Intelligent architectures enabling flexible service provision and adaptability

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Abstract: The evolution of mobile communication systems to 3G and beyond introduces a new era in advanced multimedia service provision to mobile users. The success of next generation networks is highly dependent on the availability of a plethora of functionality-rich applications, accessible via a variety of network infrastructures and terminals. This vision can be realized only through the co-operation of various business players (e.g., application developers, content providers), in addition to the mobile operator. The specification by major standardization organizations of open APIs for network access by third parties is a significant step towards this direction. However, the road to a dynamic, open environment includes major further challenges like taming the unprecedented complexity of service management that spans multiple domains and the introduction of network and systems that are dynamically reconfigurable and adaptive in order to accommodate service delivery over highly diverse contexts. In this paper we first identify the requirements of service provision in next generation networks with a particular focus on the emerging need for network reconfigurability and we proceed to describe a software framework for advanced service deployment and management as well as propose the extension of standardized open APIs for reconfigurability support.

Keywords: reconfigurability**,** service provision, open APIs, middleware.

1. Introduction

The introduction of 3G networks aims to pave the way for flexible, customized, ubiquitous service provision. Contrary to the application specific mobile system design of 2nd generation systems, the potential for flexible and adaptive service offerings is expected to foster the establishment of advanced service provision schemes, engaging business players other than the mobile operator. This fact, combined with the requirement for anywhere, any terminal, personalised access to services substantially raises the bar for service management, since it should now include sophisticated inter-domain interactions and cater for application delivery in disparate environments. Intelligent service provision platforms that mediate between various entities and undertake the bulk of the application deployment and management burden provides for this issue a solution with unique advantages. A further major requirement that comes into sight is network reconfigurability, given the diversity of both applications and service delivery contexts in the emerging, highly dynamic telecommunications era. In this paper we introduce a distributed software platform that aims to address the above-mentioned issues, exploiting network reconfigurability. The latter is supported by proposed extensions to existing, standardized mobile network APIs.

The rest of this document has the following structure: The next section discusses service provisioning in 3G networks and beyond and identifies its principal requirements like the availability of sophisticated service management platforms and the openness and reconfigurability of underlying networks. We then present the architecture and functionality of a software platform for flexible deployment and management of advanced applications to mobile users. Subsequently, we provide an example of reconfigurability extension to open APIs, by defining an API for reconfiguration of metering devices. The final sections of the paper are dedicated to conclusions and acknowledgements.

2. Service Provisioning in 3G networks and beyond

It is widely recognized that service provisioning and management in the era of 3G networks and beyond cannot be adequately addressed by schemes that are designed to support rigid, operator-centric business models and remain tightly bound to underlying network technologies [1] [2]. Although the path to next generation networks and services should be evolutionary, a substantial reconsideration of existing approaches is required. In this section, we present certain aspects of emerging service provision paradigms that are crucial to the realization of the vision of ubiquitous and personalized access to applications of unprecedented functionality and customizability. These aspects include open interfaces towards network functionality, intelligent software platforms that co-ordinate service-wide management operations as well as the very important emerging requirement for network reconfigurability as an enabler of optimized, ubiquitous delivery of advanced applications.

A. Access to network functionality through open APIs

It is expected that, in the near future, telecommunication services will be created by a multitude of independent software vendors, so that a plethora of applications can be offered to end-users. To enable third parties to develop portable, adaptable and functionality-rich services for future mobile systems and networks, various efforts have been undertaken by standardization work groups and fora towards the introduction of open network-independent interfaces. These interfaces provide applications with transparent access to network functionality (e.g., call control, location information), thus offering independent application vendors the opportunity to create advanced, network-independent services with standard software engineering tools and general-purpose programming languages.

Examples of such efforts are the following:

- ***Parlay*** [3]. Parlay is an API that provides independent software developers with access to underlying networks and allows them to control a selected range of network capabilities.
- ***JAIN*** [4]. JAIN (Java APIs for Integrated Networks) is a set of Java APIs that aim to enable the rapid development of next generation telecommunications services on top of the Java platform. The JAIN family of specifications includes a wide range of APIs from Java interfaces to network protocols (TCAP, MAP, SIP, H.323) to high level interfaces (JAIN SPA, Service Provider API) to be used by 3rd party applications for access to network functionality.
- ***OSA*** [5]. OSA (Open Service Access) is a 3GPP specification that provides a Parlay-like API, for the particular case of 3G mobile networks.

These specifications share a common philosophy: services in telecommunication networks should not be standardized (besides a very small number of exceptional cases). Standardization only specifies generic-reusable service features. Naturally, these features are available through open interfaces, so that they can be re-used by 3rd parties (not only network operators and equipment vendors) to build a wealth of services that take advantage of network-provided functionality, while being network independent.

The co-operation of the various standardization bodies results to the compatibility of the different APIs with each other. Notably, joint work on specifications is under way since 2001 and already the OSA and Parlay specifications are fully aligned.

B. Intelligent mediation through flexible service provision platforms

The necessity of flexible service management frameworks that act as mediators between the entities involved in the service provision process is unambiguously identified [6] in the context of 3G systems, where the users will be able to access an abundance of services that will be typically developed by many co-operating entities. Moreover, the diversity of service access contexts, which is inevitable in the era of pervasive, “anywhere” computing, and the co-existence of different technologies caused by the evolutionary character of the transition to next generation systems, will lead to the heterogeneity of the networks and systems that support end-user application provision. It is, thus, understandable that inter-domain, service-level management over a variety of networks will be a task of significant perplexity. Service provision platforms present a unique approach for tackling this demanding issue in an efficient and scalable manner. Essential features of such platforms would be:

- ***Support of advanced business models.*** The introduction of 3G systems is expected to be a major step towards an open, dynamic telecommunications marketplace, where a number of business players other than the mobile operator (e.g., service platform operators, application developers, content providers) will contribute to the service provision value chain.
- ***Dynamic, on-line service deployment and management.*** Rapid service deployment is one of the most significant requirements emerging together with 3rd generation networks. Thus, the typical procedures involved in initial service deployment like business level agreements (e.g., specification of service tariffing scheme, service revenue sharing between the involved business entities), update of databases and repositories containing service-related information, appropriate reconfiguration of network and system elements, application server activation and service availability announcement to users should be automated to the highest extent possible, so that they do not pose delays to the service’s commercial exploitation. It is equally important that this holds as well for subsequent service management operations, such as the modification of service attributes (e.g., minimum QoS requirements, tariff changes) and the corresponding reconfiguration actions on network and service resources.
- ***Customizable, context-aware service discovery and access.*** The envisioned capability of mobile users with highly varying preferences to access from anywhere a wide disparity of services using

diverse terminals, involves many technical challenges. Among them are the realization of intelligent, open mechanisms that enable everyone to easily and efficiently locate and execute applications matching his/her needs as well as the current characteristics of the service provision context (e.g., terminal and network capabilities, user state).

- ***Flexible charging and billing.*** The emergence of 3G systems has caused a substantial reconsideration of traditional mechanisms for the charging and billing functionality for telecommunication services. Plain connection time-based schemes are no longer adequate. The application of a variety of arbitrarily sophisticated pricing schemes is emerging as a major requirement. Moreover, a single bill should be generated per user for all basic and value-added services [7].
- ***Compliance to standardized APIs.*** It is a fundamental requirement for a service provision platform to be able to accommodate the multitude of open API-based services that are expected to emerge in 3G networks. This would involve the establishment of business relationships with open interfaces administrators and the inclusion of more complex, management software components in the platform. Such a platform could also make use of open APIs itself, thus enhancing its portability to various types of networks.
- ***Service adaptability.*** The advent of pervasive computing along with the introduction of multi-access technology networks will create the requirement for applications to be optimally delivered and executed over a large diversity of infrastructures and configurations. This not only requires the reconfigurability of supporting networks and systems, but also the dynamic adaptability of services to changing conditions.

C. The need for network reconfigurability and open APIs extensions to support reconfigurability

In 2G networks, services provided to mobile users were either rigidly integrated in network equipment or developed with proprietary tools by mobile operators or equipment manufacturers. This fact led to the availability of a limited number of services that demonstrated high-performance and reliability, but were tightly coupled with the type of network and the vendor of equipment they were running on. However, in 3G and beyond, an open market is expected to emerge, where independent Value Added Service Providers (VASPs) will be able to offer a plethora of diverse services, which will be targeted to a variety of environments, besides cellular mobile networks (e.g., desktop computers having dial-up access to the Internet or utility devices connected to a remotely manageable home area network). Consequently, applications should be to a large extent agnostic of the environment they run on, since it would not be feasible to develop separate versions for different execution contexts.

Bearing in mind the above-described situation, the need for more flexible networks that can be adapted dynamically to the requirements of the disparity of services that are provided over them, can be clearly identified. Thus, network reconfigurability becomes an issue critical to the successful development of the next generation telecommunications marketplace according to the expectations of end-users as well as market players that have substantially invested in technology. Intelligent mechanisms should exist for identifying the particular high-level requirements of an application and mapping them to appropriate reconfiguration operations on the underlying hardware and software infrastructure. These operations could be triggered during service deployment to a network or even in the course of service activation and execution.

Some examples of the types of reconfiguration actions that would be useful in a mobile network are the following [8]:

- ***Quality of Service (QoS) provisioning.*** Network equipment (e.g., routers) could require changes in their configuration, so that they can identify the transport flows corresponding to the usage of a particular service and provide them with the desired QoS. The desired QoS for a service access session by a particular user may be specific to the service (e.g., certain services may require a minimum QoS level to be accessed) and may also depend on the identity and preferences of the user.
- ***Charging and billing.*** The system employed to gather service usage data, process it and calculate the corresponding charges for the end-user, should be dynamically reconfigurable. This is the only way it can take into consideration the various charging-related events occurring in the network (tariff updates, tariffing policy changes) and subsequently produce an accurate user bill.
- ***Dynamic software downloading.*** The optimal provision of a service may necessitate certain software elements to be installed dynamically to the terminal or some place in the network during service deployment or activation. For example, due to limited bandwidth available at the radio communications link, certain service content (e.g., images, audio) should be drastically compressed, so that it can be transmitted in real-time to the user terminal. To do that, an

appropriate codec could be downloaded to a node at the edge of the mobile operator's network as well as the terminal.

Although the capability of a network to be dynamically reconfigured could by itself be a very powerful tool for service adaptation and delivery, its full potential cannot be realized if such features are not accessible by third parties. Employing reconfiguration for a restricted number of operator or equipment vendor provided services limits its impact, while opening up reconfigurability capabilities to service provision platforms and applications could create a dynamic environment where flexible, personalized, revenue-generating services will be within the reach of the user at any time and within any environment. To this end, we clearly identify the need for network reconfiguration functionality to be part of open, standardized interfaces that provide access to mobile networks, such as the OSA APIs [8]. However, OSA at present does not include explicit support for reconfigurability. We, thus, propose the extension of the OSA API with reconfigurability interfaces. This issue is elaborated in subsequent sections of this paper.

3. Generic Architecture for Advanced Service Provisioning and Network Reconfiguration through open APIs and OSA extensions

The present section introduces a distributed software platform for the flexible provisioning and management of advanced services in next generation mobile networks. The platform aims to fulfill the requirements described in the previous section, through the incorporation of intelligent adaptation mechanisms and the support of reconfigurability extensions to standardized open APIs.

The proposed framework, depicted in Figure 1 comprises several components namely, the Reconfiguration Control and Service Provision Manager (RCSPM), the Charging Accounting and Billing (CAB) System [9][10], the Metering Devices (MDs) and the mobile terminal software (MTS). The following paragraphs elaborate on the functionality of these components:

The *RCSP Manager (RCSPM)* is the central component of the platform. It co-ordinates the required procedures for dynamic application deployment and personalized, consistent and reconfigurable discovery, downloading, execution and management of services to mobile users. For that reason, it maintains information about the services offered by the platform, as well as user profile data. The RCSPM also hosts the *Reconfiguration* and the *Location Information Manager* modules described later in this paper. Detailed analysis of the functionality provided by the RCSPM and its internal structure can be found in a subsequent section.

The *Metering Devices (MDs)* [11] [12] are enhanced IP routers, whose additional functionality includes filtering of IP traffic, QoS provisioning as well as metering capabilities. They accomplish their tasks by examining transport and application layer information, in addition to the network layer data used by conventional IP routers. The MDs are dynamically reconfigurable so that their functions are applied selectively to specific transport flows (a traffic flow could be identified in different ways, e.g., by the IP address and port information in the IP packet header). In the proposed architecture they are located at the edge of the mobile network (thus, they reside in the administrative domain of the mobile operator), so that they process all service usage traffic flows between VASPs and users. This processing includes monitoring and generation of metering records (per service/per user) as well as QoS provisioning (e.g., DiffServ). In the context of the proposed framework, MD reconfiguration is typically performed by the Reconfiguration Manager of the RCSPM during application registration/update by the VASPs (cf. the description of the service deployment model in a subsequent section). Alternatively, they could be configured by the mobile operator or even by privileged VASPs. Since the MD reconfiguration interface will typically span administrative boundaries (e.g., in case that distinct entities undertake the roles of network operator and platform operator) we propose that it is provided to third parties through an open API. This interface should enable clients to specify high-level configuration information that will be subsequently mapped to appropriate actions applied to the actual devices through standardised (e.g., COPS [13]) or proprietary APIs and protocols. A detailed presentation of the proposed MD reconfiguration API is presented later in this paper.

The *Charging, Accounting and Billing (CAB)* system [9] [10] [2] is responsible for the overall control of the charging, accounting and billing processes. It collects charging information from both the standard elements of the mobile network (in the form of Charging Data Records (CDRs) and MDs (in the form of Value-Added Service Data Records, VASDRs), applies the appropriate pricing model, calculates the portions that are due to each business entity and produces a single itemised bill to each subscriber [10]. Additionally, the CAB provides advanced charging services through open APIs in order to enable the RCSPP and independent VASPs to configure the applicable pricing policies dynamically, to retrieve statistical information concerning the VAS usage (e.g. the users that currently execute a specific VAS, or the VAS that are currently being executed by a specific user), to apply content based charges and to be informed about the current status of user and VASP accounts.

The *Mobile Terminal Software (MTS)* includes functionality such as service downloading management, GUI clients for service discovery and selection, capturing of event notifications as well as service execution management. The MTS is able to identify and communicate to the RCSPM information required for customized service provision, like terminal capabilities.

In the architecture presented in Figure 1, the complexity of the service deployment is to a large extent moved from VASPs to the service platform. Service and underlying network independence are achieved by applying an open service deployment model that will be described later in this paper. Moreover, the intelligence required to implement the user-centric service provision adaptation and network reconfiguration functionality is placed on the service platform, thus lowering requirements on mobile terminals and extending the service provision domain. The mobile terminal need not adapt to service provision requirements; rather service discovery and delivery is adapted by the platform to user preferences, terminal capabilities and network characteristics. Furthermore, the advanced charging service enable dynamic introduction of new pricing policies, reconfiguration of existing ones, on-line provision of revenue balance to the VASPs and production of a single itemised bill for each user.

The RCSPM

In this section we elaborate on the functionality and architecture of the Reconfigurability Control/Service Provision Manager (RCSPM) introduced in the previous paragraph.

The RCSPM is the main component of the proposed framework

These components are the following (as depicted in Figure 2):

- **Service Deployment Manager.** Through this module the VASPs are able to register their services with the RCSPM framework and thus make them available to mobile users. Service deployment includes storing service information in the service database maintained by the platform operator, as well as performing certain reconfiguration actions in the network (e.g., configuring network devices to produce service usage monitoring information or allocate resources for provisioning of the appropriate QoS to users of the service). During the deployment of the application, the VASP provides a high-level description of service attributes and requirements. This service information is encoded in XML and should conform to a universally common XML Document Type Definition (DTD). The Service Deployment Manager incorporates intelligent procedures that are used to map this compact service description to specific, network-wide reconfiguration actions that are necessary for the optimal delivery of the service. This approach has the advantage that the burden of service deployment is to a large extent moved from the VASP to the platform operator, thus facilitating entry to the application provision market for independent software vendors.
- **Reconfigurability Manager (RCM).** This module undertakes network, platform and service reconfigurability. One of its major responsibilities is to extend the OSA interface, offering authorized third parties the capability to perform certain reconfiguration operations on the underlying networks and systems. To implement the exported functionality, the RCM may communicate with network and system elements (e.g., routers, billing system) via standardized (e.g., OSA/Parlay, COPS) or proprietary APIs and protocols. Moreover, the RCM is itself a client application of the extended interfaces, since it carries out reconfiguration actions that are necessary during service deployment on behalf of the VASPs (as described previously in this section).

  The RCM also comprises a generic adaptation module that is used for intelligent profile matching. An important characteristic of the adaptation module is that it is independent of the types of profiles that need to be matched and is, thus, able to accommodate profiles of any kind without modifications in its code. In the context of the proposed architecture the adaptation module is used for the customization of the service discovery procedure and for service adaptation. These functions are accomplished by employing the adaptation module for performing appropriate matching between user, terminal, network and service profiles.
- The **User Interaction Management Module (UIMM)** is responsible for all interactions between user and platform. It carries out service discovery, that is, presenting to the user listings of the available services, tailored to the terminal capabilities and user preferences and location. Moreover, it handles service selection, namely detection of the event of the user choosing an application to access and initiation of procedures necessary for service activation (e.g., packaging and downloading of application client). To achieve this, the UIMM collects information from appropriate VAS and user profiles databases, as well as terminal capability and location information that is provided by the terminal. This information is provided as an input to the RCM that performs the required intelligent matching operations and returns the corresponding results to

the UIMM, which further exploits them to co-ordinate the user experience of customized service provision.

- **Location Information Manager (LIM).** The LIM interacts with the location information's sources of the underlying network infrastructure (e.g. the LCS server [14]) to track the location and mobility of the subscribers. Then, location and mobility data along with the preferences of the corresponding subscriber, network performance data from the underlying network and usage data from users and VASPs are processed by the LIM properly to support new advanced location aware services and the respective policies. The applicable policies are propagated to the appropriate network elements through the Reconfiguration Manager of the RCSPM. By spreading the location information to any authorized entity internal and external to the platform, the LIM enriches the service provisioning approach adopted by the RCSPM with location information features, enabling better customization and personalization of the whole service offering [15]. Location tracking takes place with respect to the user privacy settings included into his user profile. Hence, LIM prompts involved user for authorization prior to any location retrieving action.
- The **Packaging and Downloading Module (PDM)** is responsible for packaging all the software components and other supporting resources (e.g., images, etc.) required for executing a service in a single archive and provide it for download to the mobile client. The single archive produced is dynamically tailored to the context of the particular VAS selection request (e.g., terminal and network characteristics, user preferences). The major advantage of producing a single file containing all the data necessary for service execution is that a client is able to download the archive over a single network connection, thus avoiding superfluous network traffic and excessive signaling.
- **User Profile Manager.** The RCSPM includes user-profiling logic, to enable service discovery, adaptation and provision according to user preferences. The user profile contains information such as user identification data (e.g., name, IMSI, security keys), generic, service independent user preferences (e.g., language, default tariff class), user interface preferences (e.g., font size, preferred media type), as well as a list of user-specific favourite services. The system gives the user the ability to view and update user profile information at any time.
- **Service Database Manager.** This module is an interface to a database of services that is maintained by the platform operator. This information is necessary to various other modules of the RCSPM that are responsible for service discovery, adaptation, management and provisioning. The service database may be dynamically accessed and updated by the VASPs.

4. Open API extensions for reconfigurable metering devices

In this section we present a specific case of an open API extension, concerning the reconfigurability of Metering Devices. We advocate the enhancement of the existing set of open APIs (e.g., the OSA Service Capabilities Features (SCF)) [16], to include support for the reconfiguration of MDs, by introducing a new service capability feature (SCF), namely the MDReconfiguration SCF.

In the scope of our proposed approach, reconfiguration actions concern essentially two types of attributes, namely state and configuration. Configuration attributes describe the desired state of a network device, and include attributes and classes for representing desired or proposed thresholds, bandwidth allocations, and traffic classification criteria. State attributes describe the actual state of a device at a particular operating instance.

The class diagram illustrated in Figure 3 depicts the proposed interface for the MD reconfiguration's purposes. It is assumed that the client discovers the MDReconfiguration SCF applying the standard discovering procedures provided by the OSA/Parlay framework. As result, the client receives an object reference to an object that implements the IpMDReconfigurationManager interface and creates a local object implementing the IpAppMDReconfigurationManager interface.

The introduced methods enable:

- Dynamic configuration of the MDs in order to start or stop monitoring traffic flows (methods *monitorFlow()* and *removeFlowMonitoring()*).Flows typically refer to IP traffic and are identified by information like IP address and port number. Modification of identification information of monitored traffic flows is also available to the API clients (*modifyFlowMonitoring()*).
- Triggering of the MDs to send immediately the metering data records concerning a specific service, a specific user, or a specific IP flow (*CollectMeteringDataDirect()*).
- Application, modification or cancellation of a specific metering policy (e.g., metering granularity, frequency of metering records generation, type and format of generated records) for an application, a user or a combination of them whenever certain conditions are met, implemented by the methods *applyMeteringPolicyDirect(),modifyMeteringPolicyDirect()* and *cancelMeteringPolicyDirect()*

respectively. Analogous functionality is included in the proposed API via asynchronous messages (*applyMeteringPolicyReq(),modifyMeteringPolicyReq()* and *cancelMeteringPolicyReq()*), targeted for cases where a client requests the application of a policy at some specific time in the future and thus does not block its execution waiting for a response. An appropriate response (e.g., *applyMeteringPolicyRes()* or *applyMeteringPolicyErr()*) are returned to the client upon the eventual completion of a request.

- Registration for receiving notifications by the MD Reconfiguration Manager whenever specific events (e.g. it may be useful for an application to be notified in case that metering parameters are modified, typically by the RCSPM) occur (*createEventNotification()*). Cancellation of the aforementioned registration as well as retrieval and modification of notification parameters are implemented by the methods *destroyEventNotification(), getEventNotification()* and *modifyEventNotification()*, respectively. The client is informed of a notification through *reportEventNotification().*
- Receipt of performance and statistical information available to the MDs, implemented by the method *sendData().*

5. Conclusions

The emergence of mobile networks of 3rd generation and beyond is expected to provide end-users with flexible and ubiquitous access to a plethora of diverse services. Thus, a need is clearly identified for the introduction of open, intelligent frameworks for advanced service management and provision. In addition to that, network reconfigurability appears to be a critical requirement for the new telecommunications era. This paper has introduced a generic framework and architecture for the overall service provision management and respective reconfiguration requirements. We proposed that reconfigurability functionality is accessible to services via suitable extensions of open network APIs. An example of an open API extension for the specific case of metering devices reconfiguration has been defined and presented in detail.

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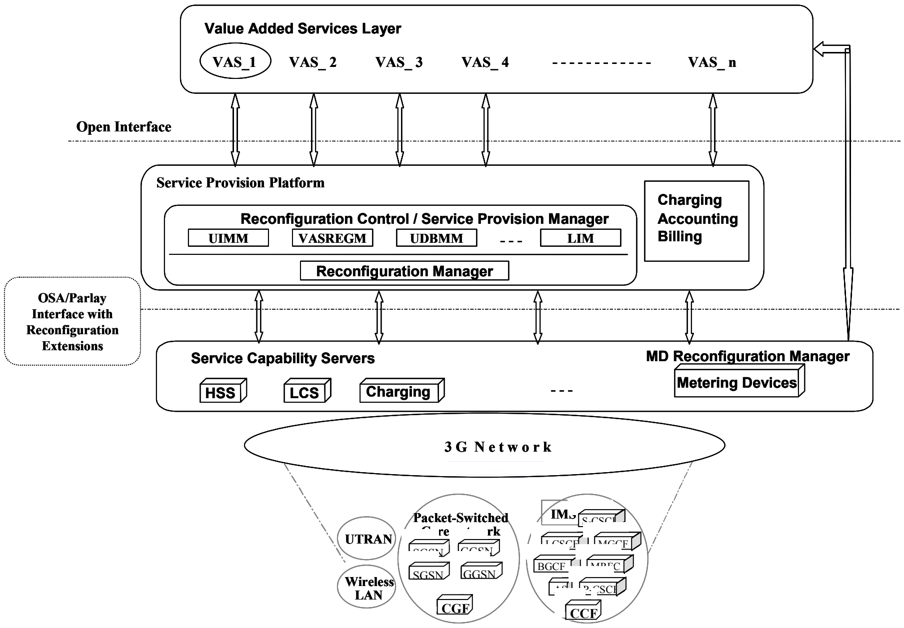

Figure 1. General architecture and example physical placement of the proposed platform.

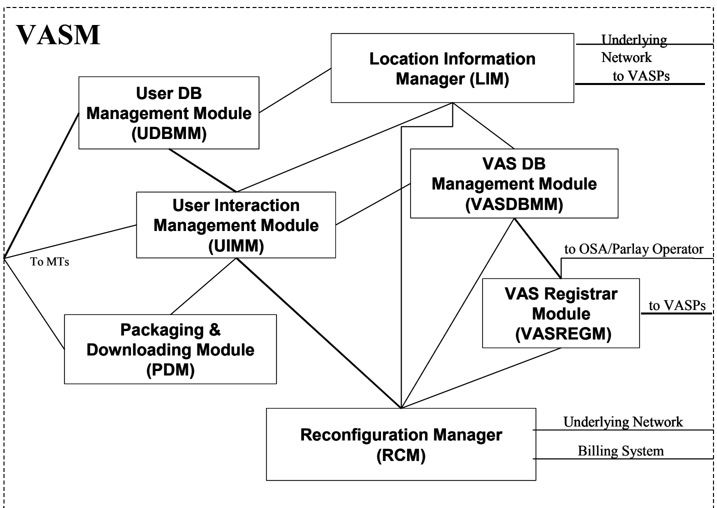

Figure 2. RCSPM internal architecture

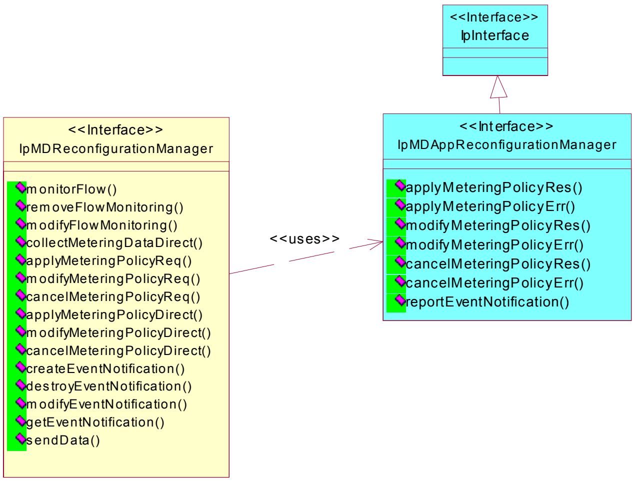

Figure 3. The Class Diagram with the proposed methods for reconfiguration