Policy-based Charging in IMS for Multimedia Services with Negotiable QoS Requirements

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Abstract— **In this work we present a model for online charging of media-rich services supporting dynamic QoS negotiation, within the Third Generation Partnership Project (3GPP) IP Multimedia Subsystem (IMS) emulated environment. In the QoS negotiation process a user, a network provider, and a service provider negotiate about the session to be initiated, resulting in an user-specific combination of media components within the final service configuration. The existing IMS Policy Control and Charging (PCC) architecture, although offering a high level of charging flexibility, is not well-suited for charging dynamic services requiring a negotiable QoS. The proposed testbed extends the policy-based PCC functionality, offering a tariff determination scenario for such services. The approach is illustrated by using the Web 3D game as an example.**

I. Introduction

Media-rich services to be offered through the 3GPP IMS [1], such as multiplayer online gaming, content sharing, and teleconferencing, demand a service platform which will support new and adaptive Quality of Service (QoS) management as well as new charging models, different from the traditional ones used for charging simple voice-based services.

Starting from Release 7, IMS offers a framework, called Policy Control and Charging (PCC) architecture, used for charging multimedia services in a flexible and efficient manner [3] [4]. The signaling protocol used within the PCC architecture is Diameter [12]. As standardized by the 3GPP, this framework supports two charging mechanisms: offline charging (resource usage is reported to the charging system after the resource usage occured) and online charging (resource usage must be authorized by the charging system before it actually takes place).

Although the PCC framework offers a high level of flexibility when used for different services, access networks, or charging models, we find it not well-suited for charging the dynamic services requiring a negotiable QoS. In the QoS negotiation process a user, a network provider, and a service provider negotiate about the session to be initiated, resulting in an user-specific combination of media components within the final service configuration. This type of service requires a process of determining the charging model by using the negotiated service configuration as an input parameter, a process which is not supported by the current PCC architecture. Moreover, within the PCC architecture, it is not specified how to determine the tariff (a price of a basic service unit) for such services, particularly when using the online charging mechanism.

In this work we present a design and a laboratory testbed implementation of a model for online charging of media-rich services, supporting dynamic QoS negotiation, based on the PCC framework. The testbed is to be used in our future research.

The paper is organized as follows. Section 2 describes related work and how our approach relates to it. In Section 3, a brief description of the PCC architecture is given. Section 4 describes the proposed model for online charging. Section 5 illustrates the testbed functionality by using the Web 3D game as an example. Section 6 concludes the paper.

II. Related Work

Fig. 1 shows a high-level view of an Online Charging System in relation to functional layers of the NGN architecture and IMS. Online Charging System is spread across all functional layers, allowing application, signaling, and network entities to participate in online charging. The related research gathers aspects of online charging for all layers. In [5], authors propose a model of an extensible online charging architecture in IMS. Their approach deals with integration of an IMS Gateway Function into application servers from the application layer, which would be able to carry out service-level charging management and communication with the charging server. However, this model is designed for the 3GPP Release 6 charging architecture, which does not support policy-based concept. In [6] a policy-based framework for modeling charging of complex services in IMS is described. This framework is oriented to the charging mechanisms at

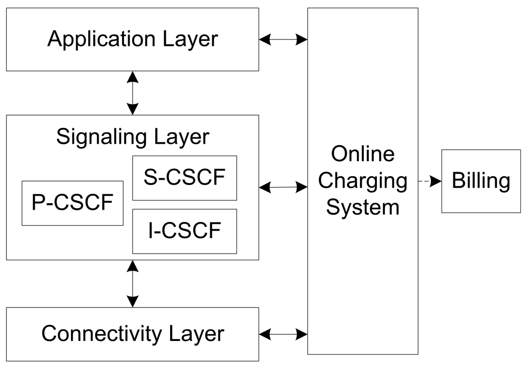

Fig. 1. Online charging concept

the application layer. In [7], authors propose a Time Interval Calculating Algorithm as a solution of online charging of multiple services consumed by a single user. The algorithm is to be used for credit control purposes at the connectivity layer. Our approach is oriented at the charging of dynamic service sessions negotiated at the signaling layer. Connectivity layer mechanisms then receive a group of policies containing negotiated session information, and must determine how to perform online charging.

We also investigated open-source solutions of available IMS testbeds. The Open IMS [8] provides implementation of Call Session Control Function (CSCF) nodes as well as a Home Subscriber Server (HSS), but provides no implementation of PCC nodes. Ericsson's charging SDK [9] provides a Diameter-based credit control, but there is a limited list of supported charging models, and it does not provide a policy-based concept. Therefore, we decided to develop a new testbed, based on the PCC architecture. We used Openblox Diameter Framework [10], an open source implementation of Diameter. Open Diameter [11], is not appropriate for our testbed since it does not provide implementation of IMS reference points we need.

III. The IMS PCC Architecture overview

The IMS PCC architecture [3] is a framework for mapping session-related data in the signaling layer to the network-related data in the connectivity layer, e.g. Quality of Service (QoS), and charging. Each packet flow, defined as a specific user data flow carried through the connectivity layer, is given a policy for QoS assurance and charging, called Policy Control and Charging (PCC) rule. A main signaling protocol used in the architecture is Diameter [12], which is the next generation Authentication, Authorization and Accounting (AAA) protocol. The protocol defines messages that are exchanged between nodes, and the basic message blocks called Attribute Value Pairs (AVP). The protocol can be extended using Diameter applications, with the possibility of adding new AVPs and messages. The 3GPP IMS PCC architecture is shown in Fig. 2.

Proxy - Call Session Control Function (P-CSCF) stands as a Session Initiation Protocol (SIP) signaling node between the IMS core and the user equipment (UE). It forwards session-related information to other PCC nodes. Policy and Charging Rule Function (PCRF) is responsible for receiving this information via Diameter-based Rx interface [13], and transforming it into a set of PCC rules. Media data from the session is mapped to a group of PCC rules, one rule for each media in the session. When creating PCC rules, the PCRF decides how a certain service data flow is treated in the packet switched network, depending od the user information stored in the Subscription Profile Repository, and the chosen charging model. Each PCC rule also contains a charging key, which identifies charging model (time, event, or volume-based model), and the charging mechanism (online or offline mechanism).

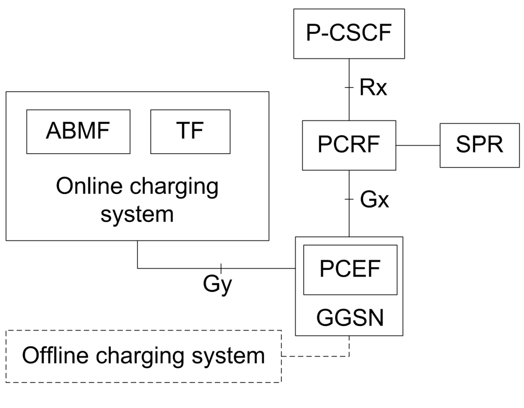

Fig. 2. The 3GPP IMS PCC architecture

The Policy and Charging Enforcement Function (PCEF) is situated at the gateway in the connectivity layer (e.g. in the GPRS Gateway Support Node, GGSN), and is responsible for receiving and applying PCC rules from the PCRF via Diameter-based Gx interface [14]. It reserves network resources and performs charging with the offline and/or online charging system. A particular point of interest is the Online Charging System (OCS), where charging is performed by using standardized Credit-control application [15] over Diameter-based Gy interface. Furthermore, the OCS contains modules for storing user credits, called Account Balance Management Function (ABMF), and for storing tariffs for all services, called Tariff Function (TF).

IV. PCC-based Online Charging for Negotiable Services with Dynamic QoS Requirements

The main idea was to create a model which would be used when implementing the charging testbed for dynamic and negotiable services. A negotiable service takes user, service, and network parameters into consideration when determining a final service configuration during service negotiation process, resulting in different configurations for different user-related parameters. In order to limit the problem to the PCC domain, we adopt the following premises about the processes at the signaling and application layer:

1) P-CSCF uses SIP for communication with other IMS entities. By using SIP, all interested parties (a user, a service provider, and a network provider) negotiate about the session to be initiated. As a negotiation result, (a set of) feasible service configuration(s) is created, depending on user/service/network parameters (e.g. requirements, capabilities, or preferences). The negotiated configuration is highly personalized, since it contains a user-specific combination of media components within the service.
2) Depending on the negotiation process, one or more possible service configurations are sorted by utility. Each of the configurations can be applied at the connectivity layer, assuming that the configuration with the highest utility is the "most desirable",

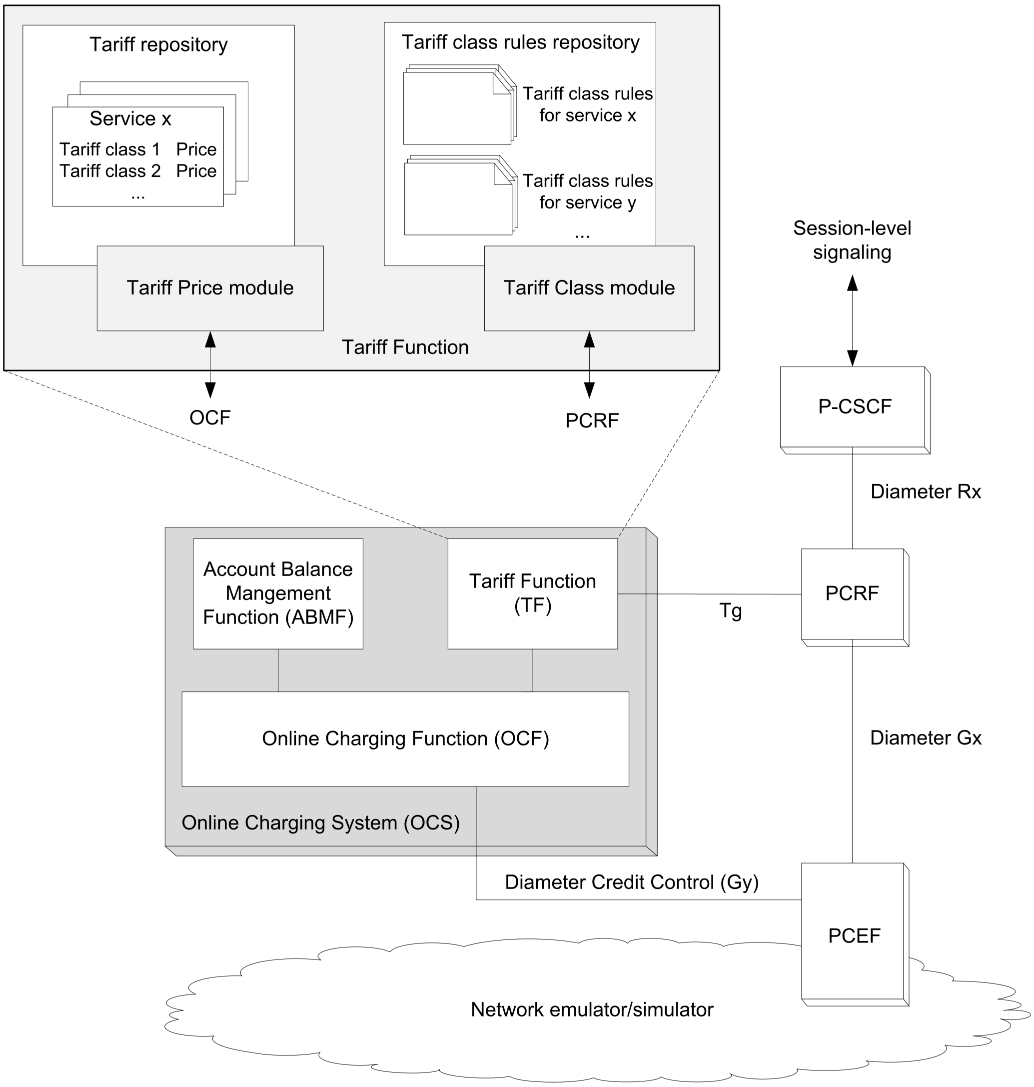

Fig. 3. Charging architecture for personalized services

and the one with the lowest utility is the "least desirable" [2].

3) After the negotiation process and prior to session establishment, P-CSCF sends all negotiated service configurations to the PCC entities, which will make decision which configuration to choose.
4) At any point of the session, another service configuration can be applied, due to a session re-negotiation or a change in network conditions.

When modeling the testbed, we also set the following requirements:

1) Design compatible with standard IMS entities
2) Access network independence
3) Service and user independence
4) Support for various charging models and mechanisms

The testbed model uses a tariff class concept, which enables mapping one of m user-specific service configurations onto one of n tariff classes by using a predefined algorithm, assuming $m > n$. This enables service provider to specify an acceptable number of different tariff classes for each service, as well as the mapping algorithm, while keeping (theoretically) the infinite number of user-specific service configurations.

Taking these premises and requirements into consideration, we modeled the policy control and charging architecture as shown in Fig. 3. In addition to the current PCC architecture, our model introduces the reference point between the OCS and the PCRF, namely Tg reference point. Tg is used for determining the tariff class of the chosen service configuration. As currently modeled, the Tg reference point uses a standard file transport protocol, but can also be easily adapted for Diameter protocol. Since the service configurations are not known in advance by the service provider, the service provider is not able to determine the tariff for the service before the negotiation process is finished. As a solution of this problem, the service provider determines a set of tariff classes for each service as well as the algorithm for determining the tariff class out of the service configuration, and leaves the tariff class to be determined by the OCS.

This approach differs from the traditional charging IMS scenarios, where a charging key, which identifies a tariff and a charging mechanism, is already given within the final service configuration, making it impossible to achieve further customization in that configuration.

A. Mapping session information to network and charging policies

The mapping process starts when the PCRF receives a list of possible service configurations from the P-CSCF during the session establishment. This is done via Diameter-based Rx reference point. (A detailed description about the necessary modification of the Rx and Gx reference points to support this data format and the signaling can be found in our previous work [16].) Fig. 4 portrays a state machine of the PCRF, describing the processes related to choosing the configuration, creating PCC rules based on the chosen configuration, and enforcing the configuration by issuing the PCC rules to the PCEF node.

In our model, the P-CSCF communicates with the PCRF in several communication scenarios. The P-CSCF is responsible for:

1) Sending a list of possible service configurations for each established session from P-CSCF to PCRF;
2) Sending requests to the PCRF to enforce particular configuration sent earlier, as a result of renegotiation process;
3) Receiving notifications about another configuration enforcement due to the change in network resources, or notifications about the currently available network resources in case that none of previously sent configurations can be enforced with actual network conditions;
4) Terminating the session.

The PCRF is responsible for:

1) Receiving a list of service configurations from the P-CSCF, selecting the best one, determining the tariff class for the chosen configuration by contacting the Tariff Function;
2) Creating a set of PCC rules by combining the chosen configuration with the information about the tariff class and sending it to the PCEF for enforcement;
3) Preparing and sending another, but previously received configuration to the PCEF to be enforced along with its tariff class obtained from the Tariff Function, when instructed by the P-CSCF to do so;
4) Receiving notifications of network resources modification from the PCEF, and trying to find the matching configuration from a set of stored service configurations.

When determining the tariff class, the PCRF sends the chosen service configuration to the Tariff Function, which returns the calculated tariff class of the service, based on the predefined algorithm.

B. Network resources reservation and charging

The state machine of the PCEF is portrayed in Fig. 5. While the PCRF is responsible for creation of PCC rules, the PCEF operates in the connectivity layer. It receives the PCC rules, reserves necessary network resources needed for session establishment, and performs online

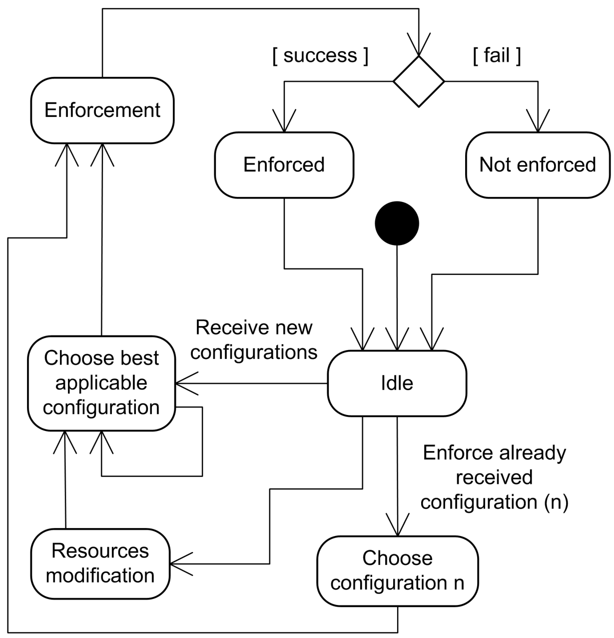

Fig. 4. The PCRF state machine

charging for the reserved resources. At this level, PCEF uses QoS parameters of each media component of the service configuration (although it is not aware of the configuration itself) to assure the neccessary network conditions neeeded for establishing the session for that particular configuration. The responsibilities of the PCEF in communication scenarios with the PCRF are the following:

1) Receiving PCC rules from the PCRF, reserving resources, and contacting the OCS to initiate the charging process;
2) Sending notification to the PCRF about available resources, if network conditions change.

A charging key from the PCC rule is used when starting a charging process with the OCS. It identifies the charging mechanism (e.g. online), charging model (e.g. time-based charging, event-based-charging, volume-based charging), and the tariff class of the service to be charged.

The main characteristic of the PCEF node in this model is network independence. We assume the network has ability to:

1) Perform channel-based network QoS reservations, where a channel is defined as an end-to-end path in the network identified by its source and destination transport addresses, where certain network QoS conditions exist.
2) Dynamically report change of network conditions to the PCEF for the already created channel(s).

C. Modifications at the OCS

The ABMF contains information about all user accounts - their *total*, *reserved*, and *available balance*. *Available balance* is the amount of money a user can afford when requesting a service. *Reserved balance* is the

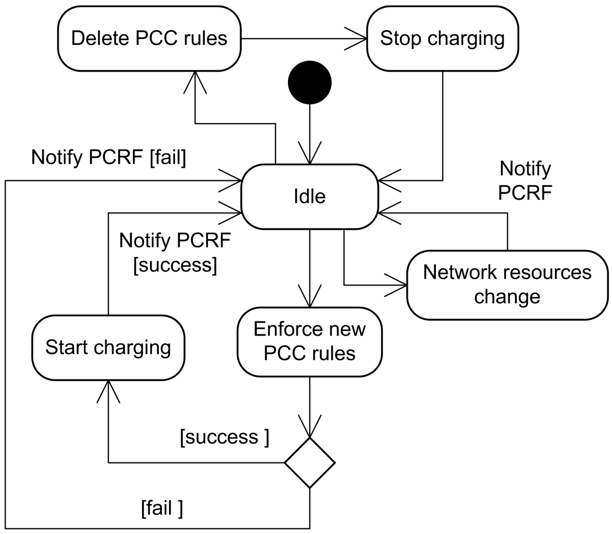

Fig. 5. The PCEF state machine

amount of money which will be spent for a requested service but is not yet spent. *Total balance* is a sum of *available balance* and *reserved balance*.

Tariff Function consists of two modules, as shown in Fig. 3: A Tariff Class module and a Tariff Price module. The Tariff Class module is responsible for retrieving an appropriate tariff class after processing the request from the PCRF. The tariff class can be provided for any combination of media components and their parameters within the service configuration, thanks to the tariff class rules of the service, stored in the Tariff class rules repository among tariff class rules of other services. A set of tariff rules contains a (provisional) combination(s) of algorithm(s) that will, using the service configuration as an input parameter, determine an appropriate tariff class. The Tariff Price module is responsible for retrieving information about tariff prices for given tariff classes of the service, and is later used in the online charging process. The tariff information is needed for credit authorization process, since the OCF needs to calculate the total price for the requested amount of service units. According to the received tariff class, a tariff price for a specific service is determined by looking in the Tariff repository.

Having received credit authorization requests from the PCEF, the OCF performs the actual online charging process. It gains necessary information about the available balance from the ABMF, and the appropriate tariff class from Tariff Function, calculates if the credit authorization is possible, and returns a response to the PCEF using Diameter-based Gy reference point and the Credit-control application.

This model supports two types of credit control: Session-based credit control and Event-based credit control. Session-based credit control is used for services for which the duration is unknown in advance, and which need session establishment (e.g. video calls, media-rich conference calls, etc.). Event-based credit control is used for services which do not need session establishment (e.g. Multimedia Messaging Service), and a single credit control authorization is enough for their authorization.

D. Testbed implementation

In the scope of this work, we developed a prototype testbed based on the described model. All nodes (P-CSCF, PCRF, PCEF, and OCS) were implemented using Java programming language. Diameter-based Rx, Gx, and Gy reference points were implemented using Openblox Diameter framework [10]. At the OCS, we developed a Graphical User Interface (GUI) for monitoring all charging events, creating new tariff classes, and for adding tariff class determination rules (Fig. 6). This GUI would typically be used by network administrator. It consists of four blocks: 1) “Account balance management” block displays user-related data, including all registered users, their available and reserved balance; 2) “Service list” block is divided into several tabs, each tab containing a list of available tariff class labels and their prices, for a different service (an example will be given later); 3) “Online charging” block displays all charging sessions which are curently taking place (left side), and charging history for each charging session (right side); 4) “Console” block displays all credit-control messages exchanged with the OCS. A middleware between the PCEF and the network is implemented, serving as a group of handlers for various network emulators. At this point, the middleware supports three different network emulators/simulators: Chanet [17] IPv6 network emulator; NIST Net [18] IPv4 network emulator; and, IMUNES [19] IPv4 network simulator, which will be used for practical testbed demonstration in the next section.

V. Example: Online charging for Inheritance Chase Game by using tariff classes

In order to demonstrate the use of the testbed, we will show how to perform online charging of the Inheritance Chase (IC) Game, within the emulated IMS environment. After starting the game, a user enters a 3D virtual environment, (Fig. 7), with the goal to find the secret “clue” which will help him find a hidden treasure. While searching the clue, he triggers the playout of a audio/video stream, informing the user where the treasure is. The initiated stream presents a new media component in the service, requiring additional network QoS to be assured, i.e. a new set of feasible and optimized service configurations. Additionally, the network can report the lack of resources needed for necessary QoS assurance for the configuration with the highest utility, resulting in enforcing the “second best” configuration from the set of previously negotiated service configurations. After finding the treasure, the game is ended, and the session with the user is terminated.

The main characteristic of this game is that it can be personalized by including user preferences and their communication capabilities in a process of creating a (set of) possible final service configuration(s) during session negotiation process within the IMS core. For example, a final configuration can depend on the user’s preference

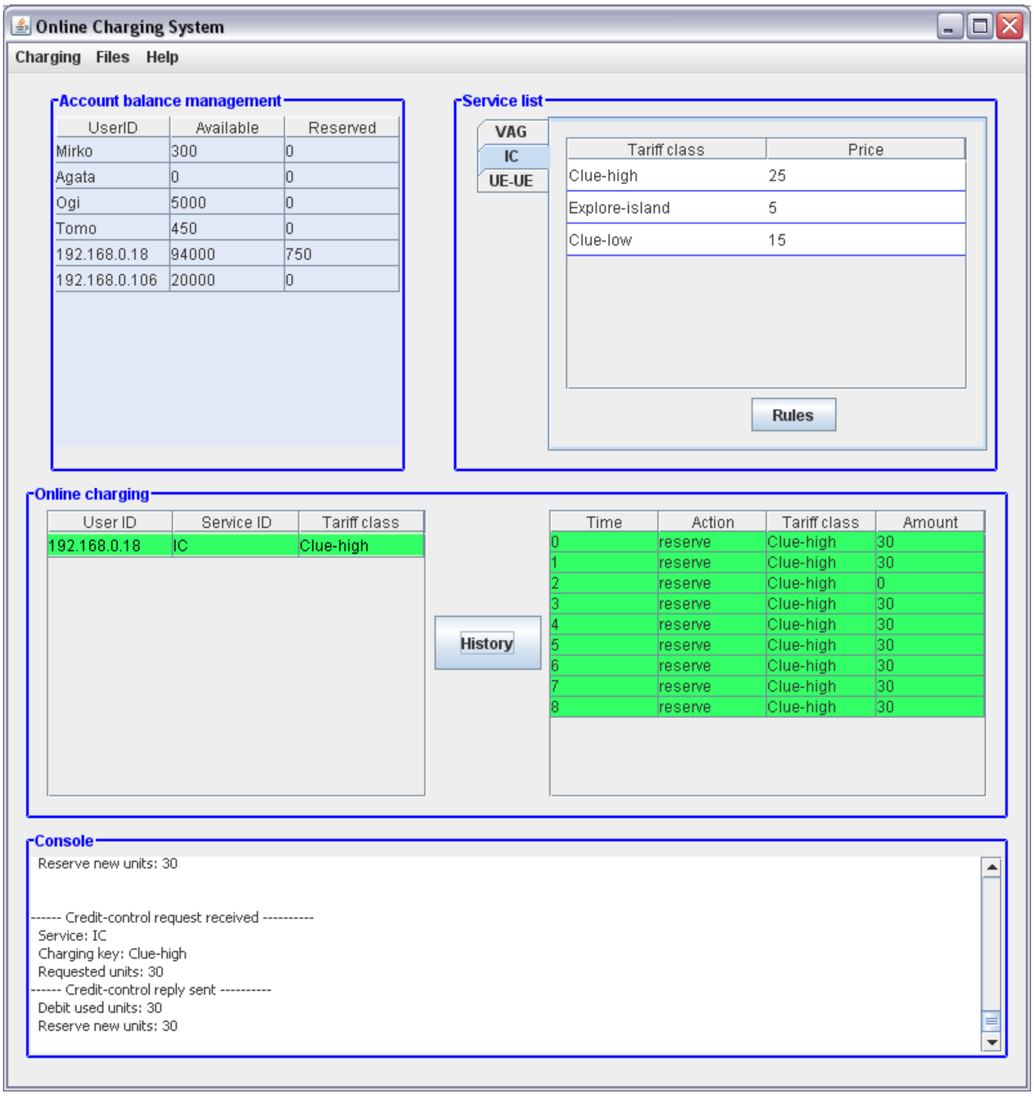

Fig. 6. Online charging GUI

on whether he prefers audio communication in the game more than text communication.

Fig. 7. Inheritance chase game

The online charging for the described scenario is performed by using the testbed. For demonstrating purposes, three tariff classes were created for the IC game, and the rules which define how to map configurations to tariff classes are shown in Table I. The table lists conditions that must be fulfilled for each configuration (first column) in order to achieve a certain tariff class (second column). For easier understanding, tariff classes are labeled by descriptional names. Normally, a tariff class along with proper conditions is specified by a service provider and is given an identification number.

TABLE I
TARIFF CLASS RULES FOR IC GAME

Configuration condition	Tariff class label
Total requested bandwidth $<$ 50 kbps	Explore island
Video and audio component exist	Clue high
Only audio component exist	Clue low

The stakeholders in this scenario have the following roles: the user is a person who plays the game; the game provider acts as a service provider, offering game content; the network provider is emulated by using IMUNES. For each session, a set of channels is created, one for each media component, with the network QoS parameters depending on the enforced configuration. At the time network resources are reserved, online charging process initiates.

A. Session establishment

Fig. 8 presents a signaling scenario related to session establishment, which requires initial download of the virtual 3D scene to the user equipment. After initial negotiation in the IMS is finished, the P-CSCF receives two possible service configurations needed for scene download. The P-CSCF sends the initial set of service configurations to the PCRF (1), using Diameter-based Authentication-Authorization Request (AAR) message. The PCRF selects the best configuration (the one with the highest utility value) and obtains its charging key by contacting the OCS (2, 3). The charging key identifies the charging model (in this example time-based charging model is selected), the service being charged, and the tariff class to be used in the charging process. In this case, tariff class "Explore island" is chosen, since it was detected that the requested bandwith summary of all media components in the configuration does not exceed 50 kbps. The chosen configuration and the charging key are forwarded as a set of PCC rules to the PCEF for enforcement (4), by using Diameter-based Re-Authentication-Request (RAR) message. If there are not enough network resources available for the chosen configuration, the PCEF fails to enforce this configuration, and notifies the PCRF about the available network resources (5), using Re-Authentication-Answer (RAA) message. The PCRF selects the next best configuration, determines (6, 7) its charging key ("Explore island" again), creates a new PCC rule and sends it to the PCEF (8). The PCEF successfully reserves resources, and initiates the online charging process by triggering the OCS (9, 10) using Diameter messages Credit-Control-Request/Answer (CCR/CCA). The OCS confirms the request and the PCRF (11) and the P-CSCF (12) are notified.

B. Change in service requirements

During the game, a user must search for clues which will lead him to the hidden treasure. After opening a clue, an audio/video stream is initiated, informing the user where to find the next clue. This initiates a change of service requirements, because additional network resources for the video conference are required. A user and a game provider initiate a re-negotiation process, which will result in creating three feasible configurations, each of them containing requested audio and video components, differing in chosen codecs. As shown in Fig. 9, the P-CSCF sends the received configurations to the PCRF (1). The PCRF receives the configuration, obtains its charging key (2, 3), creates a new PCC rule and sends it to the PCEF. This time, another tariff class is chosen, namely "Clue high", since the chosen configuration contains both video and audio component. The PCEF stops the charging process for currently active configuration, enforces the new configuration (4), initiates the charging process with new charging key (5, 6) and sends a confirmation to the PCRF (7). The PCRF forwards the confirmation to the P-CSCF (8).

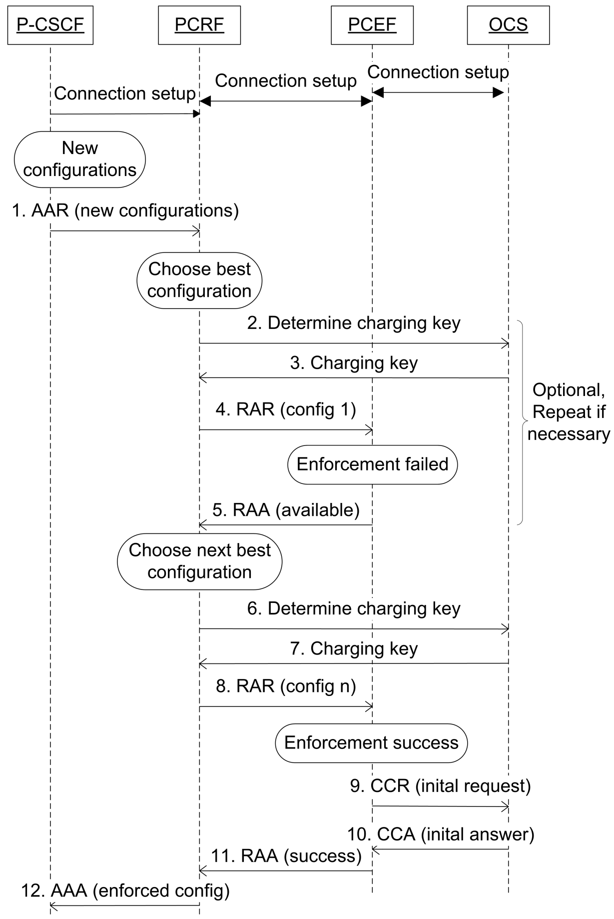

Fig. 8. Signaling for session establishment

C. Change of network conditions

In a scenario when network resources change, i.e. the previously reserved network resources are no longer available (Fig. 10), the PCEF informs the OCS to stop the charging process (1, 2) and notifies the PCRF of the available resources (3), including bandwidth, delay, jitter, and, loss rate. The PCRF chooses the next best configuration, obtains its charging key from the OCS (4, 5), sends new PCC rules to the PCEF (6) and informs the P-CSCF of the change in active service configuration (7, 8). The PCEF enforces the new configuration, and initiates the charging process again by contacting the OCS (9, 10). In this scenario, the second chosen configuration contains only audio component, resulting in a choosing different tariff class ("Clue-low").

D. Session termination

Terminating the session is performed in a usual way. The PCRF receives a message about session termination, it deletes all session-related PCC rules, it informs the PCEF to stop charging and to release network resources.

VI. Conclusion

In this work, we presented a design and implementation of a testbed for online charging of negotiable services

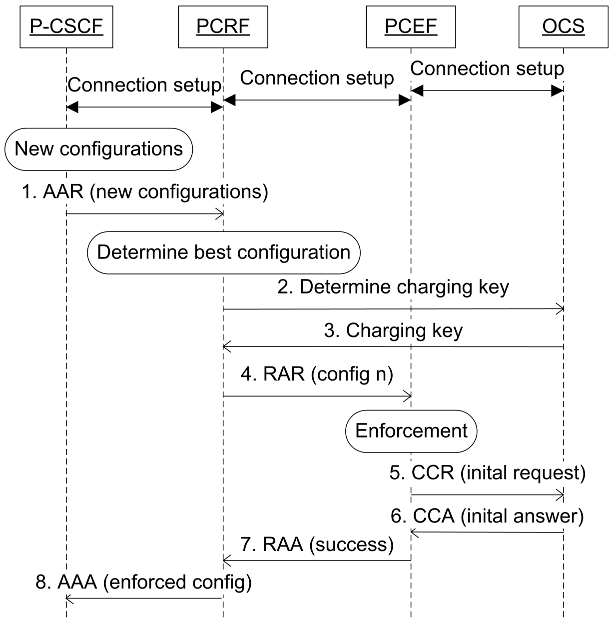

Fig. 9. Singaling during user initated service configuration change

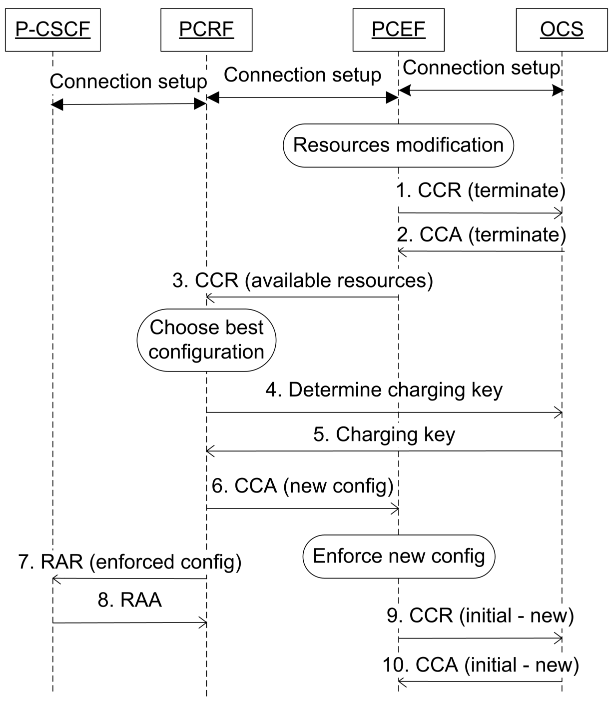

Fig. 10. Signaling during modifications of network resources

within the PCC arhitecture in IMS. The standard IMS reference points between functional entities are used. Additionally, the testbed is independent of the charging mechanism used. The architecture is service independent, meaning that each service configuration is represented with basic network-level parameters, including network QoS, and a charging key. The main contribution of the work is maintaining the ability to use negotiated QoS in a final service configuration, when using online charging mechanisms. This is achieved by modeling a mapping scenario between negotiated service configurations and tariff classes, in order to determine a final service tariff. The mapping scenario is performed by using the introduced Tg reference point.

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