Dynamic Charging Architecture and Schemes for 4th Generation Mobile Reconfigurable Systems

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Abstract. Current technological advances enable the modification of existing mobile telecommunications business models. In future mobile networks, mobile users will be able to choose from multiple network operators and service providers. This capability requires the extension of the existing charging collection information mechanisms and billing systems to assist the oncoming mass service offering by independent service providers. In the frame of the present PhD thesis an integrated platform, that extends the existing systems to provide for advanced and flexible charging mechanisms and pricing policies, was deployed.

1 Introduction

The convergence of the Internet with the mobile telecommunications world is about to modify the existing business models. This is because mass service deployment and content delivery offered by independent providers over the integrated UMTS and WiFi (i.e., 802.11.x family of products) infrastructure is now possible. The participation of additional players in the process of service provision includes them in the control and cost sharing of a provided service.

Nowadays, a mobile user must be subscribed to a network operator in order to have access to typical services (i.e., voice calls and IP connectivity) as well as value added services provided by this specific operator. The usage of value added services provided by independent entities is either free of charges or the user has to use his credit card for accessing each service, sharing several times this information with non-trusted entities. Similar relations exist between Internet users, the Internet service providers and other value added service providers.

Recent technological advances allow the introduction of new business models such as: the Network Operator Centric Model, the Service Aggregator Centric Model, and

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Content/Service Provider Centric Model. In each of these models the key actor has the overall control [1],[2].

These new business models require the existing mechanisms for charging, billing, and accounting to evolve. These terms have not the same meaning in all standardization bodies. In this PhD thesis, we adopt the 3GPP terminology, where: charging is the process of collecting information about chargeable events, billing is the process of employing specific pricing policies and issuing bills for the users, while accounting is the process of apportioning the income between the operators in the cases of user roaming. Most likely the evolved mechanisms will be based on a series of compromises between the ones used in the Internet and the ones used by mobile operators. However, ongoing efforts on standardization bodies do not converge on the adoption of the same business models [3]. Thus, the expected result will incorporate duplicated functionality for the execution of several tasks. Even worse, the overall systems' capabilities will be narrower since they focus on specific components.

The expected duplicated functionality is in contradiction to the current technical trend of merging the data and the telecommunication networks by using the same protocols (e.g., IP). Moreover, limiting the capabilities on specific business models that favor some of the existing players will not ease the mass deployment of value added services. Thus, the necessity of a platform for the management of the network functionality to provide advanced and flexible charging mechanisms for different business models seems clear.

In this PhD thesis, we propose the use of such a platform in the context of a generic architecture. This platform, is already prototyped in SDL (Specification and Description Language) and is based on the related work done in the standardization working groups for layer-based charging, where transport, service, and content usage are treated separately [4]. The proposed platform incorporates the functionality of existing network elements and enables any involved player to dynamically apply different charging requirements, policies, and schemes. The standardized OSA/Parlay framework is used to this end, since it enables independent third party providers to make use of the underlying network capabilities without exposing the communication infrastructure to unauthorized business entities [5]. Existing charging entities are extended to support not only content charges but also policy-based charging, which allows the application of the appropriate pricing policy according to user, service and/or session characteristics. Moreover, we propose the introduction of a set of open APIs for the support and management of charging-related reconfiguration actions (e.g., pricing policies updates) and the deployment of advanced charging services such as on-line charging indication, current balance of user billing and provider revenue, and on-line provision of statistical information.

In Section 2, the charging entities incorporated in the existing networks are briefly described. Section 3 discusses the currently unresolved charging issues. Section 4 describes the overall architecture for which our platform was designed, together with the proposed additional entities for charging. Section 5 presents the proposed extension of the OSA/Parlay framework. Finally, section 6 briefly discusses the advantages of the platform.

2 Charging related functionality of the existing networks

Figure 1 illustrates the existing functional entities involved in the charging and billing process in a mobile operator, an Internet Service Provider (ISP), and a Value Added Service (VAS) provider.

We start our description from the related components of a UMTS mobile operator [6]. The packet-switched domain of the UMTS is used by mobile users as the core network during the execution of a value added service and content delivery. For the provision of a service to a mobile user over the packet-switched domain the activation of a packet data protocol (PDP) context is required [7]. Each PDP context is a chargeable event and therefore it causes the generation of charging information. Both the packet-switched domain support nodes, i.e. the serving GPRS support node (SGSN) and the gateway GPRS support node (GGSN) generate charging information in form of charging data record (S-CDR and G-CDR, respectively) related to PDP contexts [8].

The charging information provided by the SGSN concerns the radio network usage, while the GGSN provides charging information regarding the external data network usage. Both of them generate charging information about the usage of the packet-switched domain network resources. A charging identifier, called charging ID, is generated by GGSN at PDP context activation and transferred to the SGSN. During a PDP context, a sequence of partial CDRs are produced by both GPRS Support Nodes (GSNs), the charging ID is used for the correlation of these partial records.

The CDRs are collected by the charging gateway function (CGF) via the standardized Ga interface using the GTP' charging protocol [9]. The CGF can be implemented in a separate network element, the charging gateway (CG) or may be distributed to several physical entities (i.e. integrated in the GSNs).

The CGF transmits the processed CDRs to the operator's Billing System using a proprietary protocol depending on the billing system. 3GPP recommends the usage of FTP and FTAM protocols, since there are a lot of variations among the implementations of the Billing Systems.

The CGF acts as a storage buffer for real-time CDRs collection and is able to perform consolidation of CDRs and pre-processing of their fields, filtering of un-required fields, and adding operator-defined fields.

A user is capable of attaching to a WLAN Access Network via a laptop computer or a PDA equipped with a WLAN interface card, a UICC card reader, and appropriate software applications. A mobile operator may provide WLAN islands as a complementary access network. In addition, an independent provider such as a wireless ISP may deploy WLANs as well. In the general business model case of independent WLAN provider and mobile operator, the 3GPP/WLAN interworking architecture [10] allows mobile users to establish IP connectivity both to their home mobile operators and to local IP networks attached to a WLAN access network. In both cases, the user is authenticated and authorized by the 3GPP AAA Server/Proxy located within the operator network.

The 3GPP AAA Server uses subscriber and service databases (i.e., the HSS) of the mobile operator to retrieve information necessary for the authentication, authorization, and billing procedures. In addition, the 3GPP AAA Server collects and processes charging information concerning the WLAN usage. This information is expressed in the form of accounting records and is sent to the operator's Billing System in order to calculate the charges [11]. Furthermore, the WLAN access gateway (WAG) and the packet data gateway (PDG) are used to provide WLAN-attached users with packet-switched services offered by the mobile operators.

The IP multimedia subsystem (IMS) has been recently introduced by 3GPP in order to enable provisioning of IP-based real-time multimedia services, including voice over IP, over the packet-switched domain and is based on the session initiation protocol (SIP) [12]. The fundamental core network elements of the IMS, including the required call session control function (CSCF) for the establishment of sessions, are able to provide charging information related to these sessions. The proxy-CSCF, the serving-CSCF, and the interrogating-CSCF generate charging records for all the SIP session they are involved with. In case a SIP session is destined to the public switched telephone network (PSTN), the breakout gateway control function (BGCF) and the media gateway control function (MGCF) are also involved and they produce charging records for these session events. The multimedia resource function controller (MRFC) provides charging information related to session bearer processing resource utilization (e.g., transcoders, bridges, etc.) and the application server (AS) when acting as an AAA proxy.

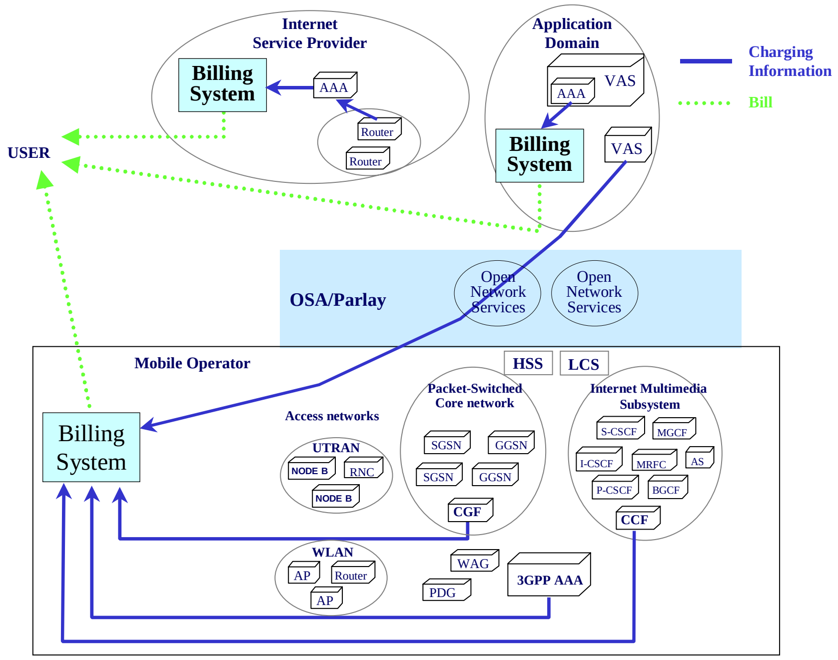

Fig. 1: Existing charging related functionality

The charging information provided by the IMS core network elements are collected by the charging collection function (CCF) via the standardized Rf interface using the IETF Diameter protocol. The CCF is a logical function equivalent to the CGF but also is able to validate, combine, aggregate and consolidate the received charging information, to generate CDRs, to remove duplicated charging data as well to support load sharing, redundancy, high availability and efficient management of the generated CDRs. Note that the charging information generated by the IMS network elements concerns the service plane and concurrently the packet-switched core network elements provide charging information for the transport plane.

The home subscriber server (HSS) is the main database of a UMTS network containing all subscription-related information for the home subscribers. This information is used to support call/session handling by the network entities but can also be used to enable an intelligent billing process. The HSS could be considered as an extended home location register (HLR), which also may contain an AAA Server for handling the respective procedures.

The location service (LCS) is the enabling technology provided by the network operator, which enables the provision of location-based services. The LCS should be able to identify and report in a standard format (e.g., geographical co-ordinates) the current location of the user and to make the information available to the mobile user, network operator, VAS providers, and service/content providers. The location information can also be used for location-based charging, location-aware content delivery, emergency calls, etc.

The ISP providing its users with Internet access incorporates a AAA architecture, for authentication of its users and gathering of usage data regarding its network resources consumption and generation of accounting records [13]. The IETF protocols, Diameter or RADIUS, are used in the AAA architecture for the transmission of charging information [14]. The ISP may apply the flat rate pricing model or a usage-based one. In case of usage-based model, the ISP incorporates a billing system for the calculation of the charges.

In the application domain, there is a wide range of services defined and deployed by independent VAS providers. Till now, the VAS are provided either free of charges or the user has to charge his credit card. In second case, the VAS provider can include AAA architecture in order to authenticate, authorize, meter IP traffic and charge its users. Moreover, the VAS providers can submit their content charges to the operator's billing system using the OSA/Parlay charging API [15].

The OSA/Parlay is a generic framework that enables the rapid creation of value added services by independent third party providers over different types of networks. Specifically, the OSA/Parlay is the specification of a set of open, standards and network-independent APIs that enables authorized service providers to control a selected range of network capabilities. The open network services offered to authorized entities concern mobility and location information management, call control and content-based charging.

3 Unresolved Charging Issues

From the above presentation it is easy to identify that currently, the different business players deploy their own functional entities for charging and billing. Therefore, there is duplication of charging related functionality and the user receives for a service execution separate bills for each charging layer by the respective provider.

Due to the static relations between the business players, the heterogeneous technologies of the charging-related physical entities, and the usage of different charging protocols, it is quite difficult to massively deploy new services offered by independent service providers. Furthermore, one of the new requirements by the users is to have one-stop bill for service execution. Obviously, such requirement is quite difficult to fulfill.

Another issue not covered in the existing charging-related components is that in the UMTS networks non-SIP services are not measured with the appropriate granularity. This is because information about non-SIP services is aggregated in the information of the PDP context they belong to. Thus, even though a PDP context may contain multiple flows the system cannot distinguish them if they are not SIP sessions.

An interesting characteristic in future mobile systems is that the mobile terminals will be capable to connect to different access technologies, even on the move and when having active connections. This means that vertical handovers between different operators even in same country will be possible (e.g., transferring active connections from a UMTS operator to a WLAN hotspot operator to achieve higher transmission rates). In such situations, different types of charging information (i.e. CDRs, accounting records) should be correlated and a single bill produced. Additionally, a more automated accounting system is necessary between the operators.

Finally, an important issue is that in existing systems dynamic charging policy cannot be employed. In this way, when a pricing policy for a user, service or content needs to change, it is a task that usually involves several business players and network components. In the following section, we propose extensions to the existing components to cater for these shortcomings.

4 Proposed additional entities for charging

Figure 2, illustrates the proposed architecture, where additional entities are introduced capable of providing integrated charging, billing, and accounting. The platform was designed taking into account the related work done in the standardization working groups and incorporating the functionality of the existing network elements.

In this architecture, a mobile user will be able to access value added services through heterogeneous access networks (e.g., UTRAN, WLAN, HIPERLAN) belonging to the same or different operators. The Internet connectivity will most probably be offered by the mobile operator but a user will also be able to access the Internet through other providers such as WLAN hotspot providers.

Taking into consideration that for non-SIP services it is not possible to collect the necessary information for service charging, we propose metering devices (MDs) to be placed at the edge of the operators' network for monitoring IP flows. The MDs should export IP flow information in a standardised way; this information should be in a standard format e.g. IP data records (IPDR).

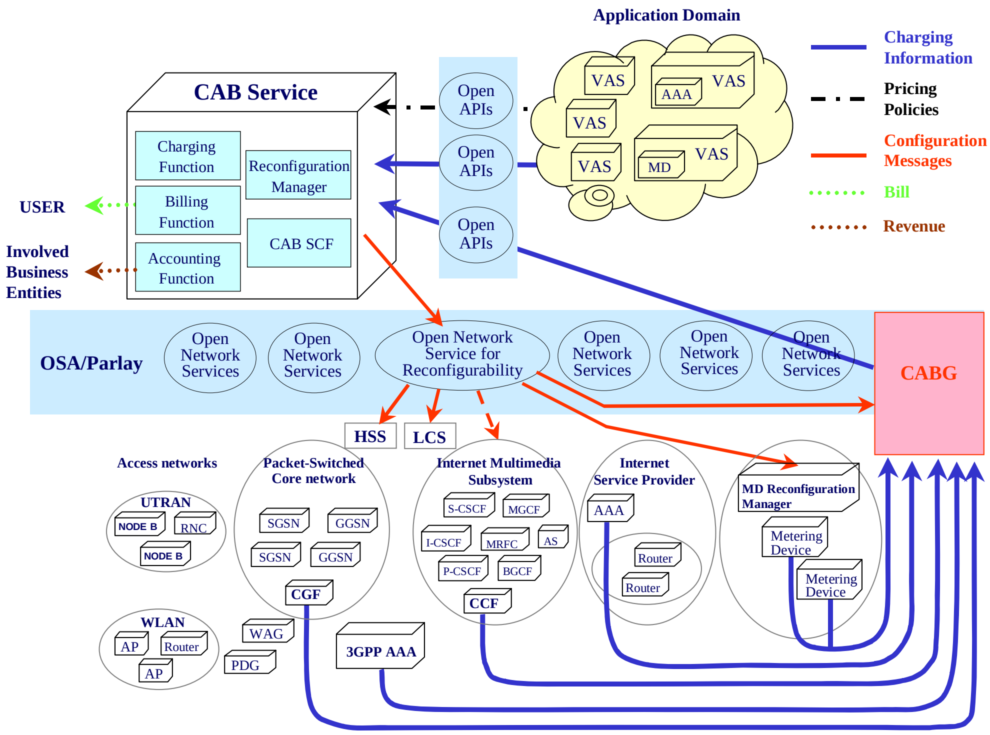

Fig. 2: A platform for Charging, Accounting, and Billing

To provide flexibility and efficiency, and contribute to avoid bottlenecks at the edge of the network, the introduced MDs are dynamically configurable, which means that they provide usage data only for flows specified in the configuration policies. The functionality of MDs is under the supervision of the MD reconfiguration manager, which is responsible for their configuration with regard to the traffic monitoring and reporting functionality. With the appropriate software extensions, the role of the MDs can be performed by existing products (e.g. NeTraMet [16] or Cisco's NetFlow [17]). An alternative solution could be the deployment of the IPmeter approach [18], where all traffic is monitored by a device that is not involved in routing tasks.

In order to have a single logical interface between the charging involved network elements and the platform for the charging records transmission, we introduce a charging accounting and billing gateway (CABG). This executes a first correlation of the collected chargeable events and transfers them to the charging, accounting, and billing (CAB) service. The entities that collect and process charging information concerning the usage of network resources (i.e. CGF and AAA) and the services' usage (i.e. CCF and MDs) support different protocols and interfaces. The CABG receives the charging records using the respective protocols over the existing interfaces, correlates the records related to a specific chargeable event and transmits it using an open standard API to the CAB service.

The CAB service can be considered as a discrete service providing advanced charging mechanisms and flexible pricing. It can be under the administrative domain of the mobile operator, a VAS provider or a third trusted party. It supports the layer-based charging and enables all the involved business players to submit their charging records on-line, to define the pricing policies dynamically, to apportion their revenues automatically, and to receive information about the current users' balance and other statistical information. Additionally, the CAB service provides mobile users with one-stop billing, on-line charging indication, and notification whenever the pricing policy of an executed service changes.

Figure 3 presents the functional entities that comprise the CAB service. In particular, it comprises the following modules:

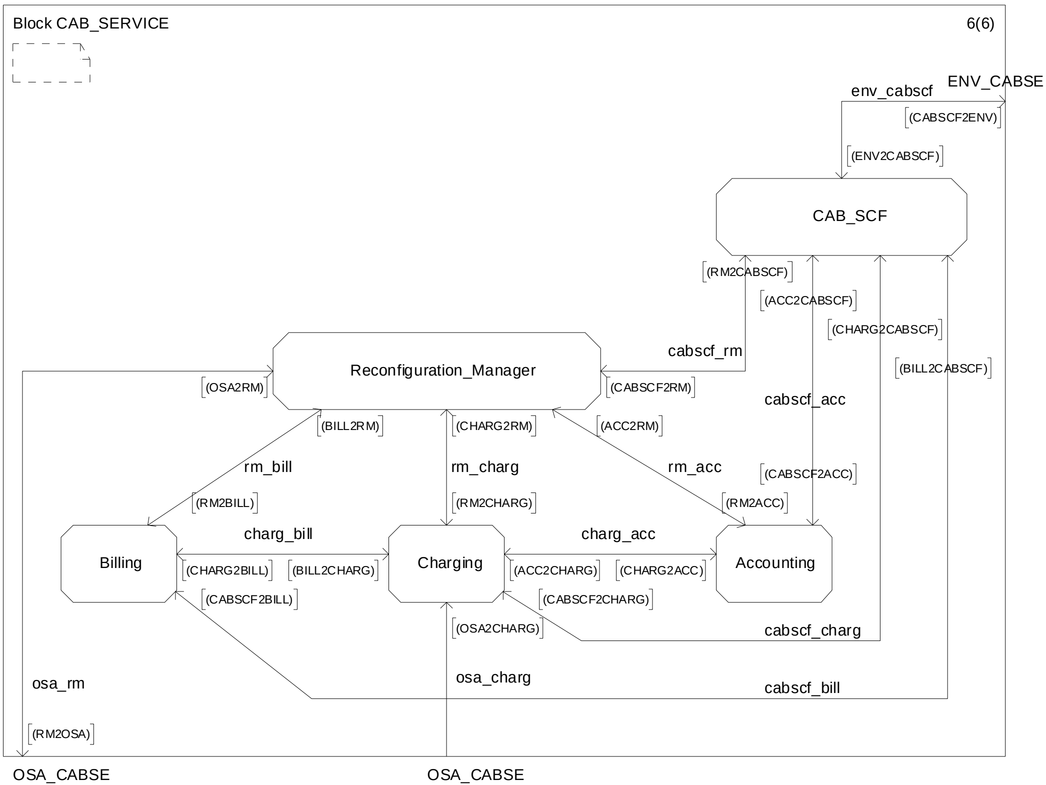

Fig. 3: CAB service functional entities

The CAB Service Capability Feature (SCF) is the functionality offered by the CAB service that is accessible via the proposed open APIs. It enables authorized business players to register a new VAS to the CAB service, to refine the parameters of a registered VAS, to define the pricing policy dynamically, and to submit charging records. Additionally, it provides authorized entities with advanced charging services such as on-line charging indication, current balance of user billing and on-line provision of statistical information. The CAB SCF incorporates the well defined Charging SCF [15] for content charging. The proposed open APIs is described in details in the next section.

The Charging module receives and processes charging information (i.e. CDRs, accounting records, IPDRs) from the network elements via the CABG as well as the usage data and content charges from authorized independent providers via the CAB SCF. Based on the applied layer-based model, the charging information and usage data are correlated. After this step, transport, service, and content records are generated.

The Billing module applies the pricing policies to the transport and service records in order to calculate the charges. The applied pricing policy depends on user, service and/or session characteristics and can be different from layer to layer. In addition, the billing process includes the content charges and produces a bill requiring payment.

The Accounting module is an automatic procedure for sharing of charges and revenues between involved business entities.

The Reconfiguration Manager module includes intelligent mechanisms for identifying the particular high-level requirements of the business players and mapping them to appropriate reconfiguration actions on the underlying network infrastructure. Specifically, in case of VAS registration, it configures the MDs to monitor the related IP flows and produce usage records according to the applied metering policy, and based on the specific pricing policy configures the billing and accounting modules accordingly. Furthermore, it supports the dynamic modification of the VAS parameters and the applied pricing policies reconfiguring the aforementioned modules appropriately. Finally, it configures the charging module to provide notification if the charging information meets some conditions in order to provide authorized entities with specific event notifications (e.g. modification of tariffs).

5 Extension of the OSA/Parlay framework

The standardized OSA/Parlay framework can be used to enable the CAB service and any authorized entity to apply different charging requirements, policies, and schemes dynamically. The OSA/Parlay framework includes functionality related to charging but at present this functionality is restricted to content charges. To this end we propose the OSA/Parlay framework to be extended allowing dynamic reconfiguration actions related to charging. Figure 4 presents the class diagram with the proposed interface for reconfiguration.

Till now the MDs export IP flow information in specific time frames; with the proposed extension the collector entity (e.g. the CAB service) can trigger the MDs to send directly the metering data related to a particular user, service, or session (the *DIRECT_COLLECT_METERING_DATA* method). This will enable authorized entities, such as the CAB service, to close the specific charging records at any time. Additionally, in specific cases, this method can be used by the CAB service for being aware of the current IP flow of a user, service and/or session.

Through the proposed API, an authorized entity can request to receive notifications (the *EVENT_NOTIFICATION* method) whenever a specific event occur (the *REPORT_EVENT_NOTIFICATION* method). The authorized player defines the condition of a specific event as well as the requested reported parameters.

The proposed API enables authorized entities, such as the CAB service, to modify the applied metering policy at any time (the *METERING_UPDATE* method). The metering policy update can concern a particular user, service or session.

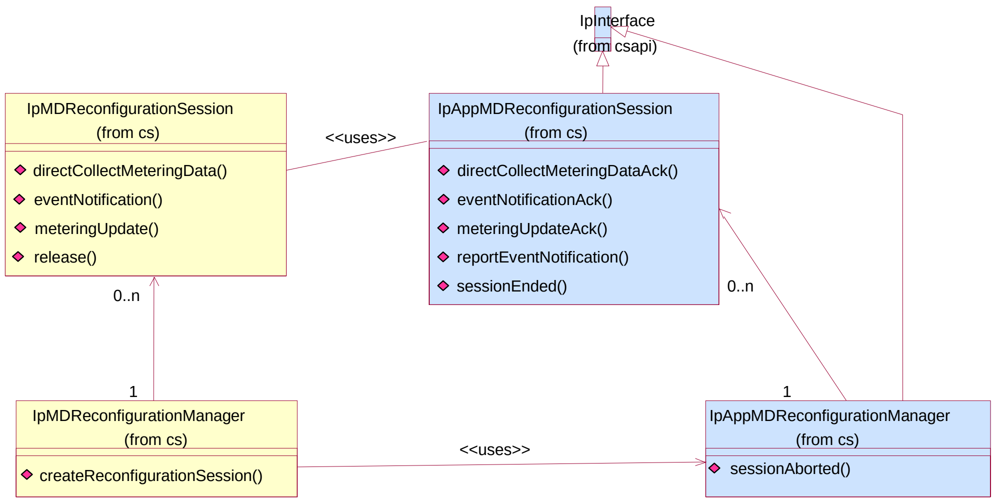

Fig. 4: Reconfiguration class diagram

In emerging business models, the application domain may contain a plethora of services with added value of the existence of AAA architecture and MDs in the VAS provider infrastructure, an independent service provider can generate accounting records or usage data on its own, or completely outsource the charging and billing process to the CAB service. Since the CAB service can be under the administrative domain of any of the involved players, we propose the CAB service to provide open APIs for the communication with any authorised business player.

Figure 5 illustrates the class diagram with the proposed open API offered by the CAB service for advanced and flexible policy-based charging.

The proposed API includes methods that allow authorized entities to submit charging information to the CAB service (the *CHARGING_RECORD* method). The submitted charging information concerns the transport and service layer, while for the submission of content charges the appropriate methods of the existing OSA/Parlay charging API implemented by the CAB are used.

It enables an authorized VAS provider to ask for its current revenue even for a particular user (the *CURRENT_PROFIT_REQ* method) and the user's balance in order to decide whether to offer or not its service or content to the specific user (the *CURRENT_USER_BALANCE_REQ* method).

Furthermore, it makes possible in particular cases a specific pricing policy, different from the predefined one, to be applied only for a session (e.g. location-based charging, discounts, etc.) (the *DIRECT_APPLY_PRICING_POLICY* method).

Through the proposed open API an authorized user is able to request for a charging indication during a service execution (the *ONLINE_CHARGING_INDICATION* method). In this case the CAB service notifies the user when a certain limit is reached (the *REPORT_ONLINE_CHARGING_INDICATION* method).

It enables authorized players (i.e. mobile operator, VAS provider, user) to request statistical provider or user information (the *STATISTICS_PROVIDER_INFO_REQ*, *STATISTICS_USER_INFO_REQ* methods).

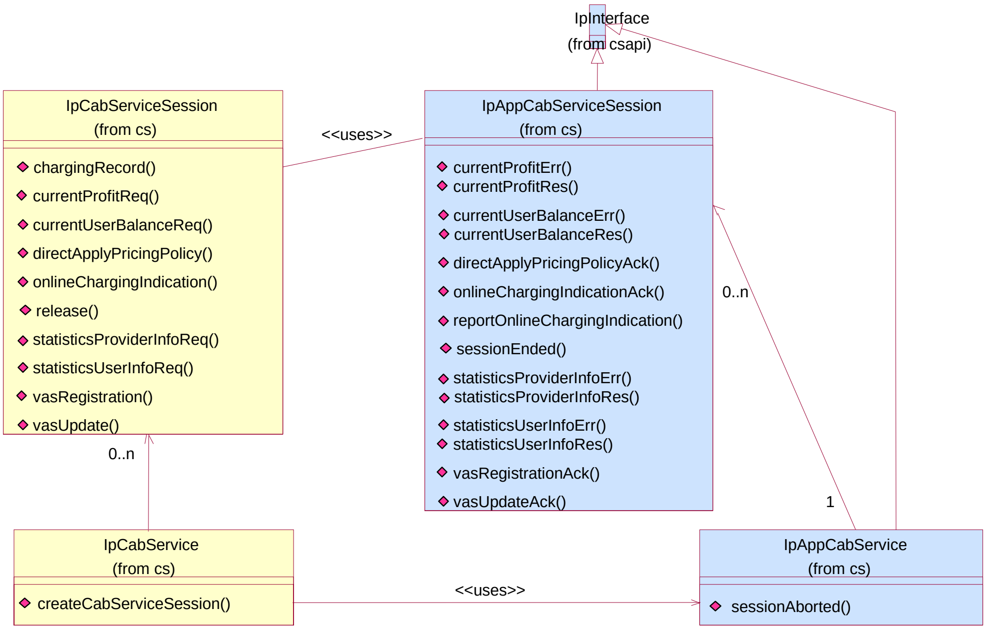

Fig. 5: Advanced charging service class diagram

Finally, the proposed API allows authorized entities to register new VASs to the CAB service in order to outsource the charging and billing process (the *VAS_REGISTRATION* method) or modify the VAS characteristics or applied pricing policy (i.e. pricing model, tariffs, report interval) at any time (the *VAS_UPDATE* method).

In the next section we appose some representing Message Sequence Chart (MSC) diagrams that illustrate part of the CAB functionality based on specific usage scenarios.

6 Conclusions and future work

To summarize, the PhD thesis proposes an open platform for charging, accounting, and billing. It incorporates various charging functionalities enabling sophisticated management and reconfiguration actions for charging purposes.

The platform has been designed to be compliant with any of the emerging business models. Its functionality can be on the administrative domain of any existing physical entity (e.g., operator) or independent third party provider. The proposed platform enables the dynamic reconfiguration of the deployed pricing policy, while provision for using advanced charging, billing, and accounting services (e.g. on-line charging indication, current balance of user billing, on-line provision of information concerning the VAS revenues, etc.) has been taken.

The CAB service distinguishes between transport, service, and content chargeable events, and correlates this information with the service and user profile as well as the location of the user, enabling the enforcement of flexible and advanced business models.

The platform also supports roaming users; it has been designed to apportion automatically the revenues between the players. Finally, one of the key characteristics of the platform is that it supports one-stop billing per service. Such a platform could serve as the common basis for the homogeneous development of charging functionality of new services.

Validation of the approach against performance metrics and constraints comprises another important research challenge, along with distribution of the CAB service functionality. Although the user requirement for one-stop billing has driven the design decision for integrated CAB service, it is our conjecture that distribution and dynamic function relocation will yield overload protection and performance boosting.

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