ISSN 2047-3338

A Convergent and Configurable Policy and Charging Architecture for Integrated Mobile Services

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***Abstract*— This paper describes a convergent and configurable On-line charging architecture for integrated services in the IMS environment, as a layered platform with separate levels for individual charging processes. Certain components on different charging levels are dynamically configurable and customizable according to service and tariff policies of operators, to allow flexible charging of different services, in real time. We describe how such elements ought to be initially set by the central provisioning system and configured by created charging rules, in order to follow dynamic changes in the service session.**

***Index Terms*— On-Line Charging System, Provisioning System, Order Management, Charging Rules, Service Policies, PCRF (Policy and Charging Rules Function), PCEF (Policy and Charging Enforcement Function) and CPS (Central Provisioning System)**

I. INTRODUCTION

PERMANENT user and market demands for new and varied services (individual, complex, multimedia, combined, etc.), as well as their availability by a different user terminal equipment and via various access networks - impose to operators the need for entire convergent architecture.

Converged telecommunication architecture includes the convergence of services, access networks, core configuration, the control and management subsystem. Also are covered and other OSS and BSS systems, as provisioning, order management, CRM, help desk, different portals etc.. One of the key aspects and requirements refers to convergent accounting, charging and billing.

Convergent charging system connecting and consolidating services and access technologies in a unified charging and billing system, with integrated mechanisms for managing user account and mediation. Realized based on open standards and interfaces (eg. with built Radius and Diameter stack), is also available to external service providers, and yet fits and operator's specific needs. Modular convergent charging architecture provides better IT consolidation because it enables flexible networking with the existing IT environment and meets business objectives. In this way reduces the number of systems in place and simplifies the management and maintenance.

Convergent charging architecture allows flexible and versatile rating, charging and billing in real time, with configurable control service and tariff policy. Such charging architecture supports quick and easy integration of new services, as well as various business models in the revenue distribution between the different parties involved in an implementation of the service. This gives the operator the ability to apply a flexible pricing policy and differentiated tariffs, according to user requirements.

II. RELATED WORK

The introduction of PCC architecture (PCC - Policy and Charging Control) [3GPP TS 23.203, R11 i R12] inherently imposes' requests to provide a certain level of quality service and support configurable and variable QoS. In the paper [1], are considered requirements for third party application control on the quality of service (QoS), Based on the analysis of policy and charging control functions in IMS. An Open Service Access (OSA) approach is presented, and designing of OSA compliant application programming interfaces to QoS management in IMS. Te authorized QoS resources model and SIP session state model are analyzed and compared. In the paper [2] are identified many requirements for policy and charging systems, including information about utilization and the paper [3] depicts a possible evolution of the Policy and Charging Control (PCC) and Quality of Service (QoS) architecture to better support fixed-mobile convergence (FMC) and more flexible core network sharing solutions.

In [4] is presented the possibility of the convergence Rating and Charging functions for service data flows, in relation to the subscriber profile. It describes the improvement of the existing Policy and Charging architecture with an expanded online charging system (OCS) and control function in LTE / EPC network. In the work [5], authors propose a model where control plan and configuration logic is moved from core network elements to the data center.

A separation by charging layers, in terms of better and independent configure ability, is proposed in a software defined networks (SDN), [6]. This concept refers primarily to the network virtualization and cloud as well as network management. In the paper [7] is shown that SDMN can provide max. flexibility, openness and programmability for operators - with no change in the terminal equipment.

In [8] is presented an IMS compatible solution for service data flows mobility among access networks. In this way, SDF mobility is transparent for mobile applications on the mobile terminal and for network mobility management. The proposed solution is tested in the IMS testing environment.

The paper [9] describes cloud computing services and an open standards-based framework to integrate IMS and cloud computing. In this way, cloud services are treated as the general IMS applications and under the control of SIP signaling and QoS mechanism of IMS. In this paper are showed the benefits of such integration.

The paper [10] presents an overview of the QoS drivers in Long-Term Evolution (LTE) and LTE-Advanced (LTE-A) networks, focusing on their QoS policy control capabilities. Proposals of policy control and management for increasing the QoS in LTE and LTE-A networks are described. This paper also includes a detailed list and analysis of the inputs to the Policy and Charging Rules Function (PCRF) that can be used for policy decision as well as a set of use cases involving the Policy and Charging Control architecture.

III. CONVERGENT ON-LINE CHARGING ARCHITECTURE

Figure 1 shows a convergent charging platform, integrated into the system architecture of the operator. Corresponding service network, access network, core and processing system are oriented to the converged charging platform, and also indirectly the control sub-systems, OSS and BSS functional units for the support, administrative control portals etc.

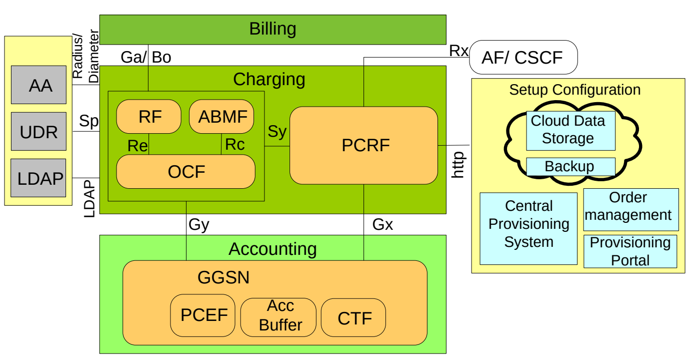

Fig. 1: Convergent and integrated charging platform

On the Figure 1 are showed only some of the supporting functions, that are relevant for the convergent charging. Central Provisioning System (CPS) enables centralized and controlled rapid and flexible activation of multiple services in an integrated manner. Also, it allows the provisioning of various functional nodes with configurable settings and specific logics, which will be described in this paper for provisioning of service and tariff policy for dynamic and flexible charging. Order Management can receive provisioning requests for service or configuration settings from admin and user portal, and forward these requests to the provisioning system (CPS).

As is known, the purpose of an On-line prepaid charging is to check user account status and authorize requested service before the service is approved to the user. All these activities the charging system should done in real time, according to operator's service and charging policies. Service policies can be related to access control, charging control and QoS control. These policies are expressed and configured by the charging rules. Control policies can be applied:

- per subject: subscriber or subscriber group
- per object: service, service components, domain, bearer
- per other contexts: QoS, charging, access to services, notification, etc.

Data for control policy evaluating may be supplied from the input message, the internal stored configuration data or external database. These data for a policy decision may be the following:

- User dynamic context information provided by the access network (GGSN), such as APN to which the subscriber is connecting, negotiated QoS or location information,
- Subscriber profile and group profile: The operator can define black and white lists of services per subscriber and/or subscriber group
- Dynamic session information received from the application layer.

Depending on these data, the main configuring and managing module for policy and charging control (PCRF – *Policy and Charging Rule Function*) checks the conditions and makes decision about service and charging policies, in the form of dynamic charging rules, which will be implemented at the network level [11].

Application Function (AF) has a role of the actual application (for example, streaming server) or a proxy that has all the service information (for example, P-CSCF in IMS). The AF transfers to the control module the set of IP flow that defines a media component, media type (for example, audio, video), application identifier, requested bandwidth, and rest of the data included in the negotiated SDP session. Communication between AF and PCRF is performed using Diameter Rx interface.

The main control module (PCRF) uses these data to create dynamic policy and charging rules per each media component, as well as to determine their associated QoS, that will be afterwards installed in the enforcement module (PCEF).

The following figure 2 shows a really dynamic charging rule created by PCRF module. This is of the test case for a video service, whose data were collected using a network protocol analyzer Wireshark 1:10:11.

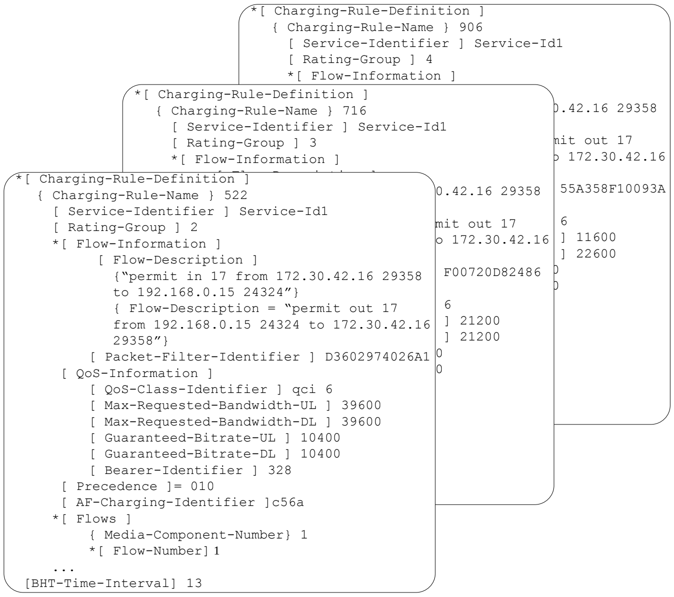

Fig. 2: Charging rules for launched a video service

Convergent charging architecture allows the initial setting and dynamic provisioning of the charging rules before and during the use of the service. In order to enable convergent and configurable charging system, it is necessary to separate the layers of charging processes (accounting, charging, billing) in the charging architecture, with clear and defined interfaces. This approach logically divides the charging architecture into the configurable domains that are aware of the service and the user and those that are not. This is in line with the SDN (Software Defined Networks) concept, where control and data plan are explicitly separated [5], [7].

In order to realize configurable and convergent charging architecture, separated by charging layers or across domains that follow the user and the service context, this paper will be based on a standard IMS On-line architecture and PCC (Policy and Charging Control) architecture [14]. IMS requires a signaling negotiation between two parties establishing a connection for a particular service to define the characteristics of the service session bearer [13].

IV. CONFIGURING OF SERVICE POLICIES

In order to configure the service policy CPS (Central Provisioning System) provides and sends to the PCRF module the next information types:

- to which MSISDN will be joined by the charging profile, rating group, for which type of media, what QoS profile will be used, etc. In this way, PCRF is able to decide the rating group to apply taking into account several input data, for example, subscriber information, accumulated usage, roaming or location. This enables to select different rating group per service taking into account the configured conditions for the subscriber or subscriber group.
- Here is available information whether a service is not included within the black list of services configured per subscriber or subscriber group basis.
- Accumulated usage either of a specific service or of total transferred traffic by the subscribers: when a periodic reasonable threshold is exceeded. When a user has exceeded his allowed consumption during a period of time, the conditions of the service delivery may be affected in the way that this user may have the blocked access to certain services or the available bandwidth restricted. In many cases, a bandwidth restriction is also connected to a "flat-rate" tariff-plan. Once the accumulated usage threshold or the expiry date is reached, operators can apply additional charging for the additional traffic. That implies that the charging information associated to the services must change.
- Here is also defined how and when a network notification informs the user when the remaining volume/time is about to expire or when it is already finished.
- Calendar conditions can also be defined here: time of day and date when the authorization is requested. It allows different results depending for instance on weekdays or times (for example services only authorized on weekends, different QoS Control at different times).
- Age, mobile terminal, or any other operator specific subscriber information may be specified here.

In thus way, the process of the service session establishing and creating of dynamic rules will be speeded up.

In response, PCRF informs whether the action: creation, modification and deletion, .successfully done.

When the subscriber data are stored in an external database PCRF is also able to receive a notification of user profile update through a SOAP/XML based message from external entities like CPS. When there is a change of the subscription type or the tariff plan (services to which he has subscribed, subscriber group to which the subscriber belongs, QoS profile, charging profile, qualification data - the default behavior for each function which PCRF controls, etc.) it is by using CPS configured on the PCRF. The change of the subscription type or the subscriber package goes through the next parts of the system: the portal or customer support (counter), order management system, provisioning system to the PCRF, and the other affected network elements. Upon reception of such notification, PCRF will reevaluate the applicable policies, taking into account the modified subscriber profile, and install within the PCEF new policies, resulting from the reauthorization.

PCRF collects information about events on the network and service level information, and along with your configuration settings creates and dynamically selects the appropriate charging rules for each service flow. Configuring of the PCRF control module can be by the network administrator, who access to the Central Provisioning System (CPS), through the admin portal and Order Management functional blocks. On the CPS are created appropriated logics and scenarios for charging rules, in accordance with the operator's strategy and policy, and descend to the PCRF module. The following illustration on Figure 3 is one example where Order Manager (OM) parses arrived orders from various portals and CPS is an activator for numerous scenarios. OM calls Fusion Block (Integration) with the method executeScenario; Fusion Block then converts web service request in the HTTP call and forwards to the CPS; CPS provisioning activates specific scenarios (actions) to the PCRF control module.

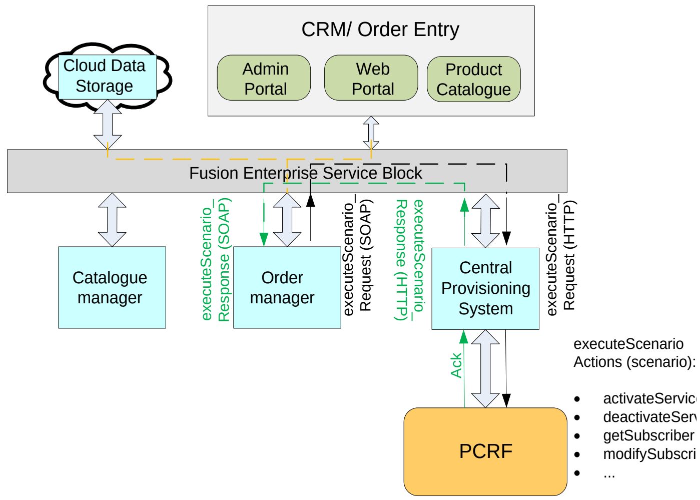

Fig. 3: An example with message flow how the order manager, over CPS, performs provisioning of PCRF configuration settings

Also, it is possible that the configuration file and settings are stored on Cloud data center (Cloud Data Storage) and if necessary, would be withdrawn or sent to the PCRF control module. In [5] the authors propose a model where control plan or configuration logic is shifted from the core network elements to the data center.

PCRF module provides all the configuration data to the accounting level - for successful and efficient accounting of resource consumption. In order to realize this, PCRF converts charging rules (relating to subscribers, service, tariff, etc.) in accounting rules that pertain exclusively to the measurement and collection of charging information, or to accounting configuration.

Charging rules that are created in the PCRF are the basis of operator's service and tariff policy. Control service policies describe for which subscribers and what services are subject to the applicable tariffs. Control policies are sent to the gateway in the access network, which runs on accounting level. In this way, the central control module PCRF is the main node for policy and charging control in an operator's network, which coordinates other nodes on the charging and accounting level to act in accordance with the operator's defined service policies.

Through this concept are integrated the policy and charging control as well as QoS control in the IMS network, to increase efficiency and reduce signaling and costs. In this way, according to the category of subscribers, the type of service which the subscriber access and local service policy (defined by Telecom operator) - IMS manages the IP network resources (e.g., the allocated bandwidth) necessary for the required service. This policy-charging integration allows more complex product offerings, being able to combine network protection policies with money spending policies.

V. RELATION AND FLOWS WITHIN LAYERED CONVERGENT AND CONFIGURABLE POLICY AND CHARGING ARCHITECTURE

When a user requests a service, its terminal is connected to the PCEF / GGSN gateway in the access network. PCEF gateway for such users and the required service requires appropriate charging rules from the PCRF control module, in other words, requires control service and tariff policy for the appropriate accounting and charging. At the same time in the request, PCEF gateway provides to the central PCRF module specific information about the service session bearer. This information will include inter alia: the IP address or domain name of the client requesting charging rules (ie GGSN-a); IP address or domain name of the server that provides charging rules (ie PCRF-a); Framed IP address (an IP address assigned to the user); Subscription-Id (IMSI; SIP URI; MSISDN); Agreed QoS; APN; RAT (UTRAN, WLAN, WiMAX); SGSN Address; Called-Station-Id (destination address and port number to which the UE connects, eg. IP address and port number of the Application Server); etc. All of this information from the GGSN's are delivered through Diameter Gx interface [16], in the CCR (Credit Control Request - INITIAL_REQUEST) for the allocation of charging rules, Figure 4.

Upon receiving the request for charging rules, the central PCRF module first, check-in at ABMF whether the user has enough credit in the account, and if there is - then on the basis of information received from the GGSN and local settings creates and selects an appropriate charging rule, for each service data flow. These rules, as well as configuration settings, delivers back to the PCEF gateway, over Gx interface in the CCA (Credit Control Answer) response. The answer is the same type INITIAL_REQUEST, as was the requirement, Figure 4.

Charging rules are delivered in the CCA response, within the "Charging-Rule-Install" AVP attribute. These rules are essentially composed of three sets of data:

- IP filters – for detection and passing through of individual IP service data flows (these are source and destination IP addresses, port numbers, up-link or down-link direction, protocol type)
    - Gate status – indicates whether the service data flow (SDF), identified with filter, can pass or not in the up-link and / or downlink.
- *Charging* data – allow to apply different charging for different services
    - Rating group or *charging* key – to determine tariff or price for service
    - Measuring method – specifies the parameter to be measured for a particular service flow (e.g., the duration of the connection or the amount of transferred data or number of certain events)

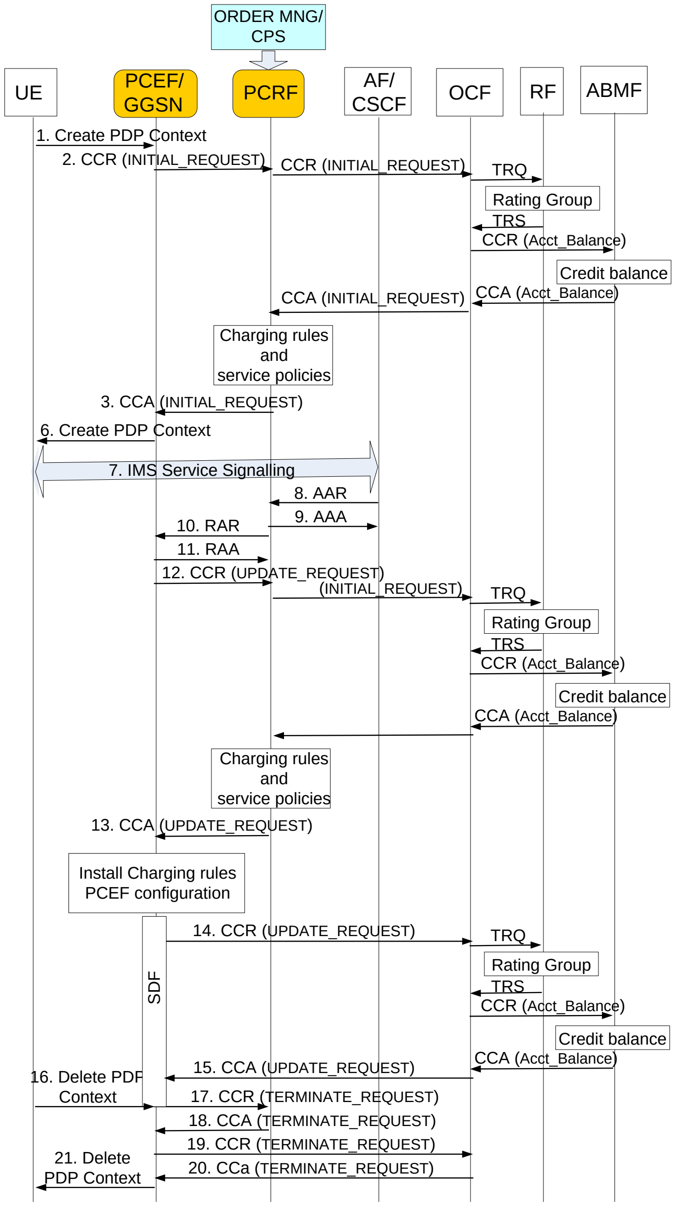

Fig. 4: Relation between processes

- Charging type - (O*n-line* or O*ff-line*)

- QoS class – represents the highest traffic class that can be used for the service data flow (conversational, streaming, interactive, background)

and also include the following information: charging rule name, priority, service identifier, correlation identifier, bandwidth (i.e., if in one session are used multiple media codecs, then as data for authorization is selected the codec with the highest rate).

If does not have enough available resources for implementation of the charging rule at the network level, the PCEF can not apply the rule and on the return message (CCR or RAA) informs the PCRF module. In the message also is information about available network resources. PCRF module with last updated data creates a new charging rule and retransmits it to the PCEF gateway to implementation.

If the PCEF may apply received charging rule, PCEF addresses to OCS system, using Diameter CCR message to credit authorization, and initiates on-line charging process. PCEF gateway informs the PCRF module on the successful implementation of charging rules, and the main control module PCRF further informs the P-CSCF function in the IMS control layer on the implemented configuration. Based on this, the GGSN gateway in the access network, via the SGSN control node, accepts the user request to activate the PDP context as IP bearer.

Upon session establishment from the Gx interface, PCRF initiates a Sy session with the OCS to retrieve policy groups for the subscriber and spending limits information. PCRF over Sy interface receives information about user threshold status to allow PCRF to make policy decisions based on this information. PCRF will storage all the information retrieved through the Sy interface for a subscriber during the service session. In this way, PCRF avoids extra queries towards OCS and to keep consistency On-line charging system will inform PCRF when any spending limit is surpassed or if the subscribed profile is changed.

When establishing a service session with a control application function (eg. Application Function - AF, which may be a P-CSCF in the IMS network or a streaming server, etc.) then begins signaling at the application level, for the purpose of arranging the service session and related media parameters, Figure 4. On the basis of information exchanged between the user's mobile terminal and the IMS network, CSCF / AF function provides appropriate IMS application information for central control module PCRF, and sends them over the Diameter Rx interface [17]. For this purpose, the AF function uses the authorization request - AAR (Authorization and Accounting Request). IMS application information in the AAR request includes:

Characteristics of Diameter Rx session: Information describing the service session and media components. Application identifier (e.g., IMS call, video streaming, messages, file download, etc.), Type of media stream (e.g., audio, video, etc), IP address and port numbers (source – e.g., the user terminal A and destination – e.g., user terminal B or an application server) of individual media streams; directions for media flows: down-link and up-link, required bandwidth, IMS Charging Identifier (ICID), Reporting events what PCRF module should be reported to CSCF / AF function (bearer establishment, bearer termination, etc.)

PCRF control module now uses received data from the AF function, along with local configuration data, and also user's and network data from PCEF - for dynamically creating and selecting the appropriate charging rules and authorized QoS. Based on information from the Rx interface (these are dynamic information - for example, when changing service and the type of media) PCRF applies logic which is defined on it (ie. provisioned based on operator service policy defined in the PCRF) for this type of service and media. So, for example. for IMS Voice goes one logic and for IMS video goes other logic on the PCRF, and these changes are made dynamically according to each individual session.

In this case when PCRF is provisioned with initial charging rule settings by CPS and supplied with dynamic information over Rx, the precedence of the charging rule has a significant role. It defines the precedence of a PCC rule in the case of overlapping charging rules within a service session. A charging rule with the precedence AVP with lower value shall take the priority over a charging rule with the precedence AVP with higher value. Moreover, precedence for dynamic charging rules is higher than for static and preconfigured ones

After that, the IP packets of running services are beginning to deliver to user, and the PCEF / GGSN gateway monitors and counts the packets (depending on specified measurement method in the charging rule for a particular service, i.e., amounts of data, the duration connections, etc.)

While using the service, the GGSN via the Diameter Gy [14] reference point addresses OCS charging system for service authorization and credit allocation, Figure 4. For this purpose are used CCR and CCA (INITIAL or UPDATE_REQUEST) messages, but now for credit allocation and control, for charging rules request. In this CCR request to the OCS system, in the "Multiple-Services-Credit-Control" AVP, is sent earlier received identifier of rating group for the user. After receiving CCR request from PCEF GGSN gateway, On-line charging system (OCS) performs the appropriate rating and assigns a certain amount of the prepaid credit to the running service. After that, OCS charging system replies to the GGSN by CCA message, to indicate the amount of allocated credit, in "Multiple-Services-Credit-Control" AVP.

When it comes to certain changes during the service session, the changes cause service reauthorization. The events that might cause the reauthorization are the following ones: events coming from network and accounting level, events from the application level, change in the subscriber profile, time based conditions within the service policies. When the change of the bearer happens (e.g., updated with the new PDP context with new QoS), PCEF access gateway sends a new request CCR UPDATE_REQUEST (with new information about the service session bearer) to the central control module PCRF, for providing of new charging rules and QoS characteristics. Central PCRF module defines a new charging rule, charging and service policies and sends them back to the PCEF, in the CCA response, within the "Charging-Rule-Install" AVP. Also, if at any time of the service session there is a change of the current service configuration (eg. a user terminal is switched to a lower resolution or there is an addition or removal of certain media components), in this case the AF / P-CSCF network function sends AAR request to the PCRF module with new information about the service session and present media components. PCRF module asks OCS system about tariff class and charging key (rating group) for the new state of service. After that, the main control PCRF module now creates a new charging rule, and sends them to apply to the PCEF gateway. PCEF immediately initiates a new charging session to the OCS with new charging key and sends an acknowledgment to the PCRF module that is implemented received charging rules.

When a user decides to end the service session, the user terminal sends a request to deactivate the established PDP context to the GGSN, the GGSN sends a CCR (TERMINATION_REQUEST) request to the central control module PCRF, to close the Charging rules request session

Thereafter charging session to the OCS charging system is closed by CCR (TERMINATION_REQUEST) request. In this message, within the "Multiple-Services-Credit-Control" AVP, in the field "Amount of credit used" is specified consumed credit for used services. OCS charging system calculates the total price for the services used, reduce the user's prepaid account for that price and sends CCA response as a return message to the GGSN. The GGSN then deletes the established context for the user's terminal.

In the end we can say, by configuring and provisioning of the main control module, to be able to monitor dynamic changes in the service session and the conditions on the network, it is possible to implement flexible policy and charging, as well as QoS control for different services. This allows the operator to make optimum use of network resources for running services.

VI. CONCLUSION

In this paper, we presented an integration of layered PCC architecture with provisioning and order management systems in the operator's network, for the purpose of configuring and provisioning of service and charging policies. Here is presented the configuration and message flow to activate some configuration scenarios on the CPS, to provide adequate service and charging rules to the main control module PCRF. A configurable charging architecture for integrated services is displayed, which enables flexible charging based on configurable dynamic charging rules.

Here is explained a BSS principle by using CPS system and configurable concept, based on the dynamic charging rules, as indicators for service and charging policies and QoS. It is shown that this platform has mechanisms that provide enhanced QoS process for policy making decision on the basis of matching and alignment: user requirements, service requirements and network constraints - with a goal to achieve maximum quality of service in the perception of users.

This architecture is implemented on the test environment as improved modification of an active architecture. The testing environment is a truly replica of the real production environment in the operator network. Here are used the same key elements, which are from different manufacturers, with all its functionalities as used in real production environment, except for less number of licenses (subscribers, processing cores, etc.). Thus, this test setup, with a smaller adjustment, is applicable for configuration of service policies in real network's conditions of telecom operators.

Future work could be in the direction of fully generalization and unification of assigning settings, where the configuration settings for the service and charging policies would be held on a cloud, from where the service providers may withdraw them to the charging and accounting level, for them implementation in the service realization.

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