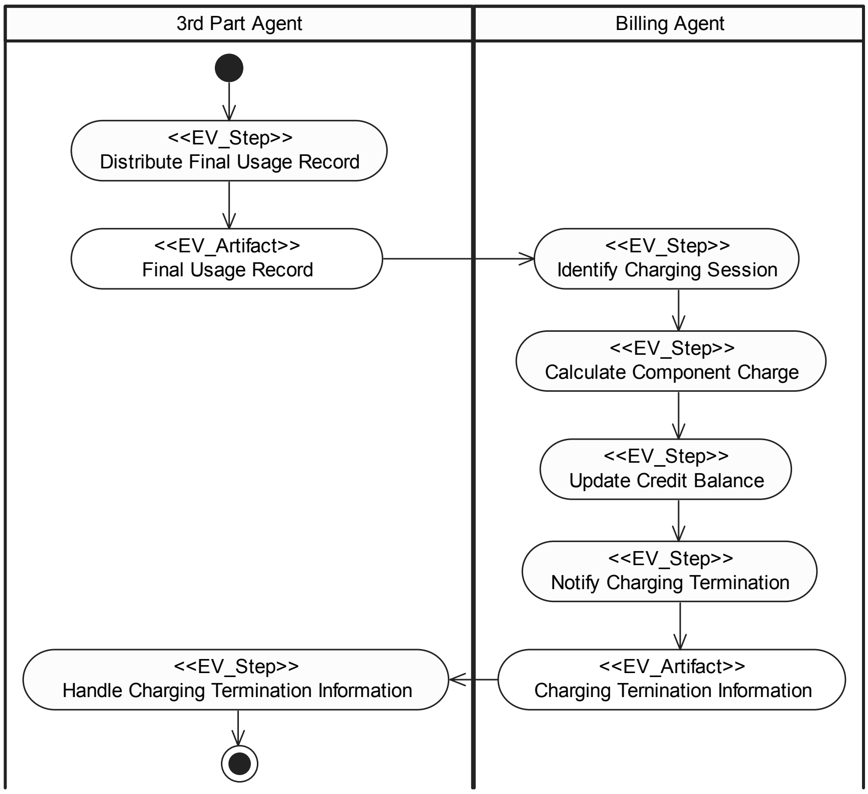

Figure 5.20. Accounting and Charging Termination Enterprise Process for Partner-facing Billing

5.5 Inter-domain Telematics Community Policies

In this section, we will present some examples of billing policies to stress the expected behavior of the `Billing Agent` in dealing with interim accounting and charging mechanism. By no means is it our aim to give an exhaustive list of options. A policy can be expressed as an obligation, an authorization, a permission, or a prohibition. Actions contrary to policies are violations. Using policies in billing architectures has been proposed in other work, for instance in [RFC3334].

There are two kinds of polices applied in the `Inter-domain Telematics Community`: *configuration* policies and *behavioral* policies:

Configuration policies impose constraints on the configuration of the community. They may impose constraints on the structure of the community, such as the population of entities (e.g. the number of `Subscribers` and

`Service Providers`). Moreover, they can impose constraints on the assignment of roles to the entities (e.g. a person can play both the role of `subscriber` and `End-user`). The roles assignment has already been addressed in §5.2.2.

Behavioral policies impose constraints on the processes and actions of the entities within the `Inter-domain Telematics Community`. The policies permit a process or an action to happen (e.g. the provisioning of a service session can start only when the corresponding billing is ready). Behavioral policies can be put in the following form:

Permissions

1. `Subscribers` are permitted to have different levels of service control depending on e.g. the usage history. The application of the policy offers potential for Customer Relationship Management (CRM). This policy can be applied to the *Credit Verification* process flow (see Figure 5.12).

2. `Subscribers` are permitted to use the following payment methods: prepaid, postpaid and credit. This policy can be applied to the enterprise process *Credit Verification* process flow (see Figure 5.12).

3. `End-users` are permitted to use services as long as they are creditworthy. This policy can be applied to the *Accounting and Charging* process flow (see Figure 5.17 and 5.18).

4. `Service Providers` are permitted to enforce a set of policies concerning the charge accumulation. For instance, the charge for a provisioned service session is computed from the charges of the constituent parts of the provisioned service session. Possible policies that can be applied to the *Accounting and Charging* process flow (see Figure 5.17 and 5.18):

   a. *Summation* – The service session charge is the sum of the charges of the constituent charges.

   b. *Weighted summation* – Each constituent charge is assigned a weight and the service session charge is the summation over the weighted charges.

5. `Service Providers` are permitted to enforce a set of policies concerning the frequency of the exchange of billing information among each other. For the exchange of service session charges, two service providers may have agreed upon a specific policy. This policy may depend on e.g. the type of the service session. As an illustration, we consider a few possible policies, which can be applied to the *Accounting and Charging* process flow (see Figure 5.17 and 5.18). It is

to be noted that we do not enter in the question of technical, operational and business appropriateness.

a. *Report any change of charge policy* – According to this policy, any change in the service session charge observed by the provider is reported to the requester.

b. *Time-based policy* – According to this policy, charges are exchanged based on time of the day.

c. *Charge-increase policy* – According to this policy, charges are exchanged based on a pre-defined increase of charges.

d. *Provider determined policy* – According to this policy, the service provider determines the exchange policy. For example, the provider may base the form of the exchange on knowledge about the service session composition and internally known charging schemes. In case for example the charge for the delivered exceeds the charge for transport, the provider may decide that charge increments incurred by the content charges will govern the service session charge exchange.

Authorizations

6. `Service Providers` are authorized to reject end-user requests based in the e.g. the usage history. This policy can be applied to the *Credit Verification* process flow (see Figure 5.12).

7. `Service Providers` are authorized to terminate service sessions based on the estimated financial risk (i.e. subscriber credit balance reaches a predefined threshold). This policy can be applied to the *Accounting and Charging* and *Accounting and Charging Termination* process flow (see Figure 5.17, 5.18, 5.19 and 5.20).

Obligations

8. `Service Providers` are obliged to show subscribers a specification of the delivered service and the related charge when requested. This policy can be applied to the *Accounting and Charging Termination* process flow (see Figure 5.19 and 5.20).

9. `Service Providers` are obliged to give subscribers e.g. (x) % rebate when the delivered service does not meet the predefined level of QoS as stated in the SLAs. This policy can be applied to the *Accounting and Charging* and *Accounting and Charging Termination* process flow (see Figure 5.17, 5.18, 5.19 and 5.20).

Prohibitions

10. End-users are not allowed to request more than a certain number of service sessions simultaneously. This policy can be applied to the *Credit Verification* process flow (see Figure 5.12).
11. Service Providers are not allowed to reveal credit balance and usage history of their subscribers/end-users to each other. This policy can be applied to the *Credit Verification* process flow (see Figure 5.12).

5.6 Conclusion

In this chapter the design of the Inter-domain Telematics Community is presented from the enterprise perspective. The focus is on the structural aspect and the behavioral aspect of the billing architecture, which lays the basis in the following chapters for further design of the Inter-domain Telematics System in the informational and computational perspectives.

Regarding research question Q1 this chapter proposes the Inter-domain Telematics System that embodies the subsystems: Provisioning Agent, 3rd Party Agent and Billing Agent. The behavior of these subsystems and their interactions are specified according to (level-3) eTOM processes. As a result, the proposed Billing Agent can be easily applied to service provisioning environments that conform to the eTOM business framework.

Regarding to research question Q2 this chapter presents the billing models that define the relationships between the involved parties such as consumers, service providers and third party providers. Furthermore, the subscriber-facing billing model and the partner-facing billing model are represented as part of the Inter-domain Telematics Community. These billing specifications respectively focus on the billing aspect between a subscriber and a service provider or between a service provider and a third party provider. The combination of the subscriber-facing billing model and the partner-facing billing model results ensures the end-to-end billing between the parties involved.

Regarding the research question Q4 the proposed service composition model helps to deal with billing of dynamic provisioning of composite services. The service session composition proposed in this chapter is inspired by the SID model and in fact is an extension of the SID model expressing the service session composition. This extension is essential for the mapping of usage records to a service session usage.

Finally, a number of policies are discussed which imply constraints on the configuration of the community structure as well as on community behavior. For example these policies apply to the processes of interim accounting and charging to limit financial risks for service providers. Although no exhaustive list of policy options has been provided, an initial set of policies is discussed which can be used for further reflection in future study.

Chapter 6 - Information Viewpoint of the Inter-domain Telematics System

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This chapter presents the inter-domain telematics system from the informational perspective. It describes the information managed by and stored within the inter-domain telematics system. The information models represented in this chapter are derived from the enterprise models presented in chapter 5. They highlight the following aspects: contact information, subscriber-facing information, partner-facing information and service composition information. This chapter provides answers to research question Q4.

6.1 Introduction

Data sharing across different administrative domains is critical for service provisioning and billing of inter-domain telematics services. On the one hand, the provisioning system needs to compose the service composition information for a particular service session. This service composition is then sent to the billing system. On the other hand, the service composition information needs to be stored within the billing system to enable the mapping between different charges to the corresponding service session. Further, the `Inter-domain`

`Billing System` needs to manage billing information in order to charge the service session usage and ultimately to bill the subscriber. Most of the functions inter-domain billing performs involve billing information. Hence, service composition models and billing information models are an important part of the design of the Inter-domain Billing System.

This chapter presents the inter-domain telematics system from the information viewpoint by highlighting the 1) *contact information model*, 2) *subscriber-facing billing model*, 3) *partner-facing billing model* and the 4) *service composition model*. According to the principles of the information viewpoint, the `Inter-domain Telematics System` can be represented by a set of information models (i.e. schemata) from the information viewpoint: *invariant information model*, *static information model* and *dynamic information model* (see also §3.2.1). An invariant information model represents the structure and relationships between information objects, which is used to create data structures for the inter-domain telematics system. A static information model represents part of the Inter-domain Billing System from the information perspective at a given point in time. It specifies the structure of billing related information and the relationships between information objects without saying how they behave in time. A dynamic information model (i.e. dynamic schema) specifies the states of information objects in time, for example a constantly adjusted credit balance or rating algorithm during a service session. This chapter focuses on the information structure expressed in terms of information objects types and their relationships. For this purpose, the concept of invariant models will be applied. In addition, static model will also be applied as to illustrate possible real life state of the information view (i.e. snapshot of the data at a certain point in time).

In order to identify the information that may be captured in the information viewpoint, Zachman [Zachman97] suggested reflecting the "six English question words": *who, what, where, when, why* and *how* to structure the analysis of information systems. Based on the Zachman framework multiple concrete questions can be put forward. Table 6.1 shows the categorized questions posed against a service usage event and its counter part, the service payment event.

Service Usage Event	
Who	Who is responsible for using the service? Who is responsible for providing the service?
What	What service is being used? What was the quality of the service What system is providing the service? What system is receiving the service?
Where	Where is the service delivered? Where is the service usage registered?
When	When is the service started? When is the service ended? When is the service use noticed / registered?
Why	Why is the service used / delivered? Why is the service terminated?
How	How much service was used / delivered? How long was the service used/delivered?
Service Payment Event	
Who	Who is responsible for paying for the service? Who is responsible for settling the payment? Who is the beneficiary of the payment
What	What is being paid for? What system is authorizing the payment? What system is processing the payment?
Where	Where is the payment done? Where is the payment event registered?
When	When did the payment occur? When was the payment registered?
Why	Why did the payment event occur?
How	How much economic compensation was received? How did the payment occur (i.e. prepaid or postpaid) ?

Table 6.1. Categorized key questions used to identify information objects

To preserve the consistency between the enterprise viewpoint the information viewpoint, here a one-to-one mapping approach is deployed [ITUX906]. For instance, the <<enterprise object>> Service Provider in the enterprise viewpoint becomes the <<information object type>> Service Provider in the information viewpoint. The mapping of a model from the enterprise viewpoint onto the information viewpoint produces a "basic" corresponding information model. Next, the "basic" information model is extended with additional information objects to ensure the completeness of this information model.

6.2 Contact Information Model

Contact information generally contains name and address of a person or an organization. This information is essential for the service provider to get in touch with the end-user, the subscriber, or the third party provider. Usually, the service provider needs to register the contact details in order to send paper invoices to the subscriber. Further, the service provider also needs to register the contact information of the third party provider in order to send financial reports. Next to paper invoices, the subscriber may be provided with an option to receive electronic invoices (e-invoicing) via an email address. The service provider may also choose to send financial reports using an email address of the third party provider.

Figure 6.1 shows the invariant contact information model. A person is coupled to a person name, whereas an organization is coupled to an organization name. Both billing address (i.e. postal address) and digital address (i.e. email address) are coupled to a party role, not directly to a person or an organization. The motivation behind this choice is to enable role-based contact management. For example, the subscriber is responsible for the payment of service usage; therefore invoices need to be sent to the subscriber. Indirectly, there exists a person or an organization that play the subscriber role. Further, the shaded information objects indicate the information objects that have been mapped from the enterprise viewpoint. The non-shaded information objects are extension of the "basic model". Table 6.2 shows detailed information of the contact information model expressed in attributes. Figure 6.2a depicts a static contact information model to illustrate a possible real-life situation of subscriber contact, whereas Figure 6.2b illustrates a possible real-life situation of the service provider contact.

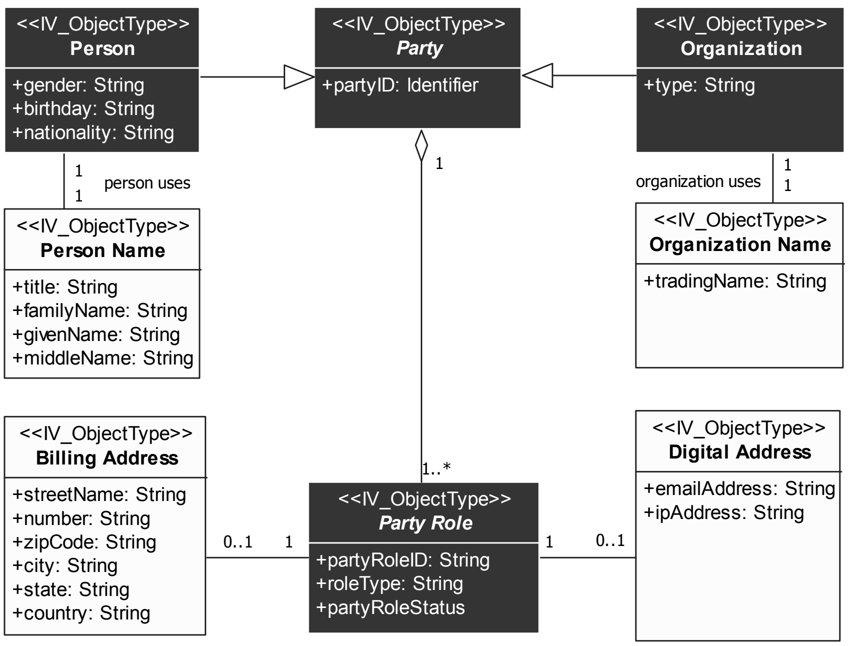

Figure 6.1. Contact Information Model – Invariant Schema

Category	IV ObjectType	Attribute	Data Type	Description
Who	Party	partyID	Identifier	A unique party identifier. This could be some string.
	Person	Gender	String	An indication of male or female.
		Birthday	String	Date of birth.
		Nationality	String	Nationality.
	Organization	tradingName	String	A trading name of an organization.
		Type	String	A classification indicating the type of a particular organization. For instance, small-office/home-office (SOHO) or a corporate.
What	Party Role	partyRoleID	Identifier	An unique identifier, which is assigned to a specific party.
		partyType	String	An identification of party role. For instance, end-user, subscriber, service provider, etc.
		partyRoleStatus	String	The status of a party role used to indicate current state of a party role.
Where	Billing Address	streetName	String	Street name.
		Number	String	House number.
		zipCode	String	Zip code.
		City	String	Name of the city.
		State	String	Name of the state.
		Country	String	Country name.
	Digital Address	emailAddress	String	Contact email address.
		ipAddress	String	Fixed ip address.

Table 6.2. Detailed Information of the Contact Information Model in Attributes

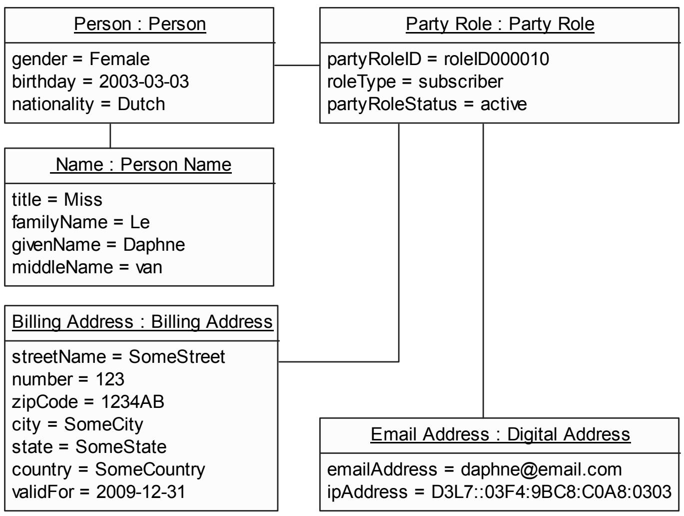

Figure 6.2a. Contact Information Model – Static Schema of subscriber contact

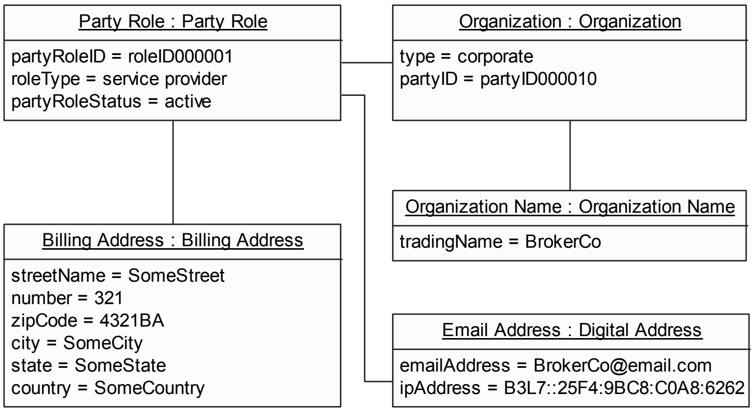

Figure 6.2b. Contact Information Model – Static Schema of service provider contact

6.3 Subscriber-facing Billing Information Model

The subscriber-facing billing information model defines the structure of the information objects which is used to construct a part of the billing database. The billing database is a collection of logically related records stored within the Inter-domain Billing System. Other parts of the billing database are covered by the partner-facing billing information model and service session composition model)..The subscriber-facing billing information model represents the information about the end-user who requests and uses the service; the service provider who provides the service to the end-user; the subscriber who pays for the service usage; and the billing provider who takes care of the billing process. Furthermore, detailed information about the service usage and the corresponding service payment is included in this information model. The service usage is coupled to the end-user information; whereas the service payment is coupled to the subscriber information (indicating who is responsible for the payment). Both service usage and service payment are attached with a timestamp indicating when these events occur. The timestamp indicates starting time, interim time and end time of a service session. The interim time is used to support interim accounting and charging. For instance, at the start of a service session, only the starting time is indicated. When a charging event takes place during the service session, the starting time and interim time are indicated. When the service session is ended, both start time and end time are indicated. The multiplicity between the service usage and the timestamp implies that a service usage can only have one timestamp, whereas one timestamp can be applied to one or more service usage (i.e. multiple service usage at the same time). Similarly, the multiplicity between the service payment and the timestamp implies that a service payment can only have one timestamp, whereas one timestamp can be applied to one or more service payments.

The end-user and the subscriber are linked via the subscriber account. This is to ensure that the service usage consumed by the user will be paid by the subscriber by means of the subscriber account. A subscriber can have one or more accounts and a subscriber account can support one or more end-users. For instance, a parent can have one or more accounts at a service provider. One of these accounts is used to allow one or more children get access to services. Further, the subscriber's account is coupled to the corresponding subscriber credit profile, which contains information about the credit balance. The charge cycle information is used to indicate the charging frequency. For example, charging at the moment when the service session is ended or charge several times during service session usage. Depending on this object, the credit balance is updated frequently during service session usage. The service usage itself is coupled to the service provided to the end-user.

Contact information is an important part of the billing information enabling the service provider to get in contact with the end-user and/or the subscriber. Therefore, person and organization is linked to contact. Both person and organization have specific names. Contact information includes a physical billing address where an invoice is sent to; an email address where an electronic invoice can be sent to; and possibly a fixed IP address.

Figure 6.3 shows the subscriber-facing billing model with the information objects and their relationships. The extension (non-shaded) of this model with respect to the "basic" model (shaded) from the enterprise viewpoint is necessary to persist and manage near real-time credit balance information for the support of interim charging. Moreover, this extension is necessary to enrich the subscriber-facing billing information model by answering the questions posed in Table 6.1. Table 6.3 provides detailed information of the subscriber billing model in terms of attributes and possible data types.

Figure 6.4a, 6.4b and 6.4c present examples of static schemas, which model the state of the Inter-domain Billing System at certain moments in time for a Video-on-Demand service (i.e. data snapshots). It assumes that an incremental charging scheme is used in this particular case. The first schema shows the state of the Inter-domain Telematics System at the start of the service session where no charge object has been created <<2007-12-31 | 00:00:00 CEST>>. The second schema shows the state 15 minutes after the start <<2007-12-31 | 00:00:15 CEST>> and the corresponding interim charge is €2,00. Finally the third schema shows the state after the service session has ended <<2007-12-31 | 00:00:30 CEST >> and the corresponding charge is another €2,00. As a result, the subscriber balance has decreased to €5,50 and provider cash has increased to €104. The objects that changes in time are indicated with dotted rectangles.

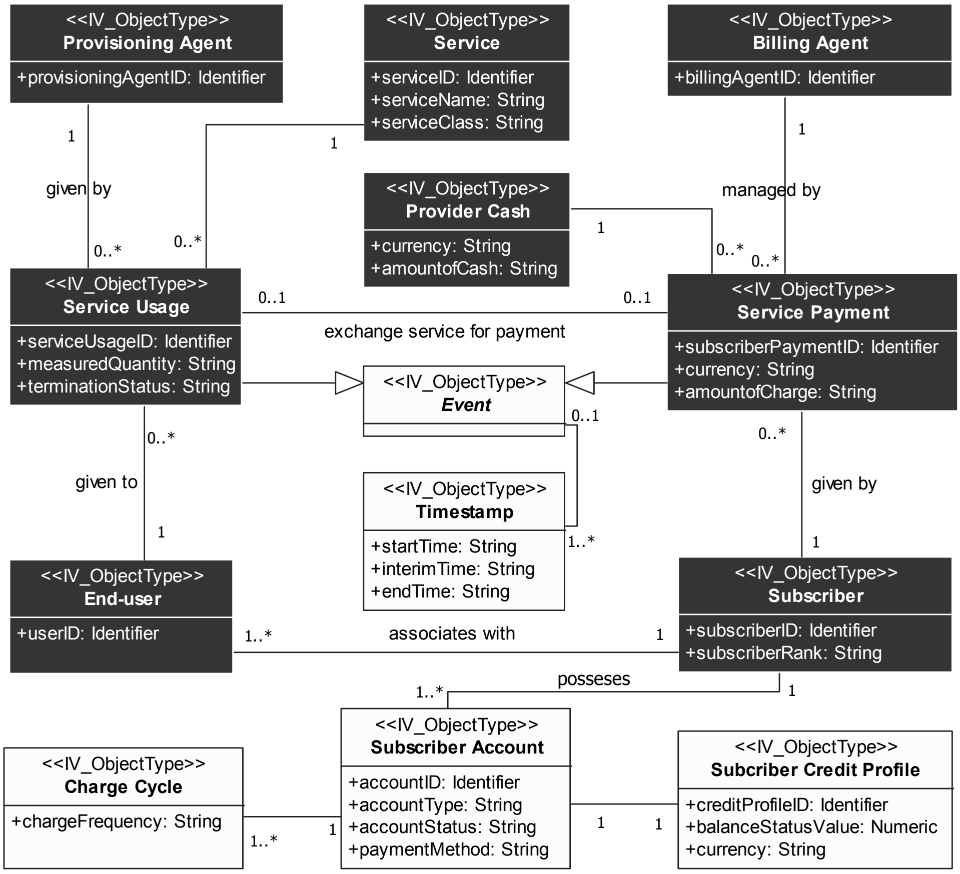

Figure 6.3. Subscriber-facing Billing Information Model – Invariant Schema

Category	IV ObjectType	Attribute	Data Type	Description
Who	End-user	userID	Identifier	A globally unique user identifier. This could be for instance a NAI.
	Subscriber	subscriberID	Identifier	A globally unique subscriber identifier. This could be for instance a realm name.
		subscriberRank	String	A classification of subscriber to assign privileges. For instance, an end-user who is related to a high rank subscriber may be allowed to continue with a service session even when the credit balance has reached a pre-defined limit. For a low rank

				subscriber, measures can be taken to terminate the service session immediately when the credit balance reached a predefined limit.
	Provisioning Agent	provisioningAgentID	Identifier	A globally unique service provider identifier. This could be for instance a realm name.
	Agent Billing	billingAgentID	Identifier	A globally unique billing provider identifier. This could be for instance a real name.
What	Service	serviceID	Identifier	An unique identifier of the requested service. The uniqueness must be true relative to the service provider, but It may also be globally unique.
		serviceName	String	A descriptive name of the service. For instance movie name.
		serviceClass	String	The requested QoS. For instance low-quality, normal-quality or high-quality.
	Service Usage	serviceUsageID	String	An unique identifier of the service session usage. The uniqueness must be true relative to the service provider.
	Service Payment	subscriberPaymentID	Identifier	An unique payment identifier.
		currency	String	An applied currency.
		amounttoCharge	Numeric	Total amount to charge for the whole service session usage.
	Subscriber Account	accountID	Identifier	A unique subscriber account identifier.
		accountType	String	A classification of account types. For instance prepaid or postpaid.
		accountStatus	String	The indication of subscriber account status. For instance, a subscriber account may be put on "hold" for some investigation. In this case, service provisioning is not desirable.
		paymentMethod	String	The method of payment. For instance by a credit card, by direct monthly direct debit, etc.
	Subscriber Credit Profile	creditProfileID	Identifier	An unique identifier of the subscriber credit profile
		balanceStatusValue	String	The actual credit balance of the subscriber, which can be updated during a

				service session.
	Charge Cycle	chargeCycle	String	The indication of charge policy. For instance, charge immediately when the service session has finished, or charge during the service session with a certain frequency.
When	Timestamp	startTime	TimePeriod	Start time of the service session.
		interimTime	TimePeriod	Interim time of the service session.
		endTime	TimePeriod	End time of the service session.
Why	Service Usage	terminationStatus	String	The reason for service session termination. For instance a service session may be terminated by the end-user or by the service provider.
How	Service Usage	measuredQuantity	String	The measured quantity of service usage. For instance x Mb of data.
	Provider Cash	amountofCash	String	The increased amount of cash.

Table 6.3. Detailed Information of the Subscriber-facing Billing Model in Attributes

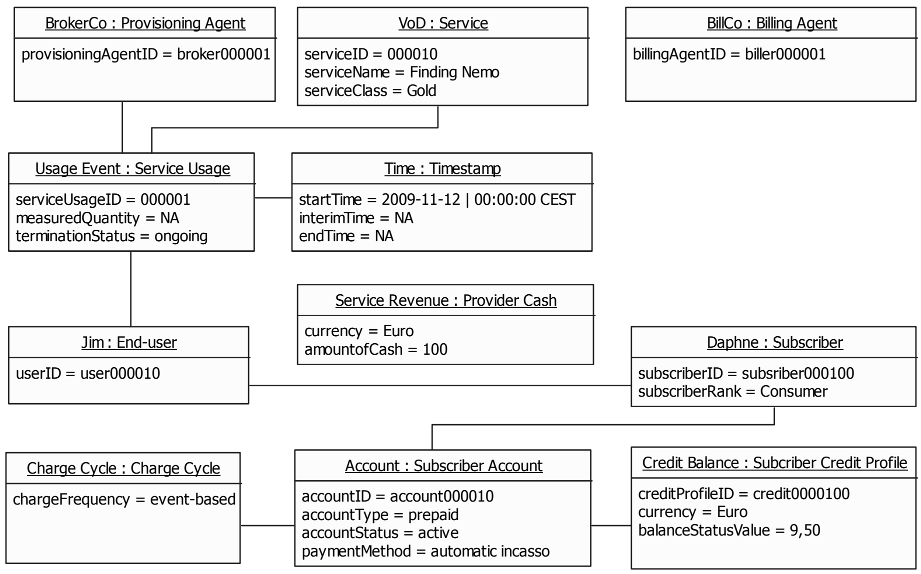

Figure 6.4.a Subscriber Billing Information Model – Static Schema (at the beginning of the service session)

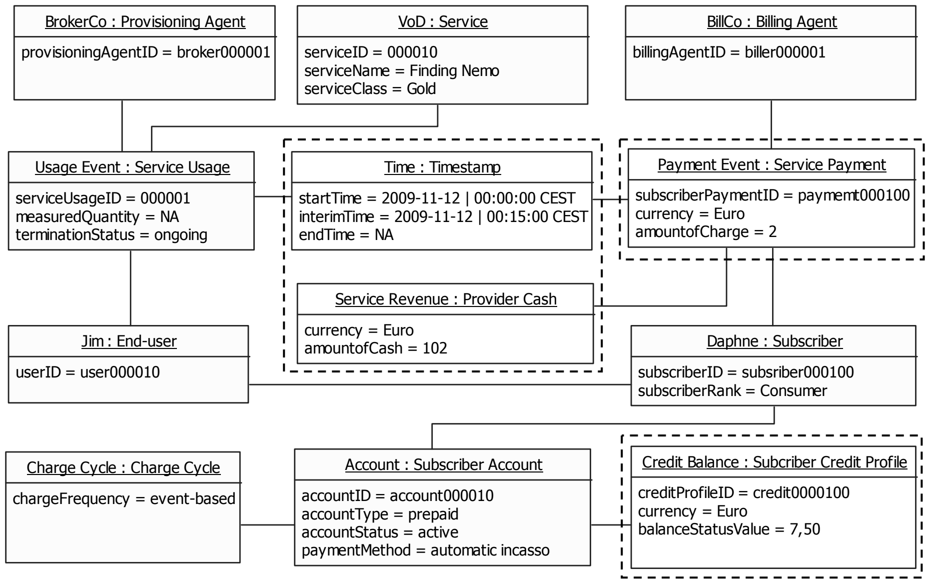

Figure 6.4.b Subscriber-facing Billing Information Model – Static Schema (after 15 minutes during the service session)

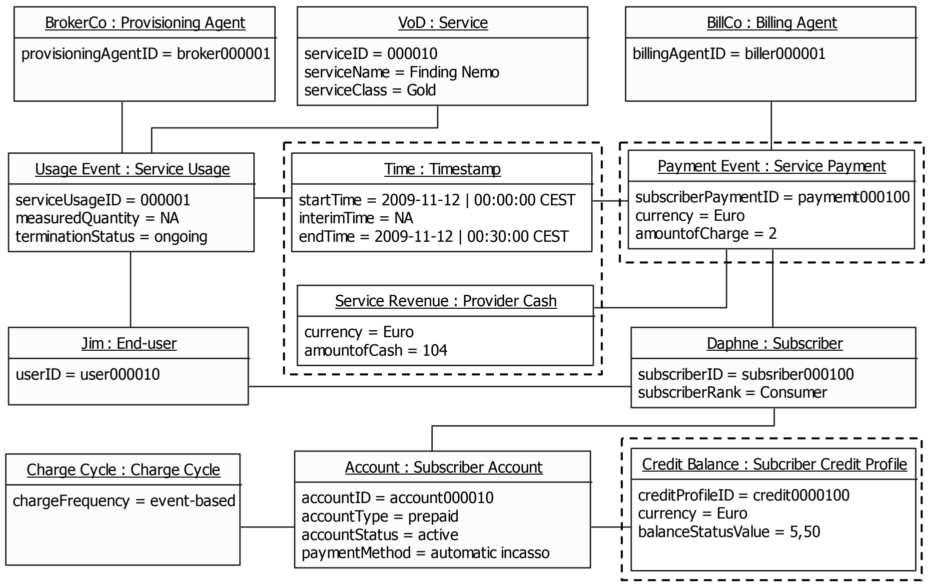

Figure 6.4.c Subscriber-facing Billing Information Model – Static Schema (when the service session has ended)

6.4 Partner-facing Billing Information Model

The purpose of the partner-facing billing information model is to enable the Inter-domain Billing System to manage and store the information, which is used to conduct billing of services provided by third party providers. As the relationship between the service provider and the third party provider is a business-to-business relationship it is necessary for the billing provider to provide information for the purpose of financial compensation. Partner billing may be conducted as wholesale billing (i.e. flat fee) or event-based billing depending on the business agreement between the service provider and the third party provider. Commonly, wholesale billing is used for basic telematics services such as connectivity services. When it comes to "high-value" telematics services such as content or high-valued information services (e.g medical consulting services), third party providers often prefer event-based billing. The partner-facing billing information model presented here is designed to support event-based billing. In case of wholesale billing, less detail will be needed.

Figure 6.5 depicts the partner-facing billing information model. The shaded information objects indicate the information objects that have been mapped from the enterprise viewpoint. The non-shaded information objects are extension of the "basic model". The <<information object type>> Partner Account and Partner Credit Profile are included in the model to support partner account management. That is, to register the amount of charge the service provider need to pay the third party provider. The detailed information about partner service usage and the corresponding partner service payment is modeled in a similar way compared to the subscriber-facing billing information model (see §6.3). Table 6.4 provides a detailed description of information in terms of attributes and data types.

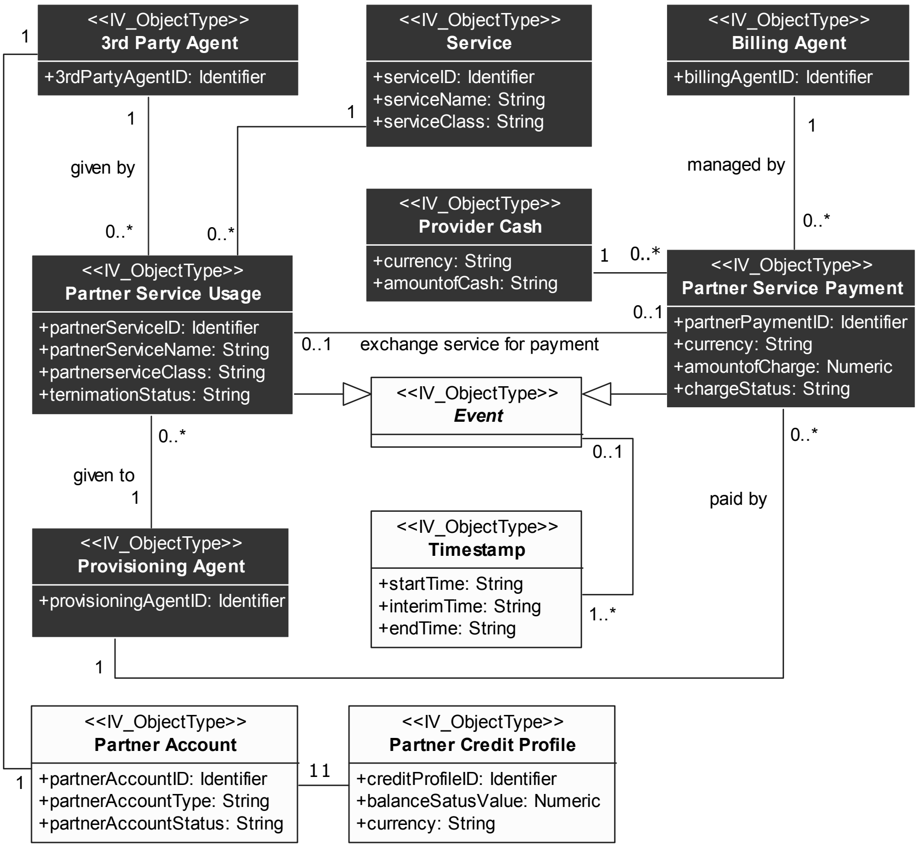

Figure 6.5. Partner-facing Billing Information Model – Invariant Schema

Category	IV ObjectType	Attribute	Data Type	Description
Who	3rd Party Agent	3rdPartyAgentID	Identifier	A globally unique 3rd party provider identifier. This could be for instance a realm-name.
What	Partner Service Usage	partnerServiceID	Identifier	An unique identifier of the requested service. The uniqueness must be true relative to the service provider, but it may also be globally unique.
		partnerServiceName	String	A descriptive name of the service. For instance movie name.
		parttnerserviceClass	String	The requested QoS. For instance low-quality, normal-quality or high-quality.
	Partner Service Payment	partnerPaymentID	Identifier	An unique payment identifier.
		currency	String	An applied currency.
		partnerPaymentID	Identifier	An unique payment identifier.
	Partner Account	partnerAccountID	Identifier	A unique partner account identifier.
		partnerAccountType	String	A classification of account types. For instance prepaid or postpaid.
		partnerAccountStatus	String	The indication of partner account status. For instance, a partner account may be put to "hold" for some investigation. In this case, partner service usage is not desirable.
	Partner Credit Profile	partnerCreditProfileID	Identifier	An unique identifier of the partner credit profile
		balanceStatusValue	String	The actual credit balance of the partner.
When	Timestamp	startTime	TimePeriod	Start time of the service session.
		interimTime	TimePeriod	Interim time of the service session.
		endTime	TimePeriod	End time of the service session.
Why	Partner Service Usage	terminationStatus	String	The reason of service session termination. For instance a service session may be terminated by the end-user or by the service provider.
How	Partner Service Usage	measuredQuantity	String	The measured quantity of partner service usage. For instance x Mb of data.

Table 6.4. Detailed Information of the Partner-facing Billing Model

6.5 Service Composition Model

In a dynamic environment where service provisioning is tailored to the demand of the end-users, service composition can be created on the fly. Recent research [Orrients03, Meyer05] has suggested using business process modeling languages (e.g. BPEL, BPEL4WS) to construct (inter-domain) service composition. In a real-life situation, services can be made available via “service interfaces” and therefore can be invoked via a message bus (e.g. enterprise service bus) across different administrative domains. The construction of service composition is based on two factors: *how* and *what*.

The *how* is concerned with binding methods of different service components. For instance, Leydekkers [Leydekkers97] has proposed a method for binding telematics services using the ODP concept. For further discussion on billing, the *how* is not relevant because billing systems do not need to know about how a composite service was composed. Instead, they only need to know what service components have been used in order to conduct billing. Hence, the *how* will be further omitted in this section.

The *what* is concerned with the modeling of necessary service components (i.e. ingredients) and their properties. The essence of the service composition model is the shared knowledge between the pair end-user and service provider and the pair service provider and third party provider. On the one hand, the service provider composes the requested service using atomic services. These atomic services can be proprietary services (provider service) or third party services (partner-facing service) or a combination of both kinds. The detailed information of the `Provider-facing Service` object type is internally accessible for the service provider. It is imaginable that a service provider would “hide” detailed service composition information from the end-user as well as from the third party provider due to business reasons. Instead, the service provider can provide the end-user with less detailed information, which is relevant for and easy for the end-user (and subscriber) to understand. Hence, the information modeled by the `<<information object type>> End-user-facing Service` is derived from the `<<information object type>> Service`, which in turn models the highest level of details about the requested service.

Figure 6.6 shows the information objects types and their relationships within the service session composition model. Detailed information of the model is provided in Table 6.5.

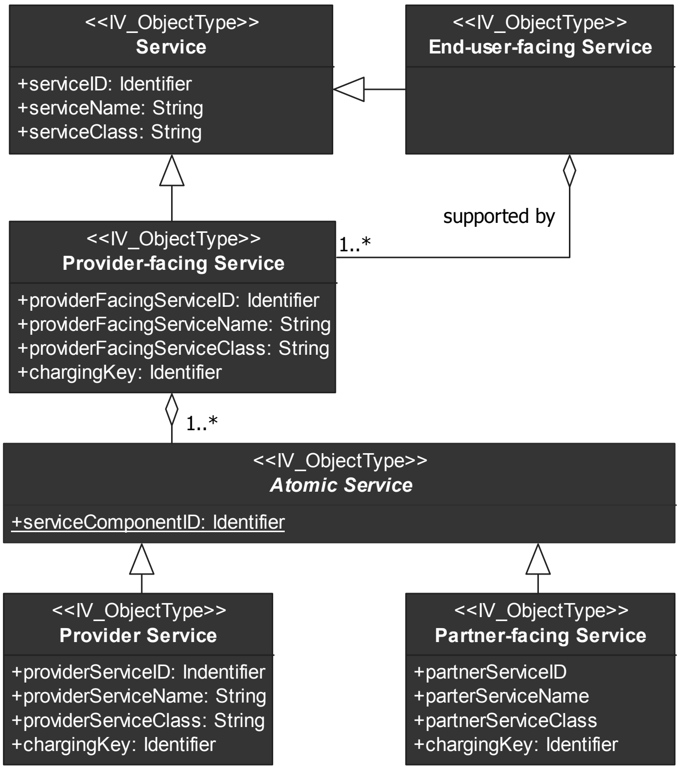

Figure 6.6. Service Composition Model – Invariant Schemata

Category	IV ObjectType	Attribute	Data Type	Description
What	Provider-facing Service	providerFacingService ID	Identifier	A unique identifier of the provider-facing service provided using provider's proprietary resources. The uniqueness must be true relative to the service provider, but it may also be globally unique.
		providerFacingService Name	String	A descriptive name of the service. For instance movie name.
		providerFacingService Class	String	The requested QoS. For instance low-quality, normal-quality or high-quality.
		chargingKey	Identifier	A unique identifier of the charge corresponding to a composite service session or a service component.
	Provider Service	providerServiceID	Identifier	A unique identifier of the service provided using provider's proprietary resources. The uniqueness must be true relative to the service provider, but it may be globally unique.
		providerServiceName	String	A descriptive name of the service. For instance movie name.
		providerServiceClass	String	The requested QoS. For instance low-quality, normal-quality or high-quality.
		chargingKey	Identifier	A unique identifier of the charge corresponding to a service component provided by the service provider
	Partner Facing Service	partnerFacingService ID	Identifier	A unique identifier of the service provided using partner's resources. The uniqueness must be true relative to the service provider, but it may also be globally unique.
		partnerFacingService Name	String	A descriptive name of the service. For instance movie name.
		partnerFacingService Class	String	The requested QoS. For instance low-quality, normal-quality or high-quality.
	Atomic Service	serviceComponentID	Identifier	A unique identifier of the service component participating in composite service session

Table 6.5. Detailed Information of the Service Composition Model

6.6 Conclusion

In this chapter the design of the `Inter-domain Telematics System` is presented from the information perspective which consists of four essential parts: contact information model, subscriber-facing billing information model, partner-facing billing information model and the service composition model.

Regarding research question Q4 this chapter provides a detailed specification of the proposed service composition model, which can be applied directly by the industry. It is shown that the application of the SID framework is suitable as a basis to model billing information models for supporting composite telematics services. Today, many service providers, especially major telecommunication companies, are using the SID framework as de-facto standard to develop information models. However, there is still some room left within the SID framework to tailor down SID models in order to meet specific needs of service providers in supporting billing of dynamic provisioning of composite services.

Furthermore, this chapter proposes the application of the Zachman framework, to put forward multiple questions in a systematical manner. This helps to determine relevant information needed to be managed and stored by the inter-domain telematics system for billing purposes.

The current standards like IETF's Diameter Base Protocol [RFC3588] and ITU's recommendation on Call Detail Recording [ITUQ.825] address only the interim accounting but they do not discuss how to deal with interim charging. As to support interim charging relevant information elements are proposed in the service session composition model. These information elements allow the billing provider to set the frequency of charge for distinct service sessions, depending on a set of business policies.

Chapter 7 - Computational Viewpoint of the Inter-domain Telematics System and Performance Consideration

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This chapter presents two models of the Inter-domain Telematics System from the computational viewpoint. The first model presents a decomposition of the Inter-domain Telematics System into three agents (i.e. sub-systems), namely: Provisioning Agent, 3rd Party Agent and Billing Agent. The second model concentrates on the Billing Agent and presents further refinement of this agent into functional components. Further, this chapter discusses indicative performance quantities from real-life cases to provide primary checks on the proposed refinement of the Billing Agent. This chapter provides answers to research questions Q1, Q3 and Q5.

7.1 Introduction

In Chapter 5 the enterprise viewpoint of the `Inter-domain Telematics System` has been specified. In this viewpoint, the system and its environment have been specified and the (enterprise) objects and their relationships have been defined. In Chapter 6, the information view of the Inter-domain Telematics System has been specified. In this viewpoint, the (information) objects are defined with detailed information in terms of attributes. The consistency between the enterprise viewpoint and the information viewpoint has been preserved based on the one-to-one mapping approach between an <<enterprise object>> and an <<information object type>> [ISO/IEC19793].

In this chapter, the computational viewpoint of the Inter-domain Telematics System is specified. In this viewpoint, the (computational) objects, the interfaces between the objects and the interactions between objects at the interfaces are defined. The consistency between the enterprise viewpoint and the computational viewpoint is guarded by the mapping of the enterprise processes (specified in the enterprise viewpoint) onto the interactions of the system entities in the computational viewpoint. That is, making sure that entities behave in such a way that they support the enterprise process accordingly (see Chapter 5) The consistency rules applied here have been proposed by Dijkman in [Dijkman04]. Further, the consistency between the information viewpoint and the computational viewpoint is guarded by the integration of the attributes defined in the information viewpoint in the operations of the computational viewpoint. That is, when an operation occurs at an interface, the information carried by this operation must be consistent with the corresponding attributes that has been defined in Chapter 6.

In the computational viewpoint, a coarse grained model will be defined first. In addition, we propose a decomposed computational view of the Inter-domain Telematics System into sub-systems. The ultimate result of the decomposition (see the definition of decomposition in §3.3) of the Billing Agent in the computational viewpoint is to provide a detailed specification of the proposed billing system (i.e. the Billing Agent) expressed in terms of computational objects, which interact at the interfaces.

7.2 Refinement of the Inter-domain Telematics System

The provisioning of composite services may involve different parties such as telecom service providers, content providers or game providers etc. Each party may provide one or more service components to the eventual composite service. Different approaches have been proposed to deal with the provisioning of composite services [3GPPTS23.228, TMFSDP08, SPICE08]. One of the common features of these approaches is a central function that is responsible for composing and orchestrating the composite services. This function is assumed to be conducted by the Service Provider. Hence the Service Provider needs to interact with 3rd Party Provider(s) to invoke the necessary service components. In addition, the `Service Provider` is also assumed to be responsible for the billing of the composite services. Along with this reasoning, this section discusses a "coarse grained" decomposition of the `Inter-domain Telematics System` into three agents: `Provisioning Agent`, `3rd Party Agent` and `Billing Agent` (see §5.2.3 for definitions).

These agents are modeled as `<<computational objects>>`, which are achieved through a one-to-one mapping of the corresponding enterprise roles from the enterprise viewpoint. Each of the above agents has a number of ports, each port is linked to a particular interface, at which interactions occur between two agents. Ports are addressable, which means that an operation can be sent to a port for a certain purpose. Figure 7.1 depicts the (course grained) computational viewpoint of the `Inter-domain Telematics System` consisting of agents, ports (modeled as filled squares) and interfaces (modeled as balls/sockets). An interface between any two objects is considered as a "one-way" interface. This implies that one object uses the interface realized by another object to send an operation. An eventual response of an operation occurs at a separate interface. This modeling choice is adopted from Raul et al [Romero08] . An alternative modeling approach is to use a "two-way" interface. This implies that a request operation explicitly expects a return value through the same interface. We found the second modeling approach not explicitly revealing the return value of a request operation and therefore not expressive enough.

An interface of a computational object is specified by a computational interface template, which is an interface template for a *signal* interface, a *stream* interface or an *operation* interface. A signal interface template is usually used to model (primitive) atomic interactions between two computational objects. A stream interface template is most appropriate to model continuous interactions such as video streaming. An operation interface template is usually used to model interactions where complex information is exchanged between two computational objects. As the interactions between the `Billing Agent` and its environment involve the exchange of complex information in different phases of the Service Accounting and Charging Life Cycle (SACLC), *operation interfaces* are used in the model that represents the `Inter-domain Telematics System`.

An ODP operation is a request/response mechanism, where a request called an *invocation*, is sent from one computational object to another and a response, called *termination*, to this request is sent (in the opposite direction) as a result. If an operation consists of only an *invocation*, it is called an *announcement*. If it consists of both an invocation and a termination, it is called an *interrogation*. In order to ensure the desired behavior of the billing processes (see Chapter 5), both *interrogation* and *termination* are used. For instance, a credit verification request from the Provisioning Agent must be answered by the Billing Agent so that the Provisioning Agent can proceed with the corresponding service provisioning process.

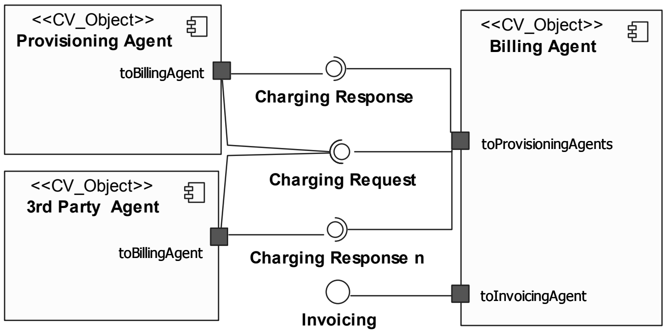

Figure 7.1. Decomposition of the Inter-domain Telematics System into Agents

The Billing Agent provides two interfaces to other agents, namely the Charging Request interface and the Invoicing interface. The Provisioning Agent provides the Charging Response interface to the Billing Agent. Whereas the 3rd Party Agent provides the Charging Response n interface to the Billing Agent. The Provisioning Agent and the 3rd Party Agent use the Charging Request interface to send credit verification request operations and charging termination operations to the Billing Agent. The Billing Agent uses the Charging Response and Charging Response n interfaces to send back responses to the Provisioning Agent and the 3rd Party Agent, respectively . Both the Provisioning Agent and the 3rd Party Agent also use the Charging Request interface to send usage records to the Billing Agent. These usage records can be either interim usage records generated during service sessions or final usage records generated at the end of each service session. Finally, the Billing Agent provides the Invoicing interface to expose invoice related information. This interface can be used by an invoice agent, which provides Subscribers with billing information and credit balance status. Figure 7.2 specifies the interface signatures containing the interactions that take place at the interfaces. The arguments specification used by each operation refers to the information specification from the information viewpoint.

Figure 7.2. Specification of the interface signatures containing the interactions occur at the interfaces

7.3 Refinement of the Billing Agent

The coarse grain refinement as presented in the previous section represents a high-level design of the `Inter-domain Telematics System`, where the `Billing Agent` is viewed as a black box. In this section we further refine the computational viewpoint of the `Billing Agent`. It first provides an overview of the refined model and the rationale behind the billing specific design choices of the system components. Then, it discusses the interactions of the involved system components of the `Billing Agent` in the different phases of the SACLC.

7.3.1 Refinement Rationale and Overview.

This section provides a brief overview of the refinement of the `Billing Agent` without going into details of the system components and their interaction at the internal interfaces. The refinement of the `Billing Agent` is made based on the enterprise process definition of the four phases of the SACLC (see Chapter 5). Following these enterprise processes ensure that the system components of the `Billing Agent` behave consistently with the enterprise processes. In addition, refinement decisions are also made based on a practical approach by looking at commercial products that commonly exist in the industry such as mediators, rating engines and high performance database solutions. To this extent, the proposed refinement of the `Billing Agent` increases the flexibility to select system components from different vendors in the implementation stage. Besides, building a billing system utilizing "market components" often results in a shorter duration of the implementation project.

The `Inter-domain Billing System` consists of the computational objects listed below:

- `Mediation` – The `Mediation` acts as a gateway with the capability to receive and to route incoming messages from provisioning systems to the `Charge Aggregator`. As the `Charge Aggregator` is a computation-intensive system component, the `Mediator` can take care of the load balancing by distributing the charging process over multiple `Charging Aggregator` instances. The `Mediation component` has a port that connects to "outward" interfaces to provisioning systems as discussed in the previous section.
- `Charge Aggregator` – The `Charge Aggregator` is mainly responsible for credit verification and authorization. It has knowledge of the Service Composition Information to conduct the accumulation of charge reservations (or claims) that belong to a particular service session. Charge aggregation is possible by correlating charging requests with a specific chargingKey that belongs to a service component and a "root" chargingKey that belongs to the service session composition. Unlike conventional postpaid billing where charge records are produced by rating engines, here charge records are produced by the `Charge Aggregator`. The rationale behind this design choice is related to the assigned intelligence of the `Charge Aggregator` to keep track of all states of all charging sessions and to aggregate the charges of the involved components. Hence, this information is used to generate the charge records.
- `Balance Manager` – The `Balance Manager` manages and updates subscriber credit balances. When the subscriber credit balance reaches a certain pre-defined threshold, the `Balance Manager` informs the `Charge Aggregator` about the balance status so that appropriate action can be taken by the `Provisioning Agent`. For instance, the `Provisioning Agent` may decide to proceed with the service provisioning based on the good history of the subscriber in question or the `Provisioning Agent` may decide to immediately terminate the ongoing service provisioning. In practice, the `Balance`

Manager will be subject to a strong audit regime because it is responsible for managing the financial obligations and rights of the subscribers. It is therefore obvious to consider the Balance Manager as a separate system component to simplify the implementation of this component. This also narrows the auditing scope later on, by taking into account only the Balance Manager and its corresponding Balance Database. In other words, segmentation makes auditing easier and compliance simpler.

- Rating Engine – The Rating Engine conducts the calculations for charge reservation for the individual service components based on the incoming charge requests. The Rating Engine retrieves the tariff and discount information (i.e. user specific charging profile) from the Tariff & Discount Database for a specific End-user and calculates the costs for different service components involved. The Rating Engine retains the tariff and discount information for the entire SACLC. Hence, it does not need to switch back to the Tariff & Discount Database during a service session. At the end of a service session the corresponding charging profile can be discarded from the Rating Engine. Today, software vendors often provide rating engines as stand-alone system components, which can be then integrated into an overall billing architecture. Thus, it is preferable to consider the Rating Engine as a system component within the Billing Agent to increase flexibility of billing system implementation.
- Balance Database – The Balance Database stores the credit balance information of Subscribers. When a charging session starts, the Balance Manager retrieves the current credit balance status of a particular End-user and his associated Subscriber from the Balance Database. The state of the credit balance changes during a charging session and this state is maintained by the Balance Manager. When the charging session terminates, the Balance Database is updated with the actual total cost of the service session. The credit information can be made accessible to Subscribers/End-users as to provide them with real-time information about their credit balance. We note that access to credit information should be managed in a secure manner to protect the database from undesired violations such as unauthorized credit balance manipulation.
- Charge Record Database – The Charge Record Database stores charge records for invoicing and auditing purposes.

A charge record is sent by the Charge Aggregator after the termination of a charging session.

- Tariff & Discount Database - The Tariff & Discount Database stores the information bound to the service portfolio offered by the Service Provider. A tariff and discount plan can be tailored down to a Subscriber or End-user specific profile according to the SLA signed between the Subscriber and the Service Provider.

Figure 7.3 gives an overview of the computational objects comprised by the Billing Agent and the interfaces between these objects.

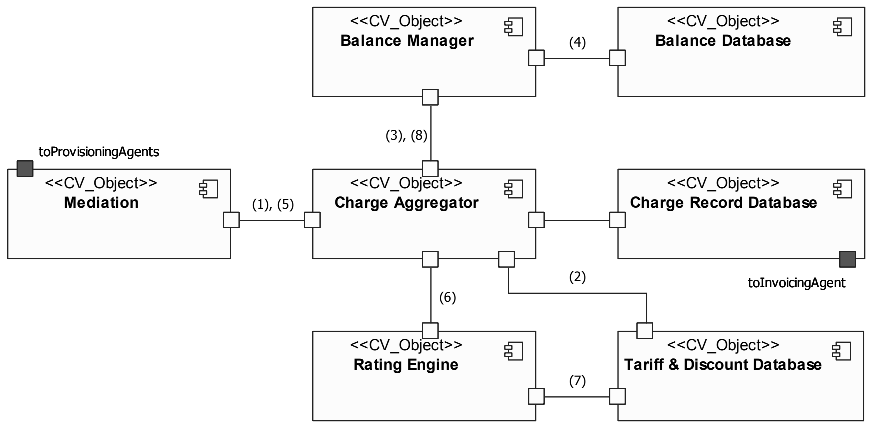

Figure 7.3. Refinement of the Inter-domain Billing System into System Components

When a credit verification request arrives from the Provisioning Agent via the Charging Request interface, the Mediation forwards this message to the Charge Aggregator (1). Next, the Charge Aggregator retrieves a service charge estimation of the requested composite service from the Tariff & Discount Database (2). Based on this estimation, the Charging Aggregator requests the Balance Manager to verify the credit balance of the Subscriber in question (3), which in turn retrieves the credit balance from the Balance Database (4). If the credit balance is sufficient, the Charge Aggregator returns a "positive" response to the Mediation, which then forwards the response to the Provisioning Agent. After the credit verification phase, different credit authorizations for the involved service components can be processed. Here, it is assumed that the Provisioning Agent and 3rd Party Agent may consist of many sub-agents. These sub-agents can send credit authorization requests directly to the

Billing Agent through the Charging Request interface. The advantage of such an approach is to increase the autonomy of sub-agents at the level of network elements to request credit reservation. This approach is also inline with the guidelines described in [3GPPTS23.228]. A credit authorization request from a sub-agent means that a network element autonomously sends an authorization request to the Billing Agent to ask if it is allowed to provision a service component for a quantity of service units (e.g. megabytes, minutes etc.) (5). Upon this request, the Charge Aggregator requests the Rating Engine to calculate the charge for this particular service component (6). To do so, the Rating Engine retrieves the End-user specific tariff and discount plan from the Tariff & Discount Database (7). Once the component charge is known, the Charge Aggregator requests the Balance Manager to create a credit claim from the current credit balance that is retained in the Balance Manager for this particular End-user (8). During the service session, subsequent service component reauthorization requests from a sub-agent (interim charging request) can result in new credit claims and thus affect the level of credit balance kept in the Balance Manager. When the sub-agent terminates its service component provisioning, a final usage record is sent to the Billing Agent, based on which, the Balance Manager can make a final adjustment to the managed credit balance for that subscriber. Once all final usage records of a composite service session have arrived, the Charge Aggregator requests the Balance Manager to adjust the credit balance accordingly and a new credit balance status is written to the Balance Database. Also, the Charge Aggregator produces a charge record for the service usage of the composite service session and stores this in the Charge Record Database.

The above brief explanation describes an example scenario of a credit verification request for a single composite service and a service component authorization for a single service component. It is clear that the Billing Agent needs to conduct the charging process for multiple composite service sessions, multiple service components and multiple End-users in real-time.

The following sections will go through the four phases of the SACLC to provide more details of the refinement of the Billing Agent. At each phase of the SACLC, the involved system components and their interactions at the interfaces are discussed.

7.3.2 Credit Verification

The purpose of *Credit Verification* is to find out whether the Subscriber's credit balance is sufficient to allow the provisioning of a requested service. When a credit verification operation arrives at the Mediation, it is forwarded to the Charge Aggregator. The format of the credit verification request message is a data type preserving the structure of the service composition, for instance using the Extensible Markup Language (XML). The Charge Aggregator looks at the <serviceID> in the <serviceSessionComposition> of the request message, then tries to retrieve the estimated charge of the requested composite service session from the Tariff & Discount Database. The reason to estimate the charge is because the duration of the requested service session is not known before hand (e.g. the user might terminate a service session at anytime). From a business perspective, it is desirable to ensure that the Subscriber has a minimum credit to be able to request a certain type of composite service. For instance, to be able to watch TV-on-Demand, the Subscriber should have, say, at least 5 Euro on the credit balance. For a phone call, the minimum credit would be 1 Euro. Charge estimation for different types of (composite) services can be pre-defined and stored in the Tariff & Discount Database. Based on the estimated charge, the Charge Aggregator requests the Balance Manager to verify the Subscriber's credit balance.

If the credit balance is sufficient, the Balance Manager returns a "positive" response (<balanceStatusValue = True>). In turn, the Charge Aggregator returns a "positive" credit verification response to the Mediation, which then forwards this response to the Provisioning Agent.

If the credit balance is not sufficient), the Balance Manager returns a "negative" response (<balanceStatusValue = False>). As a result, the Charge Aggregator returns a "negative" credit verification response to the Mediation, which then forwards this response to the Provisioning Agent.

It is important to note that both the credit balance status and the service session composition are retained in the Balance Manager and the Charging Aggregator, respectively during the rest of the SACLC. This helps to increase the performance of both system components because they do not need to go back to the databases.

Figure 7.4 depicts the system components and interfaces necessary to support the credit verification process. The shaded ports attached to the Mediation indicates the external ports outward the Billing Agent. Figure 7.5 shows the sequential interactions between the involved system components. Figure 7.6 shows the detailed specification of the interface signatures between these components. The interrogation interface signatures (<CV_InterrogationSignature> and <CV_TerminationSignature>) are used to ensure dependability in the interactions between system components. This implies that each request operation explicitly requires a response in the opposite direction. In terms of billing a business process, this mechanism allows for clear separation of concerns between system components. For instance, the `Balance Manager` is modeled as a "credit authorizer" whose main responsibility is "telling" the `Charge Aggregator` if the `Subscriber`'s credit balance is sufficient and to update the credit balance once a service session is terminated. Hence, the separation of the `Balance Manager` increases the flexibility to delegate its function to a payment service provider in a real-life business environment.

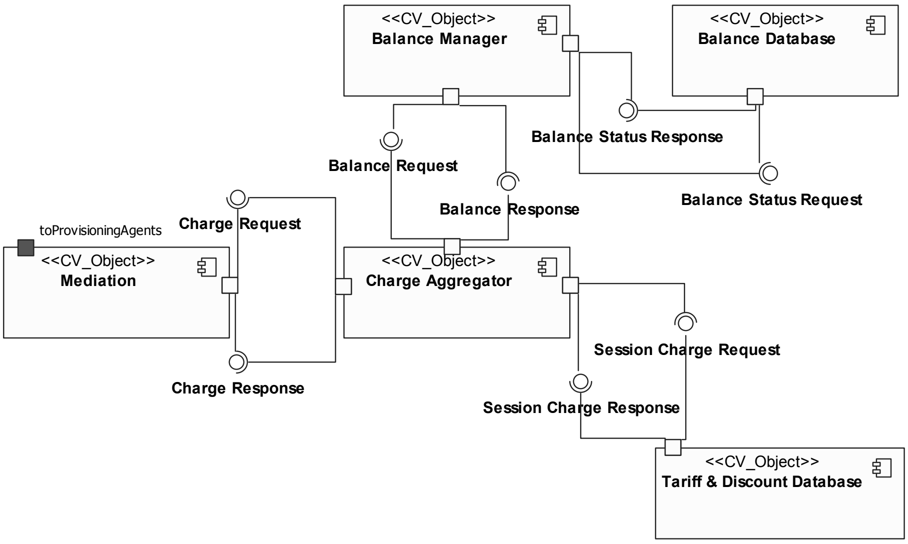

Figure 7.4. System Components and their Interfaces supporting the Credit Verification process

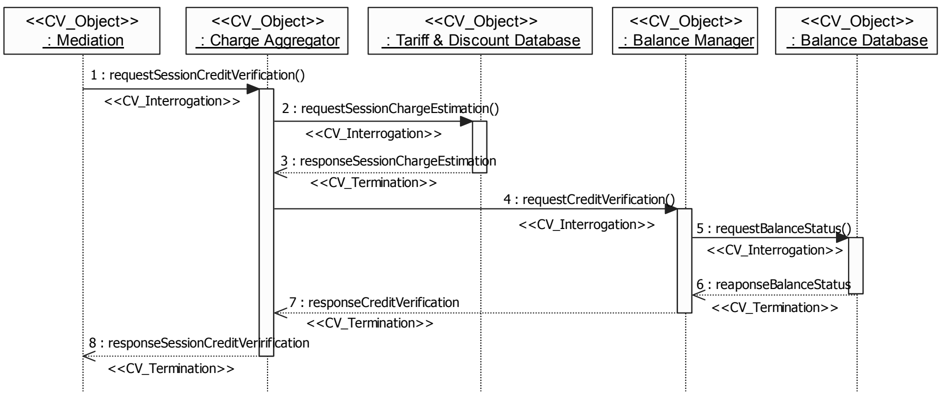

Figure 7.5. Interactions between System Components involved in the Credit Verification process

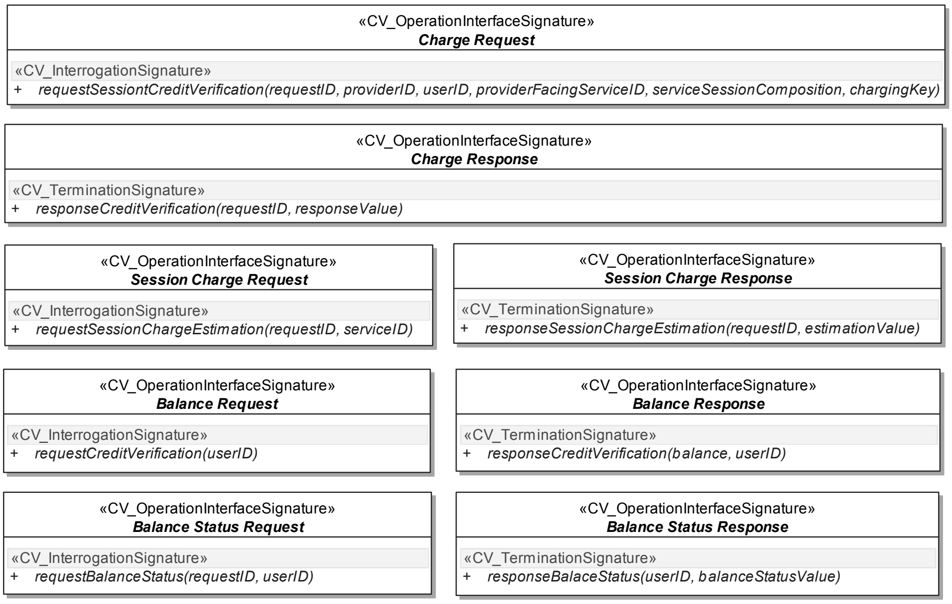

Figure 7.6. Detailed specification of the Interface Signatures – Credit Verification

7.3.3 Accounting and Charging Instantiation

The purpose of the *Accounting and Charging Instantiation* is to authorize the individual service components so that service provisioning of these components can be initiated. Five system components are involved in this phase: `Mediation`, `Charge Aggregator`, `Rating Engine`, `Tariff & Discount Database` and `Balance Manager`.

When a credit authorization request arrives at the `Mediation`, it is forwarded to the `Charge Aggregator`. A credit authorization request allows a (sub) provisioning agent (i.e. a network element) requesting authorization to provision a service component. This operation provides the provisioning agent with a possibility to submit authorization, which depends on the `<serviceUnit>`. A service unit may be some data volume (e.g. megabyte), certain time units (e.g. second) or a number of internet pages, etc. In fact, this service unit entails the frequency of charge for a service component. The `Service Provider` may enforce (sub) provisioning agents to apply a specific frequency of charge on a `Provisioning Agent` or its sub provisioning agent. For instance, the frequency of charge for a connectivity service component would be once every 10 minutes, whereas the frequency of charge for a TV-on-Demand service would be once every 5 min.

In order to proceed with the credit authorization request, the Charging Aggregator needs to know the cost of the service component. Therefore, it requests the Rating Engine to calculate this cost. The service component cost depends on: the component tariff, the assigned discount and the service unit. Furthermore, the tariff and discount plan for a specific Subscriber and the relevant End-user may depend on a number of other parameters such as time of day, quality of service, current location of the End-user, etc. These parameters are defined in a so-called "tariff & discount profile" according to the SLA between the Service Provider and the Subscriber. Upon receiving the component rating request <requestComponentRating>, the Rating Engine retrieves the End-user's profile from the Tariff & Discount Database to calculate the cost. Thereafter, the Rating Engine returns a component rating response <responseComponentRating> to the Charging Aggregator, which includes the calculated cost <ratingValue = value>. Note that the End-user's tariff & discount profile is retained within the Rating Engine during the entire SACLC.

Now the cost of the service component is known, the Charge Aggregator can ask the Balance Manager to create a credit reservation <requestComponentCreditReservation> by indicating the required amount <reservationValue = value>. Based on the current credit balance status of the End-user, the Balance Manager creates a credit reservation and provides a response to the Charging Aggregator <responseComponentCreditReservation> indicating that the credit reservation has been accepted thus, <responseValue = True>.

Figure 7.7 depicts the system components and interfaces necessary to support the service instantiation process. Figure 7.8 shows the sequential interactions between the system components involved. Finally, Figure 7.9 shows the detailed specification of the interfaces between these components.

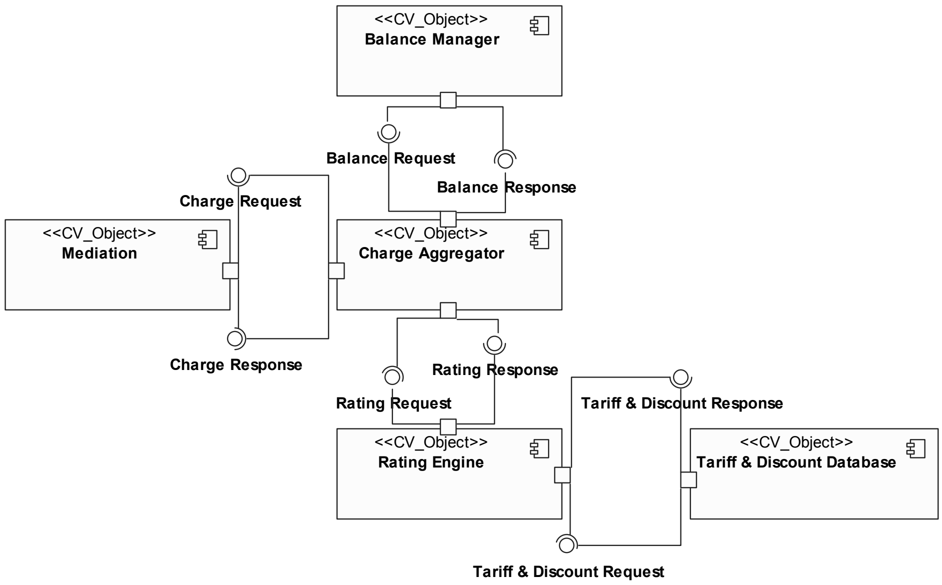

Figure 7.7. System Component and Interfaces supporting the Accounting and Charging Instantiation process

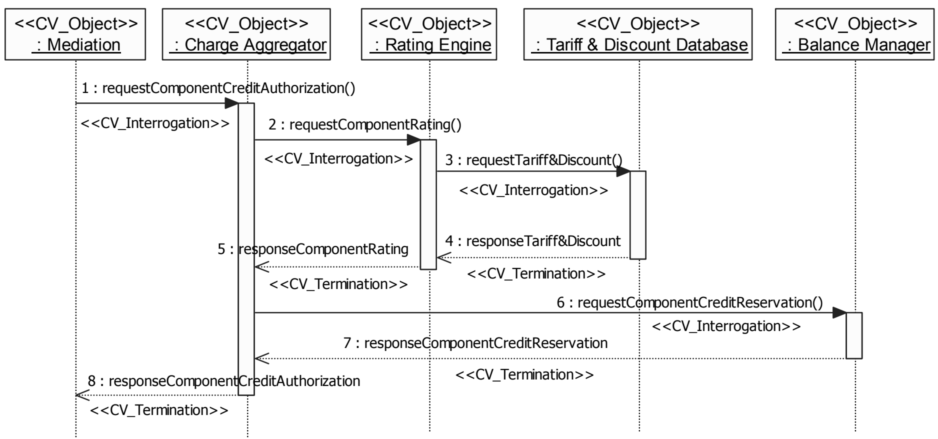

Figure 7.8. Interactions between System Components involved in the Accounting and Charging Instantiation process

Figure 7.9. Detailed specification of the Interface Signatures – Accounting and Charging Instantiation

Once all preparation for charging is done (i.e. service provisioning of all involved service component has been authorized), the `Provisioning Agent` can start the service provisioning. The trigger to start service provisioning can propagate down to different sub-agents. The manner in which the `Provisioning Agent` starts the provisioning of a requested composite service depends mainly on the orchestration strategy. For instance, it is necessary to establish a connectivity service session prior to a TV-on-Demand service session.

7.3.4 Accounting and Charging

In the previous phase, service provisioning has been authorized for a certain number of service units. The purpose of the *Accounting and Charging* phase is to reauthorize the individual sub-agents to continue with their service provisioning. Hence, during this phase, subsequent credit reauthorization requests will be sent from the `Provisioning Agent` and `3rd Party Agent` to the `Billing Agent`.

The handling of credit reauthorization requests arriving at the `Mediation` in this phase is similar to the previous phase. When a credit reauthorization request operation `<requestCreditReAuthorization>` arrives at the `Mediation`, the request message is forwarded to the `Charge Aggregator` via the `Charge Request` interface. The `Charge Aggregator` replies to this message at the `Charge Response` interface with a credit reauthorization response, which can be either "positive" or "negative" depending on the remaining credit balance status.

As the `Charge Aggregator` retains and keeps track of the costs of all continuing composite services, it can easily associate a credit reauthorization request of a specific service component with the cost, which has been calculated previously by the `Rating Engine`. Based on this (pre-calculated) cost, the `Charge Aggregator` requests the `Balance Manager` to create an interim credit reservation `<requestCreditReservation>`. This approach contributes to the efficiency of the `Charging Aggregator` and at the same time releases the load of the `Rating Engine` because no re-rating is necessary. Here, it is assumed that the service units contained in credit reauthorization requests originating from a sub-agent, remain the same. We note that there are special occasions where the `Charge Aggregator` needs to ask the `Rating Engine` to conduct a new rating. For instance, when a credit reauthorization request arrive at the boundary of two time zones where different tariff and discounting are applied. The rating step has been discussed in the previous section.

When the `Balance Manager` receives the credit reauthorization request `<requestComponentCreditReAuthorization>`, this request is held against the latest credit balance status so that a new credit reservation can be deducted. The `Balance Manager` returns a response `<responseCreditReservation>` to the `Charging Aggregator`, which can be either "positive" (i.e. sufficient credit balance) or "negative" (i.e. insufficient credit balance). In turn, the `Charging Aggregator` provides a response `<responseCreditReAuthorization >` to the `Mediation`. In order to create credit reservations, the `Balance Manager` does not need to distinguish the difference between credit authorization and credit reauthorization. This helps to simplify its functionality and at the same time to increase its efficiency.

Figure 7.10 depicts the system components and interfaces necessary to support the service accounting and charging process. Figure 7.11 shows the sequential interactions between the system components involved. Figure 7.12 shows the detailed specification of the interface signatures between these components.

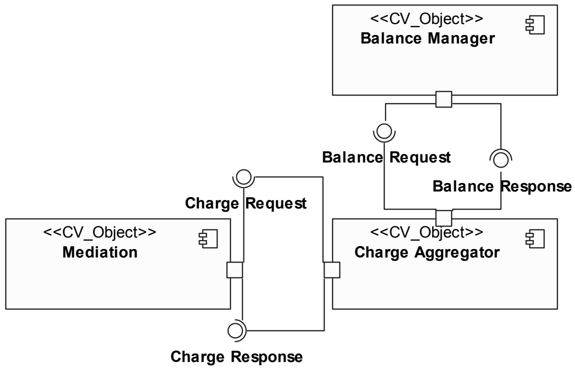

Figure 7.10. System Components and Interfaces supporting the Accounting and Charging process

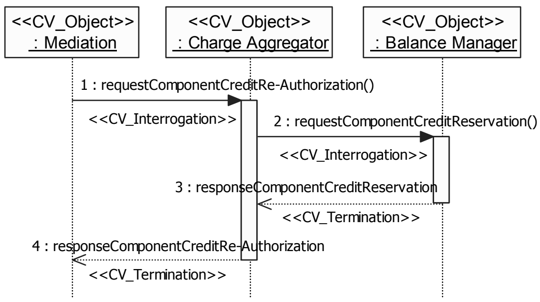

Figure 7.11. Interactions between System Components involved in the Accounting and Charging process

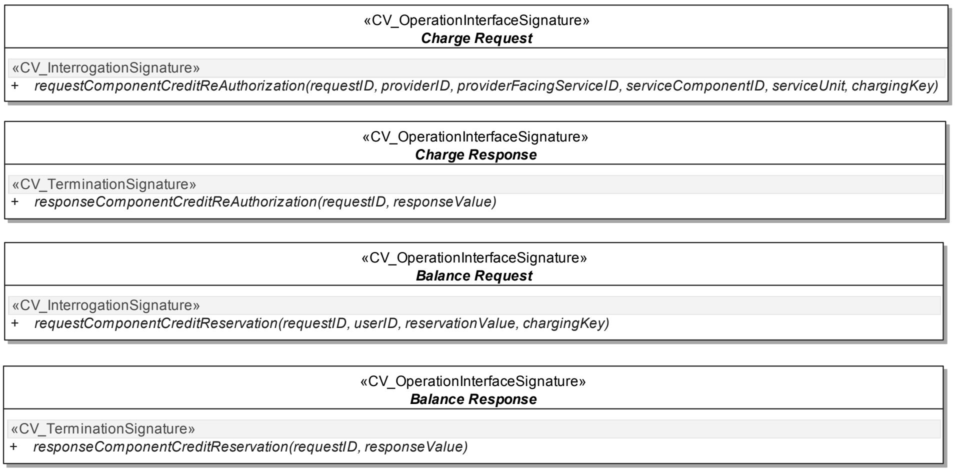

Figure 7.12. Detailed specification of the interface signatures – Accounting and Charging

Interim accounting and charging of composite services becomes complex when the composition of the ongoing composite service session changes (i.e. adding or removing service components) or when there is a tariff dependency between the involved service components. In such a situation, two major impacts on the online charging process are seen: 1) possible tariff changes of the remaining service components and 2) adjustment of the user credit balance. To deal with these issues, we would propose three charging strategies.

1. A first strategy is to apply a tariff-dependent charging scheme. Here, the Charging Aggregator must conduct credit reauthorization for the involved service components whenever the service composition changes. The advantage of this strategy is that it allows the Charging Aggregator to adjust tariffs in near real-time, which can be desirable from a business viewpoint. The trade-off is that this strategy might induce extra load on both the Charging Aggregator and the Rating Engine. 2. A second strategy could be to use a tariff-independent charging scheme. Here, the Rating Engine can apply a fixed tariff for each chargeable service component and a fixed tariff for each awardable service component (i.e. component from which an user receives compensation such as advertising). The advantage of this tariff-independent scheme is that tariff recalculation is avoided, thus avoiding extra load on the Rating Engine. 3. A third strategy is to apply a hybrid charging scheme where a combination of the two strategies is used. For example, the tariff of a connectivity service component can be fixed, whereas the tariff of a Video-on-Demand service component depends on the returns of an advertising service component. If the advertizing component is removed

from the service session, the `Rating Engine` only needs to adjust one tariff for the TV-on-Demand component.

7.3.5 Accounting and Charging Termination

In a dynamic service provisioning environment, participating service components in a composite service session might be terminated in an arbitrary order. The termination order depends on the service orchestration and service delivery logics of the `Provisioning Agent` [TMFSDP08, SPICE08]. The `Billing Agent` is not in control of the termination of service provisioning. Instead, it receives final usage records at the `Mediation` and is expected to stop the charging process for the associated service components or service session in the most logical and secure way. Hence, in this phase, it is assumed that whenever a provisioning (sub) agent terminates its service provisioning, it will generate a final usage record. The final usage record contains (amongst other details) the information about the service usage of the total session, which can be either an incremental or a cumulative service usage.

Two termination scenarios are possible:

- The `Billing Agent` first receives a service session charging termination request `<requestSessionChargingTermination>` and then the corresponding component charging termination requests `<requestComponentChargingTermination>`.
- The `Billing Agent` first receives different component charging termination requests and then the corresponding service session termination request. This occurs, for example, when a service component is removed from a composite service session.

Regardless of which of the above scenarios is used, the `Billing Agent`, or more precisely, the `Charging Aggregator` will process every component charging termination requests that arrives. In parallel, it keeps track of all terminated service components. Once the charging processes of all service components have been terminated, the charging process of the corresponding service component can also be terminated.

In more detail, when a final usage record arrives at the `Mediation`, the `Mediation` requests the `Charging Aggregator` to terminate the charging process of this particular service component `<requestComponentChargingTermination>`. As the usage of the last reauthorized period may be less than the reauthorized service usage `<serviceUnit>` in the *Accounting and Charging* phase (see §7.4.4), the `Charge Aggregator` requests the `Rating Engine` to re-calculate the cost of the final usage `<requestComponentRating>`. Upon this request, the `Rating Engine` returns a response

<responseComponentRating>, which contains the calculated cost of the final usage <responseValue>.

Next, the Charging Aggregator requests the Balance Manager to release the current credit reservation of the service component in question <requestComponentCreditClearance>. The Balance Manager compares the actual cost of the final usage <finalValue> and then it adjusts the credit reservation with this final cost. This mechanism allows the Balance Manager to manage the Subcriber's credit balance appropriately in accordance with the actual service usage. Once the credit reservation of a service component has been released, the Balance Manager returns a confirmation <responseComponentCreditClearance> to the Charge Aggregator and updates the Balance Manager with the actual total cost of the service component usage <updateBalanceStatus>.

The above termination process has a recurrent character because it repeats itself for individual service components involved in a composite service session. Once the charging termination of the last service component in a composite service session has been processed, the Charge Aggregator sends a notification via the Mediation to the Provisioning Agent to report that the service session charge is (properly) terminated. Finally, the Charge Aggregator generates a charge record for the entire composite service session and stores it in the Charge Record Database <storeChargeRecord>.

Figure 7.13 depicts the system components and interfaces necessary to support the service accounting and charging termination process. Figure 7.14 shows the sequential interactions between the system components involved. We note that invocation operations are used to store information on the Balance Database and Charge Record Database due to the "one-way" character of theses operations. Figure 7.15 shows the detailed specifications of the interfaces between these components.

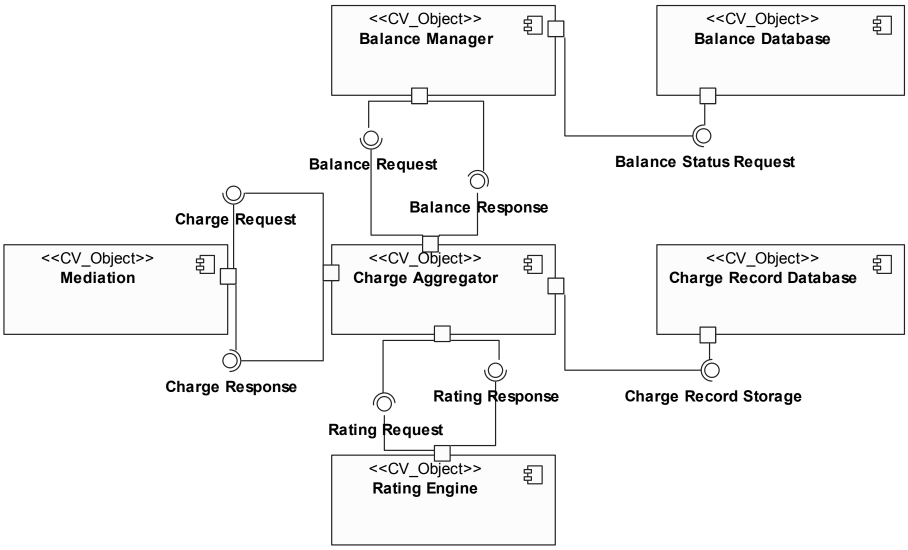

Figure 7.13. System Components and Interfaces supporting the Accounting and Charging Termination process

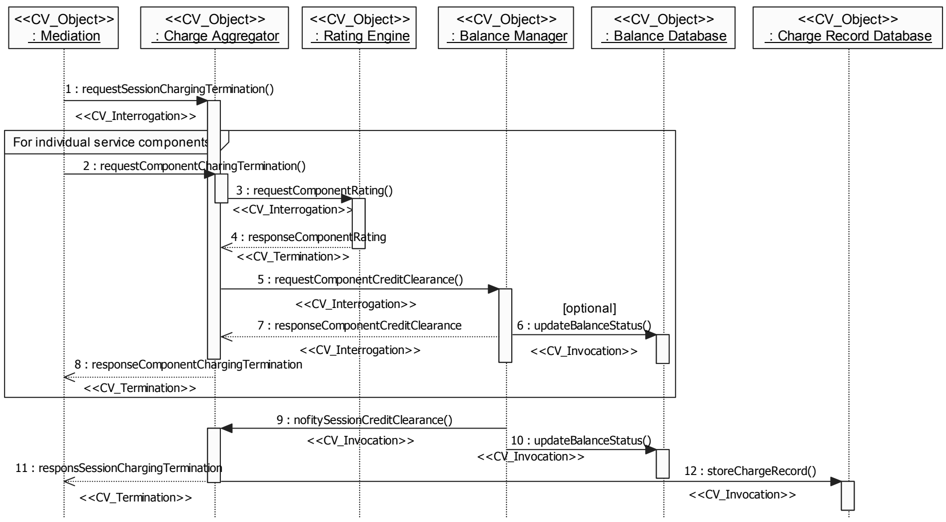

Figure 7.14. Interactions between System Components involved in the Accounting and Charging Termination process

Figure 7.15. Detailed specification of the Interface Signatures – Accounting and Charging Termination

7.4 Performance Consideration

Most telecommunication networks are subject to high peak loads during exceptional events such as natural disaster alarms (e.g. an earthquake), the Olympic Games, New Year Eve celebrations, etc. In 2009, a major telecommunication provider in the Netherlands reported processing 22 million SMS (Short Message Service) messages and 6.4 million phone calls in a 24 hour period [Vodafone09]. The peak load was found to be between 21h00 and

02h00. If we assume that all SMS messages and phone calls occurred during the peak period of 4 hours, the next estimation can made:

$$\text{Average Rate}_{SMS} = 22.000.000/(4x60x60) \cong 1.528 \text{ sms's / sec}$$
$$\text{Average Rate}_{call} = 6.400.000/(4x60x60) \cong 444 \text{ calls / sec}$$

During the inauguration of President Barack Obama on January 20th 2009, Akamai, a large content service provider reported to process 7 million concurrent live video streaming sessions worldwide through its 30.000 servers [Akamai09]. Assuming that all 7 million composite service sessions were successfully established within the first 60 seconds before the inauguration, the next session estimation can be made:

$$\text{Average Rate}_{session} = 7.000.000/60 \cong 116.667 \text{ sessions/sec}$$

Let us further assume that a video streaming composite service session consists of three sub-service components: connectivity, video stream and an advertising banner. Hence, the request rate of the sub-service session would be three times higher than the rate of the composite service session:

$$\text{Average Rate}_{sub\text{-}session} = 3x116.667 \cong 350.000 \text{ session/sec}$$

In the Obama inauguration case, a supporting billing system would need to process up to 466.667 charging events per second (i.e. 11.667 sessions + 350.000 sub-sessions) during the *Credit Verification* and *Accounting and Charging Instantiation* phase. Moreover, interim accounting and charging occurs during the *Accounting and Charging* phase, where there is no further need to setup billing for composite service sessions. Hence, assuming that the supporting system would process 350.000 charging events per second indicates a frequency of charge of once every second for a particular sub-service session. Regarding the *Accounting and Charging Termination* phase, similar performance quantities are expected as for the *Credit Verification* and *Accounting and Charging Instatiation* phase (i.e. up to 466.667 charging events per second) because terminations need to be done for individuals sub-sessions and then individual composite service sessions.

Table 7.1 shows a summary of indicative performance quantities from the above real-life examples. The indication for Germany is a rough extrapolation based on the subscriber ratio between the Netherlands and Germany of the telecommunication provider in question (Netherlands: 4 million subscribers v.s. Germany: 35 million subscribers, as of 2008) [Vodafone09].

Vodafone - New Year Eve 2009	Germany (10xNL)	Netherlands
Number of SMS messages		22*10E6
Number of phone calls		64*10E5
Average SMS per second		1.528
Average calls per second		444
Total charge events per second	**17.255**	**1.972**
Akemai Content Distribution - Barack Obama's Inauguration 2009		**Worldwide**
Number of concurrent sessions		7*10E6
Average rate of composite service session		116.667
Number of components per session		3
Average rate of sub-service session		350.000
Total charge events per second		**466.667**

Table 7.1. Indicative performance quantities from real-life cases

The above indicators are not considered as hard performance requirements (see scope in Chapter 1). Nonetheless, it is important to have in mind some indicative performance quantities to support design decisions. In particular, it is important to have some reality check on the expected capacity of the proposed billing system in order to handle real-life situations.

Real-time charging is a computationally intensive process which imposes high performance requirements on the `Billing Agent`. In order to achieve high-performance, attention should be paid to both the design aspect as well as the deployment aspect.

Regarding the design aspect, the concept of separation of concerns has been applied to the refined model of the `Billing Agent`. In this model, the `Charging Aggregator`, `Rating Engine` and `Balance Manager` are computational intensive system components. They are divided into a small set of basic functions such as: charge aggregation, rating and balance management accordingly. This approach contributes to an efficient implementation and adequate performance of these system components.

Regarding the deployment aspect, the `Charge Aggregation`, `Rating Engine` and `Balance Manager` are expected to be resource consuming in terms of CPU (Central Processing Unit) power and working memory. Furthermore, all of these system components will conduct read/write operations into their corresponding databases with very high access frequency. Recent bench marking reports from the industry have revealed promising technologies that are available to implement and deploy real-time billing systems. For instance, IBM reported its benchmarking results for a real-life production like billing system comprising of four distributed servers, which utilize POWER5+processors [IBM07]. The test results showed a real-time capacity of 11.500 charge events per second. Another test case from McObject

[McObject07] reported a benchmark of an in-memory database system based on a 160-core Linux-based SGI® Altix® 4700 server, which allows for around 88 million queries per second.

The real-life benchmarks mentioned above provide a good indication of both the technical as well as the economical feasibility of being able to implement the `Billing Agent` in practice. With respect to the Vodafone case with a maximum of 17.255 million charge events (see §7.2), it can be seen that a single instance of the `Billing Agent` in combination with a reasonable hardware configuration would be sufficient to server a large subscriber base. For the Obama case with 466.667 million charging events, it will be a bit of a problem to be able to handle all the charging events with a single `Billing Agent`. However, to meet the scalability requirements of real-time billing and charging in such a case, charge sessions need to be distributed over multiple `Billing Agents`. Here, an entire charging process for a particular composite session needs to be handled by a single `Billing Agent`.

7.5 Conclusion

This chapter presents the `Inter-domain Telematics System` from the computational viewpoint. Attention is paid to the functional decomposition of the `Billing Agent` consisting of the system components and their interfaces needed to support the SACLC (Service Accounting and Charging Life Cycle), independently of its distribution and the eventual implementation technology.

Regarding research questions Q1 the `Billing Agent` is refined into the system components: `Mediation`, `Charging Aggregator`, `Balance Manager`, `Rating Engine`, `Balance Database`, `Charge Record Database` and `Tariff & Discount Database`. The proposed refinement allows for flexibility to select system components from different vendors in the implementation stage.

Regarding research question Q3 this chapter provides detailed specification of the interfaces between the `Billing Agent` and other (external) provisioning system. At the same time it also provides detailed specification of the interfaces between the system components within the `Billing Agent`. These interfaces can be adopted by standard body such as 3PGG to accelerate standardization of interim accounting and charging of composite services.

Regarding research question Q5 this chapter proposes an interim accounting and charging mechanism for dynamic provisioning of composite services. One of the complexities that the `Billing Agent` needs to deal with is the billing of composite services in real-time. This aspect is addressed by having the ability to aggregate and merge different charges from the same service session.

Further, the `Billing Agent` is designed with the capability to adjust and update `Subscribers`' credit balance status based on interim credit reservations. This allows for decreasing financial risks from the `Service Provider`'s perspective.

The design choices made, based on the intuitive separation of concerns helps to master billing complexities and allows large scale events to be handled. With current advanced hardware technology, especially in-memory databases, deployment of a single `Billing Agent` as proposed would be sufficient to support large telecommunication service providers.

Chapter 8 – Design Evaluation

This chapter evaluates the design of the billing system. It discusses how the design of the proposed Inter-domain Billing System meets the desired requirements stated in Chapter 3. This includes the two main categories: 1) business requirements and 2) billing system requirements. The latter consist of: functional requirements and data requirements. The evaluation will highlight the advantages and discuss possible trade-offs of the chosen design.

8.1 Introduction

A billing system and its models must capture business requirements to justify its business relevance. In addition, these billing models must also meet system requirements to justify desired functional behavior and performance of the proposed billing system. There are several software evaluation methods that permit evaluation of specific software system quality and allow engineering tradeoffs to be made among possibly conflicting quality goals. An overview of software evaluation methods can be found in [Mattsson06]. In general, the evaluation methods found in the literatures provide a framework to evaluate software quality aspects such as modifiability, flexibility, maintainability, extensibility and integrability. These methods often restrict themselves to a particular class of systems and focus on only one quality aspects. For instance, the ALMA method (ALMA) [Bengtsson04] restricts itself to the modifiability aspect of business information system. More precisely, the ALMA method provides only insight on future adaptation issues of specific information architectures and their related impact.

In this work we do not apply these standard evaluation methods because the scope of our requirements (see Chapter 3) is restricted to business and functional aspects, where these methods are not suitable to be applied. Instead, a pragmatic approach is used to evaluate the design of the proposed billing system based on intuitive reasoning. The purpose of this chapter is to discuss *how* the design of the Inter-domain Billing System by means of the different viewpoints has met the desired requirements as stated in Chapter 3. In particular the four billing models are considered: contact information model, subscriber-facing billing information model, partner-facing billing information model and the service composition model.

The next sections present two parts of design evaluation. First, an evaluation on business requirements will be provided, which examines how the models have met the defined set of business requirements. Second, an evaluation on a set of functional requirements and data requirements will be discussed, which examines how the billing models support the defined set of functional requirements and data requirements, respectively.

8.2 Evaluation of Business Requirements

It must be possible to support both static and dynamic business relationships between customers and service providers (BR1)

In Chapter 3, the customer role has been mentioned as a role that has a business relationship with a service provider. However, the description of the customer role is not accurate enough to enable flexible business role model. In order to support dynamic nature of business relationships, the customer role has been described more precisely in Chapter 4 based on the subscriber role and the end-user role. This allows for the construction of a value network in which the subscriber is involved in payment and contract relationship with the service provider and the end-user is involved in a usage relationship with the service provider and/or a third party provider (see §4.1.2). To this extent, it is possible for the end-user to build up a static (long-term) as well as dynamic (i.e. short-term) usage relationships with the service provider in order to obtain desired services. For instance, a child may be allowed to consume services from a service provider on an irregular basis, based on the subscription of the parents.

Although the customer role has been "refined" into an end-user role and a subscriber role, dynamic relationships between subscribers and service providers still need to be enabled. Very often, the business relationship between a subscriber and a service provider is static (i.e. long-term). To establish a business relationship with the subscriber, the service provider usually obtains a payment contract signed by the subscriber to ensure that it can collect the money from the subscriber. The service provider may ask the subscriber to agree on a monthly automatic money transfer from the subscriber' bank account. This payment relationship is a major constraint, which makes dynamic relationships between subscriber and service providers impossible. To overcome this problem, the business role payment provider may be introduced. The payment provider acts as a linking bridge between subscribers and service providers. As a result, the payment provider pays the service providers on behalf of the subscriber. The payment provider role can be fulfilled by an independent party.

The Reference Business Role Model used in this thesis (see §4.1.2) does not include the payment provider role because this thesis mainly focuses on billing and not payment. However, the Reference Business Role Model is flexible enough to be extended with the payment provider role. More precisely, existing relationship between the subscriber and the service provider can be replaced by a business relationship between the payment provider and the service provider. In turn, a business relationship between a subscriber and a payment provider can be introduced. A successful commercial role out of such an extension of the Reference Business Role Model is Bango [Bango09].

Furthermore, the design of a `Billing Agent` is based on clear separation of concerns, where the real-time credit balance management function is assigned to a dedicated system component called `Balance Manager`. From a payment perspective, the `Balance Manager` acts as an "authorizer" or a gate keeper of the `Subscriber`'s credit. This system component can be assigned to the payment provider role.

Hence, it can be concluded that the proposed billing models supports both static and dynamic service provisioning to the end-user. Therefore, BR1 has been fulfilled.

It must be possible to support business relationships between service providers and third party providers (BR2)

The business relationship between a service provider and a third party provider is expressed in the Reference Business Role Model (see §4.1.2). In fact, the third party provider is a special kind of "service provider" that is involved in payment and contract relationship with the service provider. It is possible that the party that plays the service provider role is the same party playing the subscriber role toward the third party provider. This allows for the construction of the value network in which the third party provider is able to engage in both static and dynamic usage relationships with the end-user, depending on the service provider's needs.

The participation of third party providers has been explicitly taken into account in three design viewpoints, namely: enterprise viewpoint, information viewpoint and computational viewpoint. Hence, the Reference Business Role Model used in this thesis together with the proposed billing model support business relationships between service providers and third party providers.

It must be possible for service providers to outsource billing to other business partners (BR3)

In Chapter 5, the billing provider role has been treated as an independent role in relation with other business roles that have been introduced in the Reference Business Role Model. The billing provider role is considered as an "enabling" role for supporting service provisioning, that is to provide billing to support service provisioning. The separation of billing from service provisioning has been kept consistently according to the eTOM Business Process Framework [TMFeTOM09]. This allows service providers who do not want to invest on costly billing infrastructure to outsource to a business partner, Billing Service Provider, specialized in billing.

As the separation the billing provider role has been defined clearly from the service provider role at the business level and the separation of the billing and service fulfillment has also been well-defined at the process level, it can be said that outsourcing of billing is possible with the billing system proposed by this thesis.

It must be possible for a third-party business partners (e.g. payment service provider also called "customer account provider") to pay service providers on behalf of the customers (BR4)

The subscriber role has been defined explicitly as a role which is responsible for the payment of services consumed by the corresponding end-user in the Reference Business Role Model. Different kinds of parties, for instance a person or an organization can be assigned to play the subscriber role (see §5.2.2). This allows for a flexible construction of end-user/subscriber/service provider relationships to enable many business scenarios. For example, a parent in a family can play the subscriber role, whereas the children can play the end-user role. As a consequence, the parent will be charged for all allowable services consumed by the children agreed in the contract between the parent and a particular service provider. Likewise, an employer (i.e. an organization) can play the subscriber role an employee can play the end-user role. This implies that the employer will pay all allowable services consumed by the employee.

Ultimately, the Reference Business Role Model can be extended with a payment provider role, which can be fulfilled by a business party, specialized in payment services (see also the evaluation of BR1). In this case this business party will act as an “authorizer” to allow for the credit authorization process to take place. It is assumed that this specialized party will have a one-to-many relationship with many service providers in order to provide a flexible authorization for the requested services from end-users. Hence, this thesis has satisfied the business requirement BR4.

Table 8.1 provides a summary of the above evaluation of the proposed billing system with respect to business requirements.

Business Requirement	Satisfied?	Argument
BR1 Supporting static and dynamic relationships between customers and service providers	YES	Clear separation of billing and payment in the design of the billing models. The Reference Business Role Model may be extended with the payment provider role.
BR2 Supporting business relationships between service providers and third party providers	YES	Service provider and third party provider have a bilateral static payment and contract relationship with each other.
BR3 Supporting Outsourcing of billing to other business partners	YES	Clear separation of the billing provider role and service provider role at business level as well as at process level.
BR4 Supporting third party business partners to pay service providers on behalf of the consumers	YES	Subscriber role can be played by an organization, which in turn can be an employer or a business party specialized in payment services.

Table 8.1. Summary of Business Requirement Evaluation

8.3 Evaluation of System Requirements

This section provides an evaluation of the system requirements posed on the proposed Inter-domain Billing System. The evaluation addresses two categories of requirements, namely: functional requirements and data requirements. It discusses how the proposed billing system has met a particular requirement and reason about the design choices that have been made in fulfilling the system requirements.

8.3.1 Evaluation of Functional Requirements

The billing system must be capable to verify the balances of all customers and offer this as a service to the provisioning system (FR1)

This requirement has been taken into account right at the beginning of the design. Credit verification has been explicitly defined as the first phase of the Service Accounting and Charging Life-cycle (SACLC), which is translated into the *Credit Verification* enterprise process in the enterprise viewpoint (Chapter 5). Consistently to the enterprise viewpoint, the *Credit Verification* process is supported by the behavioral specification of computational objects in the computational viewpoint (Chapter 7). These computational objects behave and interact with each other in a desired way to make sure that the credit verification of a subscriber account always takes place before a service session can start. Hence, this requirement has been satisfied by the proposed billing system.

Verification of credit balance results in an eventual permission for service provisioning. This permission depends on the business rules dictating the charge estimation for different types of composite services (see §7.3.2). Usually, service providers do not know the duration of a requested service session at forehand, but it is desirable to be able make a rough estimation of average session duration and the required minimum credit. The definition of such a business rule belongs to the domain of Customer Relationship Management (CRM), which is not considered in this work. Nonetheless, the proposed billing system provides the credit verification function to incorporate a generic set of credit verification business rules.

The billing system must support the exchange of billing related information between different domains of the service providers. The billing related information concerns service composition information, usage- and charge records (FR2)

The exchange of billing related information between different domains is addressed during the design of the interfaces in the computational viewpoint, namely: `Charging Request` interface and `Charging Response` interface (see §7.2). The first interface enables the exchange of the Service Composition Information between the service provisioning domain and billing domain. The second interface enables the exchange of billing related notifications such as "credit verification is OK" or "session charging termination is OK". Furthermore, these two interfaces also support the exchange of information (i.e. interim and final usage records) between two individual provisioning sub-systems in the provisioning domain and in the billing domain. Hence, this requirement is satisfied by the proposed billing system.

Currently, the reference real-time charging model proposed by the 3GPP initiative are being investigated by many research communities. One of the major shortcomings of this charging model is the lack of supporting the exchange of service composition information to deal with charging of composite services through the so-called Ro-interface [Le09a]. The `Charging Request` interface and `Charging Response` interface solve this shortcoming.

The billing system must be capable to correlate and to merge the charges belonging to the composite service provided by the various service providers (FR3)

The correlation and merging of charges that belong to a service session is necessary to determine the total cumulative charge during the service session and the total charge at the end of the service session. This requirement has been addressed in three viewpoints. In the enterprise viewpoint (Chapter 5), service composition has been proposed. Service composition forms the basic structure, which allows for the mapping of different charges onto the service composition. In the information viewpoint (Chapter 6), detailed information has been added to the service composition to allow for the correlation of charges based on the service components IDs and the corresponding charging keys. A charging key is a unique identifier of the charge corresponding to a composite service session or a service component (see §6.5). In the computational viewpoint (Chapter 7), the service composition is persisted in the `Charge Aggregator`. This component uses service composition to actually correlate and merge the charges of the same service session [Le09b]. Hence, this requirement is satisfied by the proposed billing system.

The billing system must be capable to present and to update incurred service session charges of the service session currently in progress (FR4)

This requirement is addressed in the computational viewpoint (Chapter 7). Providing information about the incurred service session charge during a service session can be considered as “added value” to the billing process. As the service composition is built up by atomic service components, each of which is associated with a tariff. It is thus possible to keep track and store the incurred service session charge of a service session. This is handled by the `Charge Aggregator`. Once the incurred service session charge is calculated at a certain point in time (based on interim charges), this information can be immediately stored in the Charge Record Database using the Charge Record Storage interface (see §7.4.5). Hence, this requirement is satisfied by the proposed billing system.

Recent advanced database technologies [Oracle07, McObject07] have shown their capability to process business relevant information in real-time. There are two possible implementation alternatives to provide an overview of service session charges in real-time. The first option is to provide access directly to the incurred charge information cached in the in-memory database. The trade-off of this strategy is the expected extra load on the Charge Aggregator. Moreover, providing direct access to the charging process within the Charge Aggregator arises security concerns about charging data integrity. The second option is to create a bridge between the charging information persisted in the in-memory database of the Charge Aggregator and the charging information stored in an on-disk database utilizing cache agents [Oracle07]. This option would help to relief the load on the Charge Aggregator. At the same time it would also take care of data security issues. The main trade-off of this last option is the information delay between the in-memory database and the on-disk database.

The billing system must be capable to present to each customer an overview of incurred service session charges of the recently terminated service sessions (FR5)

In the evaluation of the previous requirement, it is stated that the proposed billing system is capable of providing the information about incurred service session charges of the service session in progress. As the interim accounting and charging mechanism is explicitly recognized and process by the Charge Aggregator (see §7.4.5), which stores the final charge of a services session after all constituent final charges of belonging to a service session have been processed. This information can be provided to the subscriber as an overview of incurred service session charges of the recently terminated service session. Hence, this requirement is satisfied by the proposed billing system.

The billing system must be capable to present an overview of current customer balance (FR6)

The customer credit balance (or more precisely the subscriber credit balance) is managed by the Balance Manager (Chapter 7). This object keeps track of every charge of the subscriber credit balance due interim charges and final charges. The current credit balance is also stored in the Balance

`Database`, which can be provided to the subscriber in real-time. Hence, this requirement is satisfied by the proposed billing system.

We note that access management of the `Balance Database` must be managed in a secure manner due to security restrictions and data protection compliances. In the case that the `Balance Manager` is delegated to an independent financial institution such as an Payment Service Provider, the credit balance management is subjected to strict electronic money regulation such as the European Payment Service Directive (EPSD) [PSD07]. Both security aspect and electronic money compliancy are deliberately left out of scope in this work.

It must be possible to set and to adjust in the billing system the granularity of incurred service session charge increments at run time (FR7)

The capability to adjust the granularity of charge increments allows the service provider to manage financial risks. Depending on the estimated value of a service session or/and the subscriber profile, the service provider would apply a specific frequency of charge for a particular service session or even during a part of the service session. The adjustments of enterprise behavioral policies have been discussed in the Inter-domain Telematics Community Policies (see §5.5). Furthermore, the interim accounting and charging mechanism supported by the proposed billing system is independent from the policies applied to the frequency of charge. For example, in the last half of a soccer match, the service provider would decide to increase the frequency of charge because the tariff of the second half is higher than the first half. This allows for flexibility to vary the granularity of charge increments. Hence, this requirement is satisfied by the proposed billing system.

The billing system must inform the provisioning system whenever the customer's balance has exceeded a maximum or minimum threshold and whenever a service session charge has reached a certain limit (FR8)

The functionality to send a notification to the service provider's provisioning system when the subscriber credit balance has exceeded a maximum threshold (in case of postpaid) or a minimum threshold (in case of prepaid) allows the service provider to control financial risks (see §5.4.3). The service provider can decide whether the ongoing service session should be terminated or should be carried on. This decision can be based on the subscriber profile. For example if the subscriber has a trustworthy and loyal profile, the service provider may decide to continue with the service provisioning even though an "out-of-credit" notification has been received. The functionality to support this requirement has been specified in both the enterprise viewpoint (Chapter 5) and the computational viewpoint (Chapter 7). More precisely, in §5.4.3 the step <Reauthorization Credit Request> has been defined explicitly in the *Accounting and Charging* process. In Chapter 7, the corresponding operations <responseComponentCreditReservation> and <responseComponentCreditReAuthorization> have also been defined at the interfaces Balance Response and Charge Response, respectively. These two interfaces together enable sending out-of-credit notifications toward the Mediation, which then forward this notification to the service provider provisioning system. Hence, this requirement is satisfied by the proposed billing system.

Table 8.2 provides a summary of the evaluation of the functional requirements of the proposed billing system.

Billing Issue	Requirement	Satisfied?	Argument
Inter-domain Billing	FR1 Supporting verification of credit balances	YES	Credit verification function has been explicitly taken into account during the design. Credit verification is driven by business rules that belong to the CRM domain.
	FR2 Supporting exchange of billing related information	YES	Exchange of billing related formation is supported by the Charge Request and Charge Response interfaces.
Service Composition Information	FR3 Supporting correlation and merging of charges	YES	Correlation and merging of charges has been addressed consistently throughout the design. The service composition model forms the basic structure for charge correlation, whereas the Charge Aggregator uses this composition structure to conduct charge correlation and aggregation.
Interim Accounting and Charging	FR4 Providing an overview of incurred service session charges of the service session currently in progress	YES	Charge Aggregator persists the information about the incurred service session charges. This information can be written on the Charge Record Database, which can be accessed by the subscriber or the end-user in real-time.
	FR5 Providing an overview of incurred service session charges of the recently terminated service	YES	Information about service session charge of recently terminated service session can is kept on the Charge Record Database.

	sessions		
	FR6 Providing an overview of current customer balance	YES	Current credit balance status can be provided via the `Balance Database` under a secure regime.
	FR7 Supporting adjustment of the granularity of charge increments	YES	Proposed billing system supports interim accounting and charging mechanisms, which is independent from the frequency of charge as well as the amount of interim credit reservation.
	FR8 Supporting out-of-credit notification toward provisioning systems	YES	`Balance Manager` is obliged to generate an "out-of-credit" notification whenever the pre-defined credit threshold is reached.

Table 8.2. Summary of Functional Requirement Evaluation

8.3.2 Evaluation of Data Requirements

Customer – The billing system must store the information that represents real world customers (DR1)

The information representing real world customers is crucial for the billing process because it enables the identification of end-users and their corresponding subscribers. In turn, it ensures that the service charges can be effectuated with the appropriate subscriber account. In Chapter 6, the contract information model has been proposed (see §6.2), which presents real world subscribers and end-users. This model encompasses relevant contact information of both subscribers and end-users such as name, postal address and email address. Furthermore, the subscriber-facing billing information model (see §6.3) presents the relationships between the `serviceProviderID`, `subscriberID` and `userID` within the context of a service session usage. The decoupling of the subscriber role and end-user role allows for flexibility of role-based contact management. For instance, the subscriber is responsible for the payment of service usage, therefore invoices can be sent to the subscriber (e.g. a company) instead of the end-user (e.g. an employee). Hence, this requirement is satisfied by the proposed billing system.

Service Provider – The billing system must store the information that represents real world service providers (DR2)

The information representing real world service providers and third party providers enables identification of the parties involved in the service provisioning. The contact information model (see §6.2) also presents real world service providers and third party providers such as content provider or billing provider. This model encompasses relevant contact information of service providers and third party providers such as organization name, postal address and email address. Furthermore, the partner-facing billing information model (see §6.4) presents the relationships between the `serviceProviderID`, `3rdPartyProviderID` and `BillingProviderID` within the context of a service session provisioning. This billing information model provides the structure for organizing and storing partner charging and billing information based on which revenue sharing can be conducted. Hence, this requirement is satisfied by the proposed billing system.

Balances – The billing system must store the information about the balance of a customer. Each balance is associated with a representation of a real world customer (DR3)

Customer (or subscriber) credit balance information is crucial for real-time billing because credit verification and credit authorization depend on the status of this information. Credit balance information is subjected to strict security measures such as data access and data integrity. Therefore, it must be protected according to the applied compliant restrictions. Security aspects are not considered in this work. Instead, it addresses the informational and functional aspect of credit balance information. To this extent, the `Subscriber Credit Profile` information object encompassed by the subscriber-facing billing information model (see §6.3) is proposed, which represents the subscriber credit balance. This information is stored in the `Balance Database`. During a service session, the credit balance status associated with this session is kept within the `Balance Manager`. When the service session is terminated, the `Balance Manager` updates the `Balance Database` with a new balance status. Hence, this requirement is satisfied by the proposed billing system.

Service Session – The billing system must store the information that represents service sessions. Service sessions are representations of the "product" typically provided by one or more service providers to a single customer who requested that particular service session (DR4)

Service session information is essential for the accounting and charging of composite services. It expresses the relationship between the constituent service components in a composite service session. In Chapter 5 and 6, the service composition model has been presented from the enterprise viewpoint and the information viewpoint, respectively. The proposed service composition models are inspired by the TM Forum's Shared Information/Data (SID) model [TMF-GB922TMFGB922].

Moreover, each composite service session is composed of one or more service components. Each service component is assigned with a unique `serviceComponentID`, which is related to a unique `chargingID`. Based on the service composition and the acquired usage records, the corresponding costs of individual service components can be calculated and aggregation of individual charges can be conducted for a particular service session. Hence, this requirement is satisfied by the proposed billing system.

Service Session Charge – The billing system must store the information about the charges of a service session to be paid by the customer who requested the service session and to be received by the service providers who took the responsibility for provisioning that service session (DR5)

The information about the charges of individual service components during a service session is persisted within the `Charge Aggregator` as presented in §7.3. As the proposed billing system is designed to support interim accounting and charging, interim usage records that arrive at the interface of the `Mediation` are forwarded to the `Charge Aggregator`, upon which the `Charge Aggregator` asks the `Rating Engine` to calculate the charges of each usage record. During a service session the `Charge Aggregator` retains all charges of the involved service components. When the service session is terminated, the `Charge Aggregator` generates a charge record representing the service session charge consisting of different component charges. The charge record is stored in the `Charge Record Database` for invoicing and auditing purposes. Hence, this requirement is satisfied by the proposed billing system.

Resource Usage Charge – The billing system must store the information about a resource charge (DR6)

Resource usage charge is represented in §6.5 as the charge corresponding to a service component usage in the service session composition model. A service component charge is uniquely identified by its `chargingKey`, which is linked to the service session `chargingKey`. As a result, there is a one-to-one projection between the real world resource hierarchy and the charging keys hierarchy. This allows for derivation of service session charges from the resources usage charges. At the same time, the combination of resource hierarchy and corresponding charging keys hierarchy (i.e. the structure and relationships between charging keys) also provides business relevant information which is used for revenue sharing between the involved partners. Hence, this requirement is satisfied by the proposed billing system.

Table 8.3 provides a summary of the above evaluation of the proposed billing system with respect to data requirements.

Billing Issue	Requirement	Satisfied?	Argument
Inter-domain Billing	DR1 Supporting information that represent real world customers	YES	Contact information model presents relevant contact information of real world subscribers and end-users. In addition, the subscriber-facing billing model presents the relationships between the involved parties in the context of a service session usage.
	DR2 Supporting information that represent real world service providers	YES	Contact information model presents relevant contact information of real world service provider and third-party providers. In addition, the partner-facing billing model presents the relationships between the involved parties in the context of a service session provisioning.
	DR3 Supporting information about the balance of the customer	YES	Subscriber-facing billing model encompasses (among others) the `Subscriber Credit Profile` information object, which represents the balance of the subscriber.
Service Composition Information	DR4 Supporting information that represent service session	YES	Service composition model represents the information about the constituent service component and their relationships in a composite service session. Moreover, the service composition model is inspired by the TM Forum's Share Information/Data (SID) model.
Interim Accounting and Charging	DR5 Supporting information about the charges of a service session	YES	Information about the charges of individual service components during a service session is persisted within the `Charge Aggregator`. When the service session is terminated, the `Charge Aggregator` generates a charge record representing the service session charge consisting of different component charges.
	DR6 Supporting information about a resource charge	YES	Resource usage charge is represented as the charge corresponding to a service component usage in the service session composition model.

Table 8.3. Summary of Data Requirement Evaluation

Chapter 9 – Conclusions

This chapter presents the contributions and conclusions for the research presented in this thesis. It also identifies possible directions for further research.

9.1 Main Conclusion

The provisioning of composite telematics services to end-users often involves multiple business parties. In order to deliver next generation services, service providers need the ability to support inter-domain billing of dynamic service provisioning. Existing billing architectures and billing systems are not adequate to support these new business requirements.

The main problem statement of this thesis is how to define a billing system supporting inter-domain, dynamic service provisioning. In Chapter 1 three challenges are identified, namely:

(a) **Inter-domain Billing -** Inter-domain billing refers to the management of the sub-processes involved in the billing process, which are distributed across several domains.

(b) **Service Composition Information** - Service composition information deals with the one-to-one mapping between the charges and the service composition.

(c) **Interim Accounting and Charging -** Interim accounting and charging refers to the generation of interim usage and charge records enabling the monitoring of the service charges and the updating of the customer's credit balance during the service session.

In total the thesis addresses the following (sub)-research questions:

Q1. What are the subsystems embodied in the proposed billing system?

» From the Enterprise Viewpoint, this thesis proposes the *Inter-domain Telematics System* that embodies the subsystems: *Provisioning Agent*, *3rd Party Agent* and *Billing Agent*. The behavior of these subsystems and their interactions are specified according to (level-3) eTOM processes. As a result, the proposed billing system (i.e. *Billing Agent*) increases its applicability in a service provisioning environment that conforms to eTOM business framework (Chapter 5).

From the Computational Viewpoint, the billing system is refined into the system components: *Mediation*, *Charging Aggregator*, *Balance Manager*, *Rating Engine*, *Balance Database*, *Charge Record Database* and *Tariff & Discount Database*. The proposed refinement allows for flexibility to select system components from different vendors in the implementation stage (Chapter 7).

Q2. What are the relationships between the subsystems?

» From the business perspective, this thesis proposes the billing models that define the relationships between the involved parties such as consumers, service providers and third party providers. The subscriber-facing billing model and the partner-facing billing model are represented as part of the *Inter-domain Telematics Community*. These billing specifications respectively focus on the billing aspect between a subscriber and a service provider or between a service provider and a third party provider. The relationship (i.e. combination) of the subscriber-facing billing model and the partner-facing billing model results ensures the end-to-end billing between the parties involved. Furthermore, the relationships between the subsystems within the *Inter-domain Telematics System* are described by their interactions in exchanging billing related information. Furthermore, (Chapter 5).

Q3. What kind of billing interfaces are needed?

» This thesis provides detailed specification of the interfaces between the proposed billing system and other (external) provisioning system as well as the specification of the interfaces between the system components within the billing system. These interfaces can be adopted by standard bodies such as 3PGG and Parlay to accelerate standardization of interim accounting and charging of composite services (Chapter 7).

Q4. What kind of service composition information must be shared between a provisioning process and the corresponding billing process, in order to correlate and aggregate charges of used service session components?

» This thesis provides a detailed specification of the proposed service composition model, which can be applied directly by the telecommunication and internet industry. It is shown that the application of the SID framework is suitable as a basis to model billing information models for supporting composite service, especially when dealing with correlation and aggregation of charges (Chapter 6).

Q5. How can an interim accounting and charging mechanism for composite services be incorporated in the proposed billing system?

» This thesis proposes an interim accounting and charging mechanism for dynamic provisioning of composite services. One of the complexities that the proposed billing system needs to deal with is the billing of composite services in real-time. This aspect is addressed by having the ability to aggregate and merge different charges from the same service session. Further, the billing system is designed with the capability to adjust and update subscribers' credit balance status based on interim credit reservations. This allows for decreasing financial risks from the service provider's perspective (Chapter 7).

9.2 Contributions

The main contribution of this thesis is the proposal of an inter-domain billing system that supports dynamic service provisioning of composite services.

To our best knowledge, we are the first to design a billing system that supports interim accounting and charging of composite services. In the past, several research initiatives have investigated interim accounting and charging *and* charging of composite services as two separate problem domains. For instance, the IETF has proposed an interim accounting mechanism for single services in the DIAMETER specification [RFC3588]. Both 3GPP and TM Forum have addressed charging issues of composite services [3GPPTS32.200, TMFSDP08], but interim accounting and charging has been kept out of scope when dealing with composite services. Today, with the emerging development in dynamic service provisioning and strong requirements on credit balance control, interim accounting and charging *and* charging of composite service can no longer be considered separately. To this extent, this thesis provides answers to current billing needs of the telecommunication industry.

Next to the main research contribution above, this thesis also provides a number of sub research contributions which are described in the following.

Combining Reference Model RM-ODP and Operations Program NGOSS

This thesis combines the reference model RM-ODP and the operations program NGOSS to bridge the academic world and the industrial world. The framework RM-ODP, parts 1-4, was adopted as ISO standards in 1998 and is still being developed by the ODP research community. The NGOSS program has been adopted by the telecommunication industry since 2000, whereby currently the topic of interim accounting and charging is considered to be urgent.

The RM-ODP provides a scientific foundation for a specific and accurate modeling approach. From a design point of view, the advancements in RM-ODP and especially the development of UML for ODP has taken RM-ODP out of the realm of conceptual languages and transform RM-ODP into concrete language to express and communicate designs. The realization of the ODP Profiles and their incorporation in well-established design and modeling environments facilitates the design of domain specific systems such as billing systems.

Other than RM-ODP, the NGOSS program specifies domain specific models and concepts, namely those for the design of new generation OSS/BSS. Considered this way, RM-ODP and NGOSS are complementary. In this thesis, we use two of the four NGOSS framework pillars, namely the Enhanced Telecom Operations Map (eTOM) and the Shared Information/Data Model (SID). The eTOM specifies a blueprint of business processes relevant for the new generation OSS/BSS. The purpose of this blueprint is to serve as a common basis for communication and for OSS/BSS design, thus promoting reuse. The eTOM concepts and terminology can easily be related to those of the ODP enterprise viewpoint as follows: an eTOM process corresponds to an *enterprise step*; and an eTOM process flow corresponds to an *enterprise process*. The SID specifies the entities and their relationships that are of concern for the design and development of OSS/BSS. Furthermore, the SID builds on a small set of well-established analysis and design patterns, thereby promoting reuse and extensibility. Relating SID entities to the ODP enterprise viewpoint, we can say that SID entities define domain specific *enterprise objects* and *enterprise roles*. In our work we mainly borrow concepts from the SID Party model and the SID Service model.

Providing scientific fundament for auditing of billing

This thesis describes the *subscriber-facing billing* model and the *partner-facing billing model*. Both models are constructed using the economic duality principle of REA (Resource-Event-Agent). These models provide a solid basis for auditing purposes of billing. Moreover, the combination of these billing models constitutes an end-to-end billing model. This allows service providers to support both auditing of billing towards subscribers as well as towards third party providers.

Currently, SID does not yet include a model that captures the economic rationale of service provisioning. Since this is essential for a billing system, we propose the use of the REA pattern, which is an accounting domain specific theory. The REA framework was conceived already back in 1982 [MacCarthy82]. More recently, an ontological analysis has been given [Geerts02]. In the context of service accounting and charging, the REA framework models the economic rationale of service provision.

Addressing billing needs of the industry

This thesis proposes a billing system that addresses actual billing needs of providers/operators, namely: interim accounting and charging of composite services. These needs have been recognized by standard bodies such as the ITU, ESTI, TM Forum and 3GPP.

In the last decade, telematics networks and services have undergone impressive advancements in both network capacity and service delivery infrastructures. To master the complexity of dynamic service provisioning of composite services, the above standard bodies have been investigating and standardizing service delivery frameworks. Since much attention has been paid to the development of service delivery frameworks, many billing issues still remain.

Our proposed billing design contributes to current activities of standard bodies regarding the development and standardization of billing. More boldly, the proposed billing system can be used as a reference billing architecture to implement next-generation large-scale billing systems for the telecommunication industry.

Billing system design using clear separation of concerns
In our work, we have applied the principle of separation of concerns to the design. The proposed billing system consists of a set of system components which serve as constituent building blocks. This approach allows for flexible and cost effective implementation of large-scale billing systems using system components available in the market.

Today, many dedicated billing vendors focus not only on offering complete billing solutions, but also on stand-alone system components such as mediation, rating engine and credit balance manager. Guided by the proposed design, system architects can combine a broad range of system components in order to achieve the most optimal implementation in terms of costs and performance.

9.3 Future Research Directions

To further strengthen the billing models and concepts presented in this thesis, various topics could be considered for further investigation. This section discusses some of these topics and identifies their possible research directions.

Performance Aspects
The term "interim accounting and charging" directly associates itself with performance aspects of billing systems. The work presented in this thesis discusses some performance aspects; but by no means has it addressed performance aspects in a systematic profound way. Further investigation on performance aspects of the system components embodied by the proposed billing system would provide insights about their performance indicators. In particular, attention should be paid to the charge aggregation system component since this component is expected to be computing intensive. This is due to the required capability of it to correlate and aggregate charges of composite service sessions in run time. To achieve high performance, efficient engineering techniques should be explored in combination with state-of-the-art technologies such as in-memory databases.

Multiple Balance Types
Sponsored content and services are profitable business for most of the service providers. On the one hand, service providers enable third party providers to deliver advertisements in exchange for financial compensation. On the other hand, service providers may provide free airtime to customers to increase

customer retention. Thus free airtime can be defined as e.g. free call minutes, free SMS messages or even monetary value on a credit balance. Further investigation on the impact of multiple balance types would help to develop flexible solutions for balance management. In turn, this provides service providers with the ability to build interesting business cases with their customers and third party providers.

IMS-based Charging

The 3GPP has developed a framework for off-line and online charging of IMS-based services. Current Online Charging System (OCS) specified by 3GPP does not support an online charging function for composite services. The proposed billing system in this thesis can contribute to further development of the OCS. Regarding the interfaces of the OCS, one of the main impacts of our proposed billing solution is on the Ro reference point [3GPPTS32.296]. The current specification of the Ro reference is only capable of supporting "flat" structure of service components. Thus, no distinction can be made between a composite service as a whole and of its (sub) service components. However, the hierarchical structure of service components and their corresponding charging keys are critical for the determination of the charging dependencies between service components. Future investigation on desirable adaptation/extension of the Ro reference point is an essential step to enable the exchange of the proposed Service Composition Information sent from provisioning systems to the OCS. Altogether, having a hierarchical structure of service components, their corresponding charging keys and an adapted Ro reference point will allow for flexible charging policies. Hence, this extension of the capability of the Ro will support a broad variety of business models between service partners in different domains.

Bridging billing and payments

Payment is a necessary enabler for service provisioning because without payment, no service will be delivered. In turn, interim accounting and charging depends on the current status of credit balance of consumers. In our design, the balance management has been considered as a separate entity. The advantage of this separation is that balance management can be delegated to a Payment Provider. By doing so, consumers will benefit from flexible and open payment services. This will lower payment obstacles and increase consumer's willingness to consume services from a wide range of service providers. Further investigation on the possibility to incorporate the payment provider role in the presented Business Reference Model could deliver relevant research outcome for the telecommunication and payments industry. Recently, the EU commission has approved a number of payment directives for the telecommunication sector [EU71707]. For example, directives on tariff and balance threshold while roaming. Such regulations would have major impacts on payment and balance management in particular. Hence, research efforts on legal aspects of payment and balance management are highly relevant.

Further outlook

Finally, as telecommunication providers and other service providers are facing the challenges of ensuring seamless payment process in conjunction with billing, solving the real-time billing issues of composite services need to be realized in the time to come. On the one hand this requires an acceleration of standardization of service composition related to billing and interim accounting and charging mechanisms. We advocate for the adaption of the proposed billing models by the standardization body such as the 3GPP. On the other hand, billing is an expensive business process due to its complexity and high transaction volumes. Therefore telecommunication providers and third party providers should consider the delegation of their billing to third parties in order to reduce operational costs. In the end, the consumers may benefit from such outsourcing of billing.

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Abbreviations

3GPP	3rd Generation Partnership Project
AAA	Authentication Authorization Accounting
ALMA	Architecture-level Modifiability Analysis
API	Application Programming Interface
ASM	Application Specific Module
BAN	Body Area Network
BPEL	Business Process Execution Language
BPEL4WS	Business Process Execution Language for Web Services
BR	Business Requirement
BSS	Business Support System
CAMEL	Customized Applications for Mobile network Enhanced Logic
CDMA	Code division multiple access
CDR	Call Detail Record
CORBA	Common Object Requesting Broker Architecture
CPU	Central Processing Unit
CRM	Customer Relationship Management
CRs	Charge Records
DPE	Distributed Processing Environment
DR	Data Requirement
EDGE	Enhanced Data Rates for Global Evolution
EPSD	European Payment Service Directive
ESTI	European Telecommunications Standards Institute
eTOM	enhanced Telecom Operations Map
FAB	Fulfillment, Assurance and Billing & Revenue Management
FCAPS	Fault, Configuration, Accounting, Performance and Security
FR	Functional Requirement
GBA	Global Billing Association
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
ICT	Information and Communication Technology
IETF	Internet Engineering Task Force
IMS	IP Multimedia Subsystem
IN	Intelligent Network
IP	Intelligent Peripheral
IP Network	Internet Protocol Network
IPDR	Internet Protocol Detail Record
IRTF	Internet Research Task Force
ISO	International Standardization Organization

ISP	Internet Service Provider
ITU	International Telecommunication Union
M3I	Market Managed Multi-service Internet
MAP	Mobile Application Part
MDA	Model-Driven Architecture
MF	Mediation Function
MMS	Multimedia Messaging Service
MSC	Mobile Switching Center
NAS	Network Access Server
NEF	Network Element Function
NGOSS	New Generation Operations Systems and Software
OCL	Object Constraint Language
ODL	Object Definition Language
ODP	Open Distributed Processing
OMG	Object Management Group
OSF	Operations System Function
OSI	Open System Interconnection management framework
OSS	Operations Support System
P-SCP	Prepaid Service Control Point
PSTN	Public Switch Telephone Network
QAF	Q Adapter Function
QoS	Quality of Service
RADIUS	Remote Authentication Dial-in User Service
REA	Resource-Event-Agent
RM-ODP	Reference Model of Open Distributed Processing
SACLC	Service Accounting and Charging Life Cycle
SCEP	Service Creation Environment Point
SCP	Service Control Point
SDP	Service Data Point
SIB	Service Independent Building Block
SID	Shared Information and Data model
SIP	Service Initiation Protocol
SLA	Service Level Agreement
SMP	Service Management Point
SMS	Short Message Service
SSP	Service Switching Point
SS7	Common Channel Signaling System Number 7
SSLC	Service Session Life Cycle
TAM	Telecom Application Map
TAP	Transfer Account Procedure
TCP	Transmission Control Protocol
TIA	Telecommunications Industry Association

TICA	Time Interval Calculation Algorithm
TINA	Telecommunications Information Network Architecture
TM Forum	TeleManagement Forum
TMN	Telecommunications Management Network
TOM	Telecom Operations Map
UML	Unified Modeling Language
UMTS	Universal Mobile Telecommunications System
URs	Usage Records
VoD	Video-on-Demand
VoIP	Voice-over-IP
W3C	World Wide Web Consortium
WiFi	Wireless Fidelity
WIN	Wireless Intelligent Network
WSF	Workstation Function
XML	Extensible Markup Language

Overview of Viewpoints

Viewpoint	Entity	Entity Type
Enterprise Viewpoint	Inter-domain Telematics	EV_Community
	Party	EV_Party
	Person	EV_Party
	Organization	EV_Party
	Party Role	EV_Role
	End-user	EV_Role
	Subscriber	EV_Role
	Service Provider	EV_Role
	3rd Party Provider	EV_Role
	End-user Agent	EV_Role
	System Agent	EV_Role
	Subscriber Agent	EV_Role
	Provisioning Agent	EV_Role
	3rd Party Agent	EV_Role
	Billing Agent	EV_Role
	Inter-domain Telematics System	EV_Object
	System	EV_Object
	End-user-facing Service	EV_Object
	Provider-facing Service	EV_Object
	Service Usage	EV_Object
	Service Payment	EV_Object
	Provider Cash	EV_Object
	Provider Service	EV_Object
	Partner-facing Service	EV_Object
	Partner Service Usage	EV_Object
	Partner Service Payment	EV_Object
	Product	EV_Object
	Service	EV_Object
	Atomic Service	EV_Object
Information Viewpoint	Party	IV_ObjectType
	Party Role	IV_ObjectType
	Person	IV_ObjectType
	Organization	IV_ObjectType
	End-user	IV_ObjectType
	Subscriber	IV_ObjectType
	Provisioning Agent	IV_ObjectType
	3rd Party Agent	IV_ObjectType
	Billing Agent	IV_ObjectType
	Person Name	IV_ObjectType
	Billing Address	IV_ObjectType
	Digital Address	IV_ObjectType
	End-user-facing Service	IV_ObjectType
	Provider-facing Service	IV_ObjectType
	Service Usage	IV_ObjectType
	Service Payment	IV_ObjectType
	Provider Cash	IV_ObjectType
	Provider Service	IV_ObjectType
	Partner-facing Service	IV_ObjectType
	Partner Service Usage	IV_ObjectType
	Partner Service Payment	IV_ObjectType
	Service	IV_ObjectType
	Atomic Service	IV_ObjectType
	Subscriber Account	IV_ObjectType
	Subscriber Credit Profile	IV_ObjectType
	Charge Cycle	IV_ObjectType
	Event	IV_ObjectType

	Timestamp	IV_ObjectType
	Partner Account	IV_ObjectType
	Partner Credit Profile	IV_ObjectType
Computational Viewpoint	Provisioning Agent	CV_Object
	3rd Party Agent	CV_Object
	Billing Agent	CV_Object
	Mediation	CV_Object
	Balance Manager	CV_Object
	Charge Aggregator	CV_Object
	Rating Engine	CV_Object
	Balance Record Database	CV_Object
	Charge Database	CV_Object
	Tariff & Discount Database	CV_Object
	Charging Request	CV_OperationInterfaceSignature
	Charging Response	CV_OperationInterfaceSignature
	Charging Response n	CV_OperationInterfaceSignature
	Invoicing	CV_OperationInterfaceSignature
	Charge Request	CV_OperationInterfaceSignature
	Charge Response	CV_OperationInterfaceSignature
	Balance Request	CV_OperationInterfaceSignature
	Balance Response	CV_OperationInterfaceSignature
	Balance Status Request	CV_OperationInterfaceSignature
	Balance Status Response	CV_OperationInterfaceSignature
	Session Charge Request	CV_OperationInterfaceSignature
	Session Charge Response	CV_OperationInterfaceSignature
	Rating Request	CV_OperationInterfaceSignature
	Rating Response	CV_OperationInterfaceSignature
	Tariff & Discount Request	CV_OperationInterfaceSignature
	Tariff & Discount Response	CV_OperationInterfaceSignature
	Charge Record Storage	CV_OperationInterfaceSignature

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Samenvatting

De technologische vooruitgang van datageoriënteerde netwerken, informatie- en communicatiediensten maken toegevoegde waarde diensten zoals muziek, mobiele TV, video-op-verzoek en eHealth beschikbaar voor het grote publiek. Een groot deel van deze diensten zijn *samengestelde diensten*, opgebouwd uit meerdere dienstcomponenten aangeleverd door mogelijk verschillende dienstenleveranciers.

Hedentendage brengt de dynamische levering van samengestelde diensten grote complexiteit met zich mee ten aanzien van de billing of verrekening van deze diensten. Dit komt doordat factuurinformatie, afkomstig van verschillende leveringssystemen, moet worden geaggregeerd. Namelijk, elke gebruikte dienstcomponent heeft een bijbehorende prijs, die aan de hand van de dienstsamenstelling of compositie gecorreleerd moet worden om zo uiteindelijk de prijs van de aan de klant geleverde samengestelde dienst te bepalen. Een extra complicatie voor de verrekening van samengestelde diensten ontstaat indien we per direct willen verrekenen. Hierbij vindt de verrekening plaats tijdens het gebruik van de dienst of direct na de beëindiging van een gebruiksessie. Dit in tegenstelling tot "achteraf" verrekeningsmechanismen waarbij verrekening van het dienstgebruik plaatsvindt pas na het einde van een gebruiksessie. Met de toename van prijzige samengestelde diensten willen veel consumenten per direct kosten- en factuurinformatie ter beschikking hebben om hun uitgaven te beheren. Daarnaast hebben ook dienstenleveranciers actuele managementinformatie nodig om financiële risico's te beheren. Verder treedt er nog een extra complicatie op wanneer juist verschillende derde partijen deelnemen aan het leveren van de samengestelde dienst. Een verrekeningsproces waarbij meerder partijen zijn betrokken vraagt zo om standaardisatie van de uitwisseling van factuurinformatie en om open systeeminterfaces. Huidige billing of verrekeningssystemen kunnen het per direct verrekenen van samengestelde diensten niet ondersteunen. Nieuwe architecturen voor verrekeningssystemen zijn dus noodzakelijk. Deze behoefte wordt ook onderkend door standaardisatie-organisaties zoals de ITU, ETSI, TM Forum en 3GPP.

Het doel van dit proefschrift is nu het ontwerpen van een verrekeningsysteem dat in staat is om dynamisch levering van samengestelde diensten over meerdere dienstenleveranciersdomeinen mogelijk te maken. Om tot een ontwerp te komen van het beoogde *Inter-domain Billing System* richt het onderzoek zich op drie aspecten: *verrekenen over meerdere domeinen*, *dienstensamenstellingsinformatie* en *tussentijdse verrekening*.

Dit proefschrift stelt een verrekeningssysteem voor om de levering van samengestelde diensten te ondersteunen. Het voorgestelde systeem is gedefinieerd en gespecificeerd vanuit het business perspectief, informatie perspectief en functionele perspectief. Zo definiëren we met verrekeningsmodellen de relaties tussen de betrokken partijen zoals klanten, dienstenleveranciers en derde partijen. De opgestelde verrekeningsmodellen focussen op het verrekeningsaspect tussen een klant en de dienstenleverancier en tussen een dienstenleverancier en een derde partij. Daarmee vormen deze modellen de hele facturatieketen tussen de betrokken partijen. Verder is ter ondersteuning van de correlatie en aggregatie van de kosten van samengestelde diensten een informatiemodel voor dienstsamenstelling (compositie) gedefinieerd en gespecificeerd. Dit model kan specifiek toegepast worden in de telecommunicatie- en internetindustrie. Het laat zien dat het SID framewerk van het TM Forum geschikt is om als basis te dienen voor het modelleren van verrekeningsmodellen ter ondersteuning van samengestelde diensten. In het bijzonder geldt dit voor de ondersteuning van correlatie en aggregatie van kosten. Tenslotte definiëren en specificeren we een mechanisme voor tussentijdse verrekening van samengestelde diensten. Tussentijdse verrekening refereert naar het genereren van tussentijdse gebruiksrecords en verrekeningsrecords ten behoeve van de controle op de kosten en het saldo van de klant tijdens een gebruiksessie. Het factureren over meerdere dienstenleveranciersdomeinen vertaalt zich in het beheer van subprocessen die gedistribueerd zijn over meerdere administratieve domeinen. Ons onderzoek definieert en specificeert de subsystemen in het verrekeningssysteem, de relaties tussen deze subsystemen en tenslotte, de interfaces tussen het verrekensysteem en zijn omgeving en tussen de subsystemen.

De wetenschappelijke bijdrage van het uitgevoerde onderzoek is meervoudig: 1. Het beschrijft een verrekeningssysteem dat huidige behoeften van ICT dienstenleveranciers adresseert, namelijk: tussentijdse verrekening van samengestelde diensten. 2. Het combineert het referentiemodel RM-ODP en het programma NGOSS en vormt daarmee een brug tussen de academische wereld en de industrie. 3. Het beschrijft de facturatiemodellen die een solide basis vormen voor auditdoeleinden. Deze modellen zijn geconstrueerd met behulp van het principe van de economische dualiteit van REA (Resource-Event-Agent). Tenslotte, 4. Het principe van scheiding van functionaliteiten is toegepast op het ontwerp van het voorgestelde verrekeningssysteem en omvat hiermee een verzameling van systeemcomponenten. Op hun beurt dienen deze systeemcomponenten als bouwblokken. Deze benadering maakt het mogelijk om flexibele, kostenefficiënte en grootschalige verrekeningssystemen te realiseren op basis van verkrijgbare systeemcomponenten in de markt.

Dit proefschrift is ingedeeld als volgt. Het begint met een presentatie van de onderzoekscontext, definities, terminologie, voorbeeldscenario's van videotransmissie en van medische zorg op afstand (eHealth), onderzoeks-probleemstelling, doelstelling en scope (Hoofdstuk 1). Eerst wordt een overzicht gepresenteerd van gerelateerd onderzoekswerk op het gebied van facturatiebeheer (Hoofdstuk 2). Vervolgens wordt de geprefereerde ontwerpaanpak geadresseerd op basis van een aantal potentiële ontwerpmethodologieën (Hoofdstuk 3). Verder wordt de verzameling van architectuureisen bestudeerd, die de basis vormen voor het ontwerp van het voorgestelde verrekeningssysteem (Hoofdstuk 4). De belangrijke gezichtspunten van het omvattende *inter-domain telematics system* sturen het ontwerp van het voorgestelde verrekeningssysteem: het *Enterprise Viewpoint* adresseert de verschillende deelnemers die betrokken zijn in het businessproces voor het leveren van diensten aan consumenten en om de geleverde diensten te factureren (Hoofdstuk 5); het *Information Viewpoint* beschrijft de informatie die het verrekeningssysteem beheert ten behoeve van dienstlevering en facturatie (Hoofdstuk 6); het *Computational Viewpoint* presenteert de functionele entiteiten van het *inter-domain telematics system* en hun onderlinge relaties. Het bespreekt ook de benodigde interfaces voor de uitwisseling van factuurinformatie tussen de betrokken deelnemers in de dienstlevering naar de eindgebruikers (Hoofdstuk 7). Tenslotte wordt het ontwerp van het voorgestelde *Inter-domain Billing System* geëvalueerd tegen de systeemeisen afkomstig van Hoofdstuk 3 (Hoofdstuk 8). Afsluitend worden de wetenschappelijke bijdragen samengevat en worden mogelijke richtingen voor toekomstig onderzoek geïdentificeerd (Hoofdstuk 9).

List of Publications

- M. van Le, G.B. Huitema, F.J. Rumph, L.J.M. Nieuwenhuis, B.J.F. van Beijnum, "*Design of an Online Charging System to Support IMS-based Inter-Domain Composite Services*", IFIP/IEEE International Conference on Management of Multimedia Networks and Services (MMNS 2009), Venice, Italy, October 26-27, 2009.
- M. van Le, F.J. Rumph, G.B. Huitema, B.J.F. van Beijnum L.J.M. Nieuwenhuis, " *Online Charging for IMS-based Inter-Domain Composite Services*", ICQT09 Advanced Internet Charging and QoS Technology, Aachen, Germany. May 2009.
- M. van Le, B.J.F. van Beijnum, L.J.M. Nieuwenhuis, G.B. Huitema, "*An Enterprise Model for Real-time Inter-domain Billing of Services*", 5th International Workshop on ODP for Enterprise Computing (WODPEC 2008), Munich, Germany, September 15, 2008.
- M. van Le, T. Binsted, "*Mobile Financial Services: Risks and Opportunities*", AtosOrigin white paper, WIMA 2008, Monaco, April 2008.
- M. van Le, B.J.F. van Beijnum, G.B. Huitema, "*A Service Component-based Accounting and Charging Architecture to Support Interim Mechanisms across Multiple Domains*", 9th IEEE/IFIP Network Operations and Management Symposium (NOMS 2004), Seoul, Korea, April 19-23, 2004.
- M. van Le, B.J.F. van Beijnum, G.B. Huitema, "*Formalization of Real-time Accounting and Charging Requirements*", IFIP/IEEE International Conference on Management of Multimedia Networks and Services (MMNS 2003), Belfast, Northern Ireland, October 7-10, 2003.
- M. van Le, B.J.F. van Beijnum, B.L. de Goede, "*Real-time Service Accounting*", IEEE Workshop on IP Operations and Management, Dallas, TX, USA, October 2002.
- M. van Le, B.J.F. van Beijnum, B.L. de Goede, "*Formal Modeling of Service Session Management*", IFIP/IEEE International Conference on Management of Multimedia Networks and Services, Santa Barbara, CA, USA., Oct. 6-9, 2002.