Online charging in IMS for multimedia services with negotiable QoS requirements based on service agreements

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Abstract: In this work, an online charging model is presented based on the IMS policy control and charging (PCC) framework, which takes into consideration user's agreements with the service provider (e.g., user loyalty programme, service subscription, etc.), with the possibility of providing online charging for services requiring a negotiable QoS in dynamically changing network conditions. The model aims to provide charging for services consisting of a number of media components, where the treatment of each media component within the charging system may differ based on the user's agreement with the service provider. For such services, the QoS negotiation process typically involves various stakeholders (user, network provider, service provider, etc.), and it results in a customised, user-specific combination of media components within the final service configuration. The existing IMS PCC architecture is not well-suited for charging services requiring a negotiable QoS. The proposed model builds upon and extends the online charging architecture specified in the IP multimedia subsystem (IMS) Release 8, and requires less signalling than the standard architecture. The proposed model is illustrated by using the imaginary adaptable movie stream service as a case study.

Keywords: policy control; IMS; online charging; session negotiation; PCC architecture; QoS; service agreement; multimedia services.

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1 Introduction

Networked multimedia services to be offered through the 3GPP IMS (3GPP TS 23.228, 2008), such as multiplayer online gaming, content sharing, and teleconferencing, demand a service platform which supports adaptive quality of service (QoS) management, as well as novel charging models suitable for such services.

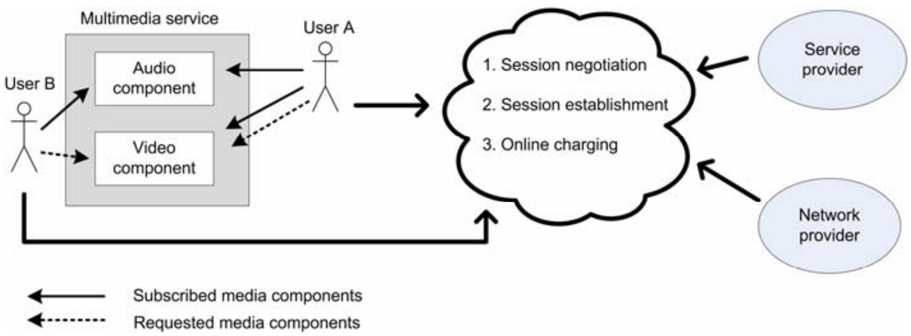
In the Release 8 (3GPP TS 23.203, 2008), IMS offers a framework, called Policy Control and Charging (PCC) architecture, used for charging multimedia services in a flexible and efficient manner. The signalling protocol used within the PCC architecture is Diameter (Calhoun et al., 2003). As standardised by the 3GPP, this framework supports online charging, which requires the charging system to authorise the resource usage before it actually takes place. For a detailed overview on the IMS PCC, the interested reader is referred to the works of Balbas et al. (2009) and Kuhne et al. (2007).

Although the PCC framework, in general, is flexible and applicable for a variety of services, access networks, and charging models, it is not well-suited for multimedia services with negotiable QoS requirements in dynamically changing network conditions. By ‘service with negotiable QoS’ we consider a service offered in two or more service configurations, which differ in required network resources, and consequently the user perceived quality. The process of negotiation, as described later, can trigger the change in an active service configuration based on dynamically changing network conditions. In the session negotiation process a user, a network provider, and a service provider negotiate about the session to be initiated, by using service requirements, network capabilities, and user preferences as input parameters. The result is a user- and session-specific combination of media components included in the multimedia service and the associated QoS parameters within the final service configuration. This type of service requires a process of determining the charging model and a tariff (a price of a basic service unit) by using the negotiated service configuration as an input parameter, a process which is not supported by the current PCC architecture. Moreover, in general case, charging treatment of each media component within the service configuration may differ based on the user’s agreement with the service provider (e.g., user loyalty programme, service subscription, time of the day, etc.) In the following text we will use service subscription as a running example, meaning that an end user can partially subscribe to a (group of) selected media component(s) provided by the service, by establishing a contract with the service provider. Normally, information about all subscribed service components for a single user is stored in a subscription profile. Later, when initiating the service, the user may not be limited by the subscription profile and request any combination of supported media components.

Figure 1 illustrates an example of session negotiation for two users that wish to initiate imaginary multimedia service that supports audio and video components. User A is subscribed to the audio and the video component, and user B is subscribed only to the audio component of the service. If the video component is requested between users A and

B during the session, the charging system should be able to treat the video component differently for users A and B, although it requires the same network resources.

Figure 1 Two cases of session negotiation, establishment and charging for a multimedia service (see online version for colours)



In this work, we present an online charging model for services requiring a negotiable QoS in dynamically changing network conditions, based on the IMS PCC framework, which takes into consideration service agreements as described above. The model introduces new charging mechanisms during the session negotiation and establishment phase as well as during the active session. Finally, the presented model is illustrated by using the imaginary adaptable movie stream service as an example.

The introduced functionality enables PCC architecture to utilise complex session-level negotiation mechanisms and to dynamically adapt online charging process to the negotiated and user-customised service configurations. Moreover, the model provides a dynamic tariff determination process enabling flexible online charging, in a process of mapping customised configurations to predefined tariff classes by using new interface in the PCC architecture. The result is a more flexible charging system regarding service customisation as well as reduced Diameter signalling as compared to the standard architecture.

The paper is organised as follows. After the review of the related work in Section 2, Section 3 gives a brief description of the IMS PCC architecture. Next, Section 4 describes the proposed model for online charging, while Section 5 describes necessary modifications to the PCC architecture to support the model. Section 6 illustrates the model functionality by using the adaptable movie stream service as an example. Section 7 concludes the paper.

2 Related work

The problem of charging multimedia services in IMS has been addressed by Jennings and Malone (2006). In their work, they use a two-phase rating process for establishing total price of the service. In the first phase, individual prices of each media component are calculated, while in the second phase a total price of the service is calculated, depending on a combination of included components. As a further work, Xu and Jennings (2007) propose a process for automated generation of charging schemes for multimedia services.

Differing from that approach, our research investigates the effect of user subscription to a group of media components on the service negotiation process within the IMS domain.

Oumina and Ranc (2007) describe a policy-based framework for modelling charging of complex services in IMS. This framework is oriented towards the charging mechanisms at the application layer. Kurtansky et al. (2007) propose a time interval calculating algorithm as a solution for online charging of multiple services consumed by a single user. The algorithm is used for credit control purposes at the connectivity layer. Our approach is oriented at the charging of service sessions negotiated at the signalling layer and forwarded to the connectivity layer as a group of policies, containing negotiated session information and charging instructions.

Various types of multimedia services must be followed by appropriate charging models. This work aims to provide an online charging model for a group of multimedia services that require service subscription, by building upon and extending our previous work by Grgic et al. (2009).

3 The IMS PCC architecture (Release 8)

The 3GPP specification TS 23.203 (2008) specifies a framework for mapping session-related data in the signalling layer to the network-related data in the connectivity layer, e.g., 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. The main signalling protocol in the above framework is Diameter, which is the next generation Authentication, Authorization and Accounting (AAA) protocol. The core specification, RFC 3588, describes the base Diameter protocol which defines messages that are exchanged between nodes, and the basic message blocks called attribute value pairs (AVP). The base protocol can be extended by using Diameter applications, as well as additional AVPs and messages. Some Diameter applications have been defined by the IETF, and some by the 3GPP.

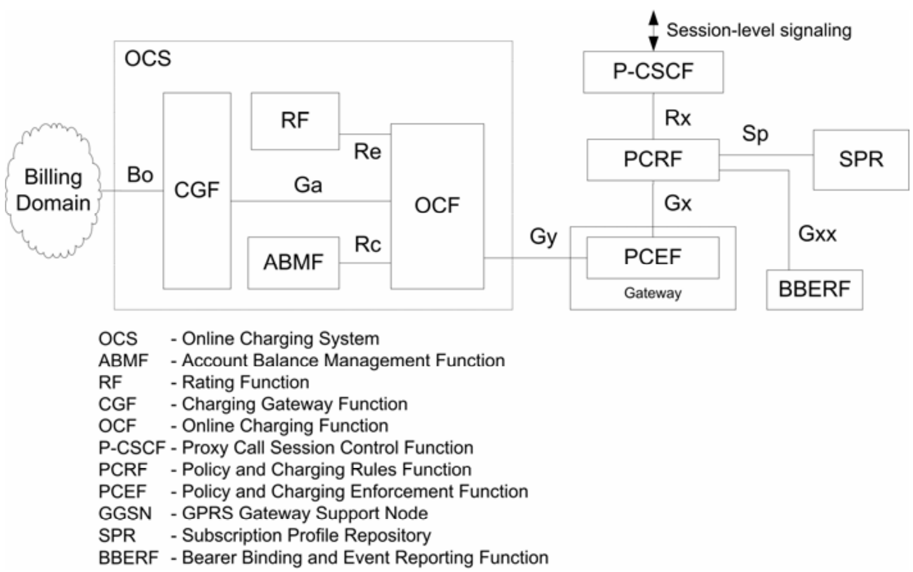
The 3GPP IMS PCC architecture (Release 8) is shown in Figure 2. The key functions are described next. The proxy call session control function (P-CSCF) stands as a session initiation protocol (SIP) signalling node between the IMS core and the user equipment (UE). It forwards session-related information to other PCC nodes. The policy and charging rule function (PCRF) is responsible for receiving this information via Diameter-based Rx interface specified by 3GPP TS 29.214 (2008), 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 flow within the session. When creating the PCC rules, the PCRF decides how a certain service data flow is treated in the packet switched network, depending on the user-specific information (e.g., allowed services, allowed QoS, location information, charging profile, etc.) stored in the subscription profile repository (SPR), and the given 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).

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 it is responsible for receiving and applying the PCC rules from the PCRF via the Diameter-based Gx interface specified by TS 29.212 (2008). 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 standardised credit-control application by Hakala et al. (2005) over the Diameter-based Gy interface. Furthermore, the OCS contains module for storing user credits, called the account balance management function (ABMF), and the module for storing tariffs for all services, called the rating function (RF).

Release 8 includes additional function, the bearer-binding and event-reporting function (BBERF) which takes over some PCEF functionalities in the case when gateway tunneling protocol is not used as the mobility protocol towards the PCEF.

It may be noted that PCC is an access-network independent, but it assumes the existence of PCEF at the access gateway.

Figure 2 The 3GPP IMS PCC architecture (Release 8)



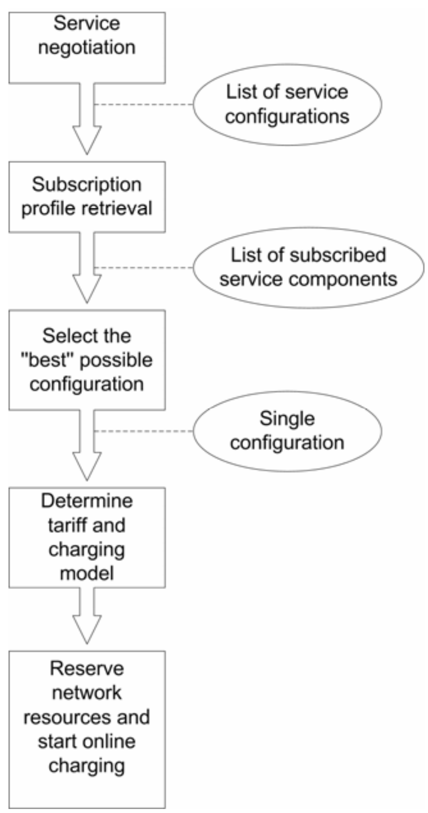
4 Online charging based on service agreements

The main idea was to create a model which would be used for charging of services requiring a negotiable QoS in dynamically changing network conditions. For such services, the user, service, and network parameters are taken into consideration when determining the final service configuration during the session negotiation process, resulting in different configurations for different user-related parameters. In order to limit the problem to the PCC domain, we adapt the following premises about the processes at the signalling and application layer, also illustrated in Figure 3:

- Signalling node (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 (set of) configuration(s) is highly personalised, since it contains a user-specific combination of media components within the service.

- A user can define certain charging preferences as an input parameter to the negotiation process, e.g. a range of acceptable service cost. Negotiated service configurations must correspond to the required range.
- Based on the negotiation process, one or more feasible service configurations are sorted by decreasing utility. Each of the configurations can be applied at the connectivity layer, assuming that the configuration with the highest utility is the most acceptable for enforcement, and the one with the lowest utility is the least acceptable, as defined by Skorin-Kapov et al. (2007).
- After the negotiation process and prior to session establishment, signalling node (CSCF) sends all negotiated service configurations to a network control node (PCRF node), which, after retrieving user's subscription profile, makes the decision on which configuration to choose.
- At any point in the session, another service configuration can be applied, due to a session renegotiation or a change in network conditions.

Figure 3 The process of determining online charging parameters



When referring to the 3GPP TR 23.810 (2008), the negotiation process described in Skorin-Kapov et al. (2007) would correspond to centralised service brokering function, situated at the central signalling node (S-CSCF). In our case, application servers involved in session negotiation will not be aware of the service broker itself. Additionally, the model in Skorin-Kapov et al. (2007) utilises an end-to-end signalling application programming interface (API) which identifies exact order of SIP signalling messages between application servers during the negotiation process.

An important aspect of the presented model is the structure and the subscription method of the service for which online charging is being modelled. We assume the multimedia service (in general) is composed of a number of media components, each of them requiring particular network resources and a subscription relationship with the user. For example, a service X can support audio, video, and the data stream components while the user A may be subscribed to audio only, and additionally request video in the session I, as listed in Table 1. In order to start the negotiation process, an end user must establish a service agreement in form of a contract with his service provider for the given service. In the contract, charging models and mechanisms are specified, as agreed between a user, a service provider, and a network provider. In the contract, the service provider offers the user a (set of) available media components for a given service, defining the guaranteed QoS of each component. A network provider, who is responsible for the session establishment between the user and the service provider, must locally store the data subset from the contract, called subscription profile, containing information about guaranteed media components, in order to perform the charging process. This profile, defining general charging policies for the service, will be used as an input parameter for creating policies for online charging of the given service. The subscription profile would typically be created when the user signs a contract with the service provider, describing all service components he/she is entitled to receive.

Additionally, the presented model follows these requirements: design must be in line with standard IMS entities and extended to support new functionality (as described later); service and user independence; support for various online charging models. The proposed concept enables a network provider to control all costs made by the user, while taking into consideration his/her relationship(s) with the service provider(s).

Table 1 Media components subset example

Supported media components for service X	*Subscribed media component for service X and user A*	*Requested media components for service X, user A, and session I*
Audio, video and data stream	Audio	Audio and video

4.1 Session negotiation and establishment

The process starts when a user initiates a session negotiation procedure involving both the service provider and the network provider. In a general case, a user's initial request may not be limited by media components listed in his subscription profile. He/she can request any component supported by the service, as shown in the example in Table 1. Subscription profile is only used to instruct the network operator how to charge for each of the negotiated components, after the session has been established. In the example of charging for the given service in the example, the charging system must treat the audio component differently than the video component, since the former has been included in the subscription.

The information regarding all agreed service configurations (each of them containing all negotiated media components, but differing in chosen codecs, QoS classes, etc.), are transferred to a network control node. Since the final service configurations are not known by the network provider before session negotiation ends, the network provider is not able to determine the tariff for the service before the negotiation process is finished. As a solution for this problem, the service provider determines a set of tariff classes for each service as well as the algorithm for determining the tariff class from the service configuration, and leaves the tariff class to be determined by the charging system in the domain of network provider, depending on the received configuration and the subscription profile.

Tariff class concept enables mapping any of *m* user-specific service configurations onto one of *n* tariff classes by using a predefined algorithm, assuming that *m* may be much greater than *n*. In the example in Table 1, tariff determination process will be held for user-customised audio and video components of a chosen configuration. This enables the service provider to specify a limited number of tariff classes for each service, as well as the mapping algorithm, while supporting a (possibly very) large number of individual user-specific service configurations.

In this case, a network provider will retrieve the stored subscription profile, select the best possible configuration, and send a tariff class request to the charging system by using subscription profile and the chosen configuration as input parameters. After processing the request and applying the predefined algorithm, the charging system will return tariff class identifier for the requested set of data.

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

4.2 Session duration

After a successful resource reservation needed for service delivery is performed at the network node, the session is initiated. As from that moment, charging process uses standard online charging methods based on credit control application, as instructed by the network control node. Tariff class and charging method identified during session negotiation are used.

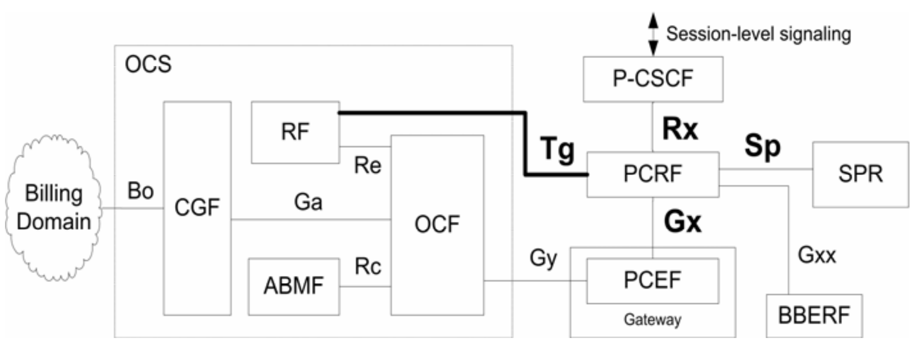
Our model supports two types of credit control: session-based credit control and event-based credit control. Session-based credit control is used for services for which the duration is unknown in advance, and which need session establishment (e.g., video calls, multimedia conference calls, etc.). Event-based credit control is used for services which do not need session establishment (e.g., multimedia messaging service), and a single credit control message is enough for their authorisation.

5 Required PCC architecture modifications

Figure 4 illustrates modified IMS PCC architecture, highlighting the new interface as well as existing interfaces that had to be modified. In addition to the current architecture, the interface between the OCS and the PCRF is introduced, namely the Tg interface. The Tg is used for determining the tariff class of the chosen service configuration, and is in more detail described later. During the service negotiation, P-CSCF node is responsible for extracting a list of feasible service configurations from a received SIP message, for each established session. Next, all feasible configurations are signalled to the PCRF node via the Diameter-based Rx interface. [a detailed description about the necessary modification of the Rx and Gx reference points to support this data format and the signalling can be found in Grgic et al. (2008)]. Additionally, P-CSCF must signal enforcement of another configuration sent earlier, as a result of renegotiation process, to the PCRF. Since the PCRF acts as a network control node in the PCC architecture, it must:

- retrieve user's subscription profile from the SPR, containing subscribed service components for a particular service (subscription profile is updated at the SPR each time a user subscribes to a particular service or one or more service components within the service, or chooses to remove any subscription)
- depending on the actual network status, choose the best applicable configuration from the set of received configurations
- determine the tariff class for the chosen configuration by contacting the RF (the request to the RF contains chosen configuration as well as the subscription profile received from the SPR)
- map chosen configuration to network and charging policies, i.e., generate a set of PCC rules by combining the configuration with the information about the tariff class.

Figure 4 Modified PCC architecture



At this point, the PCRF is ready to initiate resource reservation and charging. Next, all generated PCC rules are signalled to the PCEF node via the Diameter-based Gx interface. Since the PCEF node operates in the connectivity layer, it receives the PCC rules, reserves necessary network resources needed for session establishment, and starts online charging for the reserved resources. At this point, PCEF uses QoS parameters of each media component of the service configuration (although it is not aware of the configuration itself) to assure the necessary network conditions needed for establishing the session for that particular configuration. 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), charging model (e.g., time-based charging, event-based-charging, volume-based charging), and the tariff class of the service to be charged. Additionally, if available network resources change and the current QoS cannot be maintained (e.g., in case of user switching from UMTS to GPRS network), PCEF must trigger the PCRF node to enforce another configuration (e.g., the one which demands less network resources).

In order to apply the proposed model, certain preconditions regarding the access network characteristics must be met:

- an access network must be able to perform flow-based network QoS reservations, where a flow 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
- change of network conditions must be dynamically triggered to the PCEF, if the change affects any of the created flows.

5.1 Online charging system

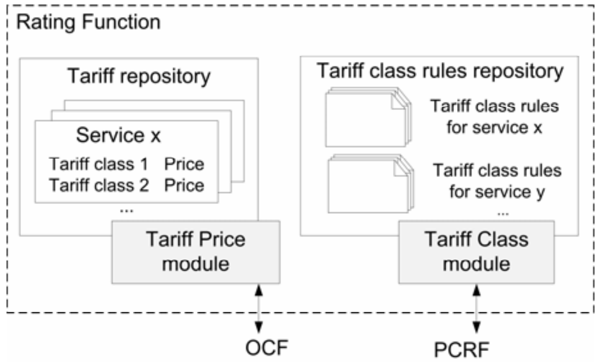
The ABMF contains information about all user accounts – their *total*, *reserved*, and *available balance*. *Available balance* is the amount of money a user can afford when requesting a service. *Reserved balance* is the amount of money which will be spent for a requested service but is not yet spent. *Total balance* is a sum of *available balance* and *reserved balance*.

The RF consists of two modules, as shown in Figure 5: a tariff class module and a tariff price module. The tariff class module is responsible for providing the appropriate tariff class after retrieving the request from the PCRF via the Tg interface. The tariff class can be provided for any combination of media components and their QoS parameters within the service configuration, thanks to the tariff class rules of the service. The tariff class rules are stored in the tariff class rules repository, for various services. A set of tariff rules contains a (provisional) combination(s) of algorithm(s) that, using the service configuration and subscription profile as input parameters, determine the tariff class. The tariff price module is responsible for providing 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 authorisation process, since the OCF needs to calculate the total price for the requested amount of service units. According to the given tariff class in the credit-control request, a tariff price for a specific service is determined by looking into the tariff repository.

Having received credit authorisation 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 RF, calculates if the credit authorisation is possible, and returns a response to the PCEF using Diameter-based Gy interface and the credit-control application.

At the same time as the online charging process takes place, the OCF sends the charging records to the CGF. After the session is ended, all charging records regarding that session (used service components, used tariff, session duration, etc.) are gathered in a single charging record file and sent to the billing domain, where will be analysed in order to share the revenue between all parties included in service provision (that process is out of scope of this paper).

Figure 5 Rating function architecture



5.2 Tg interface

Tg interface is Diameter-based. Two types of messages are modelled for the interface: tariff class request (TCR) and tariff class answer (TCA). Additionally, these AVPs are introduced: *subscription-profile*, *media-component*, *component-ID*, *subscription-level*, *tariff-class*, and *class-ID*. Other AVPs are reused from other Diameter applications.

TCR message is used for sending a tariff class request from the PCRF to the RF, and its structure is shown in Table 2. It consists of three main datasets: user identifier, chosen configuration, and the subscription profile. For sending the chosen configuration, *MDP-configuration* AVP is used, as defined in Grgic et al. (2008). It contains a list of all media components within the configuration as well as all required QoS parameters (bandwidth, delay, jitter and loss rate) for each component.

Table 2 Structure of TCR message

Attribute name	*Value type*	*Occurrence*
User-ID	String	1
MDP-configuration	Grouped	1
Subscription-profile	Grouped	1
Service-ID	String	1
Media-component	Grouped	*
Component-ID	String	1
Subscription-level	Integer	1

Subscription-profile AVP is of type *grouped* and contains a *service-ID* AVP, and the list of media components in a form of one or more *media-component* AVPs. Mark (*) indicates that this AVP may occur more than once in the message (in the case service has more than one component). Next, *media-component* AVP is of type *grouped* containing two AVPs: *component-ID* (identifying the component), and the *subscription-level* AVP. The latter one defines the user's level of subscription to the media component and is represented as an integer. Integer values are interpreted depending on the type of component, e.g. level 0 may mean that the user does not have any subscription, and level 3 that the user is fully subscribed to the component.

TCA message is used for sending the tariff class back to the PCRF, after it had been determined at the RF. As shown in Table 3, it contains *user-ID*, *service-ID*, and *tariff-class* AVPs. *Tariff-class* AVP is of type grouped and contains *class-ID* AVP (the tariff class identifier), and the *charging-model* AVP (defining charging model, e.g., time-based or volume-based charging model).

Table 3 Structure of TCA message

Attribute name	*Value type*	*Occurrence*
User-ID	String	1
Service-ID	String	1
Tariff-class	Grouped	1
Class-ID	String	1
Charging-Model	Integer	1

6 Example: online charging of the adaptable movie streaming (AMS) service

The use of the charging model presented in previous section will be illustrated by using the imaginary AMS service, provided by a third-party application server (AS). The AMS service belongs to a group of multimedia services, and is used for watching movies over the internet by utilising audio, video, and data streaming technologies. In addition to a standard video-on-demand service, this one enables a user to make adaptations to the movie being watched by ordering subtitles in different languages, and switching to another audio component containing voice in a different language (created by a process known as dubbing). By using the service and a network supporting QoS, the user can dynamically perform any of the above mentioned adaptations.

In this example, Bob is subscribed to the AMS service. His subscription package includes possibility to watch any movie currently available at the server, containing audio component in an original language, and a data stream of subtitles in Croatian language, as shown in Table 4. Bob pays a certain amount of money to the service provider to get the package, which results in storing his subscription information at the SPR. Additionally, he can order different audio component dubbed to another language, or subtitles in different language, but it will cost him extra money.

The service starts when Bob decides to watch an English movie with Croatian subtitles. When entering the negotiation process with the provider, he sets a preference of using MPEG-2 codec instead of MPEG-4 codec. After the negotiation is finished and the session is established, Bob begins to watch the movie. During the movie, his German friend Helga pays him a visit. They decide to continue watching the movie together, but this time Bob requests an audio stream dubbed to the German language, while keeping Croatian subtitles. This will trigger a session renegotiation process, since a new media component is included in the service, the one which is not included in Bob’s subscription. Next, during the movie, the underlying network load increased, which results in enforcing the ‘next best’ configuration from the set of previously negotiated service configurations, i.e., switching to another codec. Finally, the movie is ended and the session is terminated.

Table 4 Media components supported by the AMS service

Media component name	*Supported by the service*	*Included in Bob's subscription*
Video stream	+	+
Original audio stream	+	+
Dubbed audio stream	+	–
Subtitles in Croatian	+	+
Subtitles in another language	+	–

The main characteristic of this service is that it can be personalised by including Bob's preferences and his communication capabilities in a process of creating a (set of) possible final service configuration(s) during the session negotiation process within the IMS. For example, a final configuration can depend on a list of codec's that are supported by Bob's terminal.

For the purpose of this example, four tariff classes are created, as listed in Table 5 and stored at the RF, each labelled by its descriptive name. In the system, a tariff class is assigned a unique identification number. A tariff class is assigned to the service configuration, depending on the configuration properties, and the information retrieved from the subscription profile. In this example, T1 and T2 tariff classes will be applied to Bob's service if he watches the movie in an original language, but the movie with the dubbed audio component (tariff classes T3 and T4) will cost Bob more than the original audio component, although both of them demand similar network resources.

Table 5 Tariff classes for the AMS service

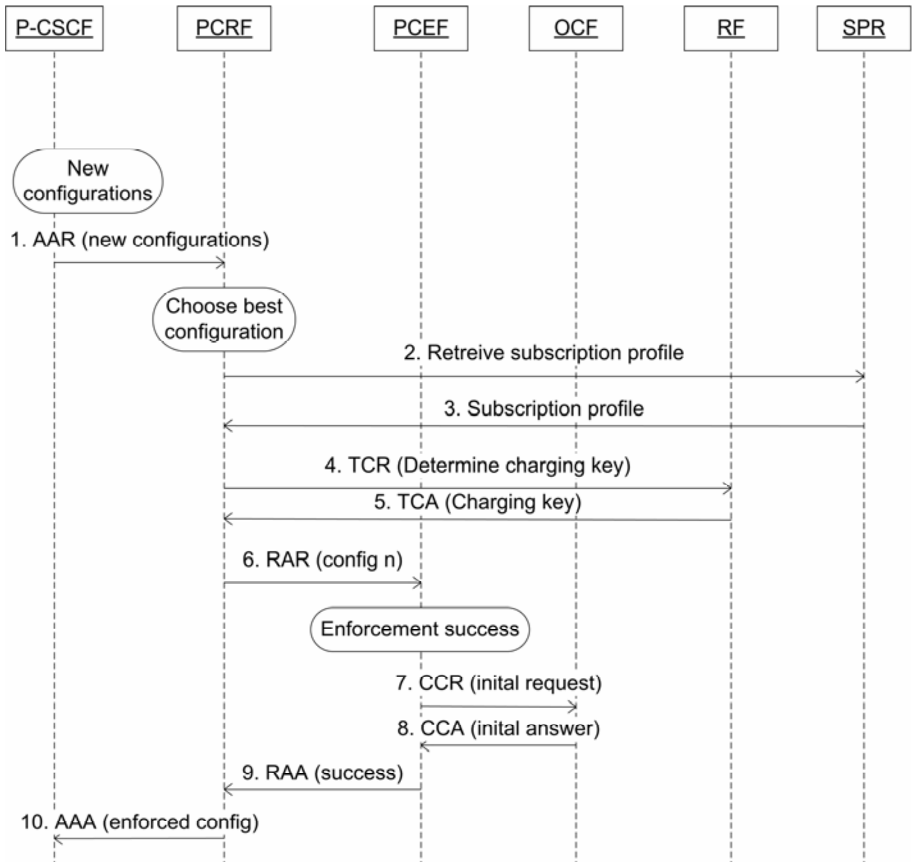
Tariff label	*Tariff class description*	*Price*
T1	Original movie	5
T2	Original movie + subtitles	8
T3	Dubbed movie (MPEG-2) + subtitles	35
T4	Dubbed movie (MPEG-4) + subtitles	30

6.1 Session establishment

Figure 6 presents a signalling scenario related to session establishment. After the negotiation process, the P-CSCF receives two possible service configurations. The P-CSCF sends both service configurations to the PCRF (1), using Diameter-based authentication-authorization request (AAR) message. The PCRF selects the better configuration (the one with the higher utility value) and obtains Bob's subscription profile from the SPR (2, 3).

Next, it sends the TCR message (4) to the RF, containing the subscription profile and the chosen configuration. RF returns the TCA (5) message, containing the requested tariff class and the charging model. These parameters will be used for creating charging key for the service, which will later be used in online charging process. In this case, tariff class T2 is calculated. The selected configuration and the according charging key are forwarded as a set of PCC rules to the PCEF for enforcement (6), by using Diameter-based re-authentication-request (RAR) message. The PCEF successfully reserves resources, and initiates the online charging process by triggering the OCS (7, 8) using Diameter credit-control-request/answer (CCR/CCA) messages. The OCS confirms the request, and the PCRF (9) and the P-CSCF (10) are notified.

Figure 6 Session establishment signalling

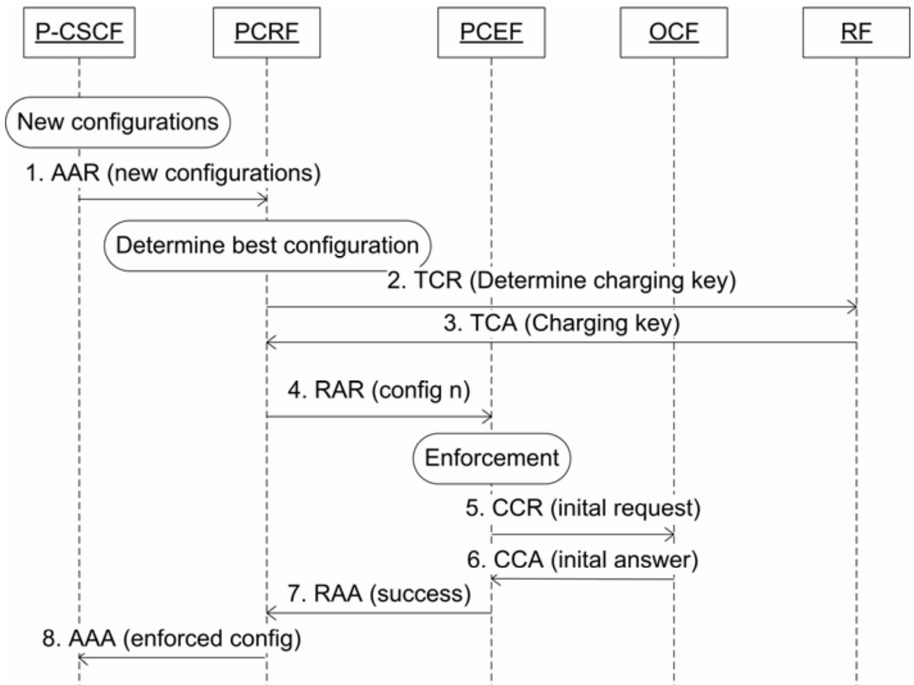


6.2 Change in service requirements

During the session, Bob decides to change audio component from original English to dubbed German. This scenario presents a change of service requirements, because different media components must be included in the session. Bob's terminal and the application provider initiate a renegotiation process, which will result in creating three feasible configurations, each of them containing requested audio, video, and data stream components, differing in chosen codecs. As shown in Figure 7, the P-CSCF sends the received configurations to the PCRF (1).

The PCRF receives the configuration, obtains its charging key (2, 3), creates PCC rules based on the configuration with the highest utility value (the one containing MPEG-2 codec), and sends them to the PCEF. This time, T3 tariff class is chosen. Note that after step 1, no subscription profile (needed for steps 2 and 3) is retrieved from the SPR, since it was retrieved during the session establishment scenario. This reduces necessary Diameter signalling in relation to standard architecture and increases performance of the system. 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). Tariff price in this case is different (higher) than in previous cases, since dubbed audio component is not included in the Bob's subscription profile.

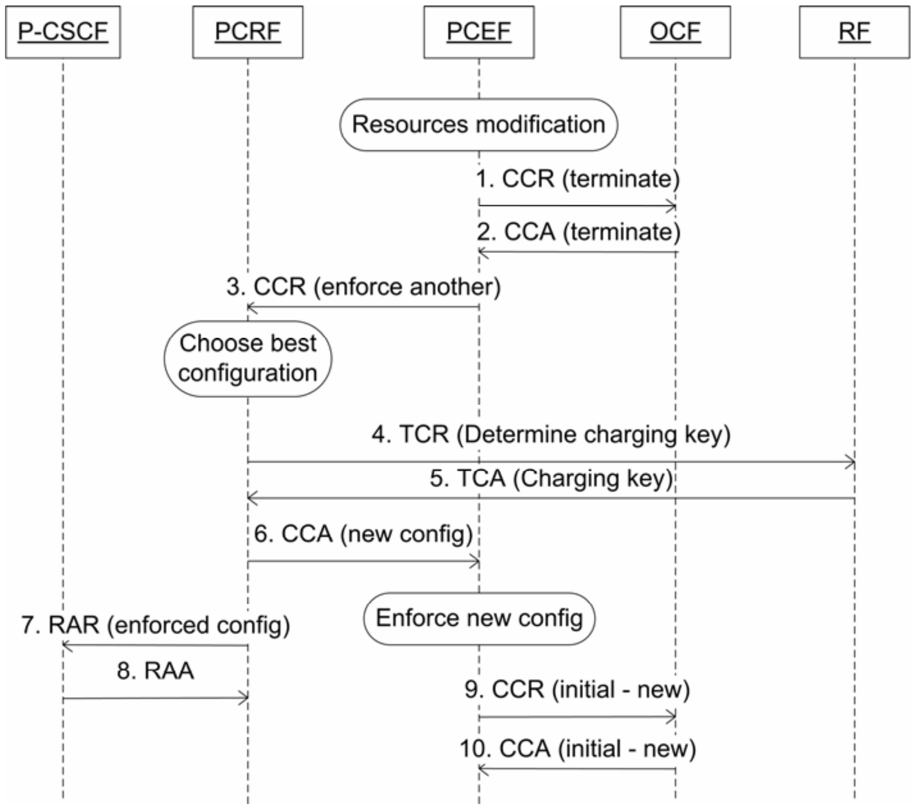
Figure 7 Signalling initiated by service configuration change



6.3 Change of network resources

In a scenario when network resources change, i.e., due to the congestion in Bob's underlying network (Figure 8), the PCEF informs the OCS to stop the charging process (1, 2) and notifies the PCRF to enforce another configuration, which would require fewer network resources. The PCRF chooses the next best configuration (the one containing MPEG-4 codec), obtains its charging key from the OCS (4, 5), sends the 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 case, the second chosen configuration, which requests fewer network resources, is given tariff class T4. This scenario also contributes to reduced signalling, since another configuration is ready for enforcement and no session renegotiation procedures are needed.

Figure 8 Signalling initiated by network resources modification



6.4 Session termination

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

7 Conclusions

In this work, we presented a model for online charging for subscription-based multimedia services with negotiable QoS requirements within the modified PCC architecture. The model uses a list of user-customised and optimised service configurations, obtained from the session-level negotiation process, as an input parameter to the charging process. In order to perform online charging, the standard PCC architecture was improved by introducing a new reference point (Tg) between the PCRF and the RF node. This interface allows the architecture to dynamically map negotiated service configurations to existing tariff classes, in order to determine a final service tariff for online charging. The architecture can be used with any access network that supports QoS, meaning that each service configuration (built from all negotiated media components) is represented with basic network-level parameters, including network QoS, and a charging key.

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