# Charging in the IP Multimedia Subsystem: A Tutorial

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## ABSTRACT

The IP multimedia subsystem enables a service-rich communication landscape and the convergence of mobile and fixed networks. However, IMS solutions can succeed only when charging for these new services is supported in a flexible and efficient manner. To meet the new challenges, the 3GPP recently introduced a generic charging framework. In this article we give a short overview of the 3GPP charging framework and then describe how IMS charging works within this framework. To illustrate IMS charging, we discuss an IMS scenario in which three persons with different payment methods conduct a teleconference.

## INTRODUCTION AND MOTIVATION

Today, mobile telecommunication operators are faced with saturating markets in developed countries and a decrease in average revenue per customer resulting from fierce competition. Especially with traditional services — such as voice and messaging — losing the cash cow function and plain data services, such as Internet access becoming a commodity, new sources of revenue in the form of feature-rich communication and multimedia services are attracting great interest. Examples are packet-switched voice services, such as voice over IP (VoIP), multi-player online gaming, content and media sharing, as well as multimodal teleconferencing. Regarding the introduction and operation of such new services, the IP multimedia subsystem (IMS) [1, 2] as a service platform offers control capabilities and promises to reduce operational and capital expenses by increasing flexibility and simplicity, based on a single infrastructure. But to realize the promised potential, it also is important to charge these new services both effectively and flexibly. Employing a flat-pricing approach would allow many opportunities stemming from the wide variety of new IMS services to remain untouched; opportunities that competitors with more customer-oriented tariff models who address their customers' individual needs would be very willing to take. On the other hand, as a platform, IMS offers the operator the possibility of a single charging solution for all introduced services.

In this article we provide a tutorial for the charging functionalities in IMS as specified by the 3GPP. IMS charging is part of a larger charging concept defined within the 3GPP Release 6 charging framework. On this basis, first we introduce the general principles and architectural considerations in order to delve into the IMS-specific details. These details are how the two major charging mechanisms, namely online and offline charging, are realized for IMS. Among other considerations, this includes: what information is collected; what protocols are used to transfer this information to the respective functional elements to process it, as well as for online charging; and how the interaction between charging and service provision is achieved. Then, we present an IMS teleconferencing example that addresses a deeper understanding regarding the previously mentioned functionality and procedures. Finally, a short summary concludes this tutorial.

## 3GPP CHARGING: COMMON PRINCIPLES AND ARCHITECTURE

IMS charging in 3GPP Release 6 are not isolated but rather are part of an overall charging concept. Its general principles and architectural considerations are introduced to form the basis of the description of the IMS-specific charging details.

With 3GPP Release 6, a common framework for charging standardization was created by describing the general charging functionalities in a single standard [3], serving as an umbrella document for all subsequent charging specifications. This became necessary as the growing number of technologies and services made the former approach of self-contained standards unfeasible. Instead of defining all charging functionality required for the respective service or technology anew each time and independently of already existing charging specifications, 3GPP Release 6

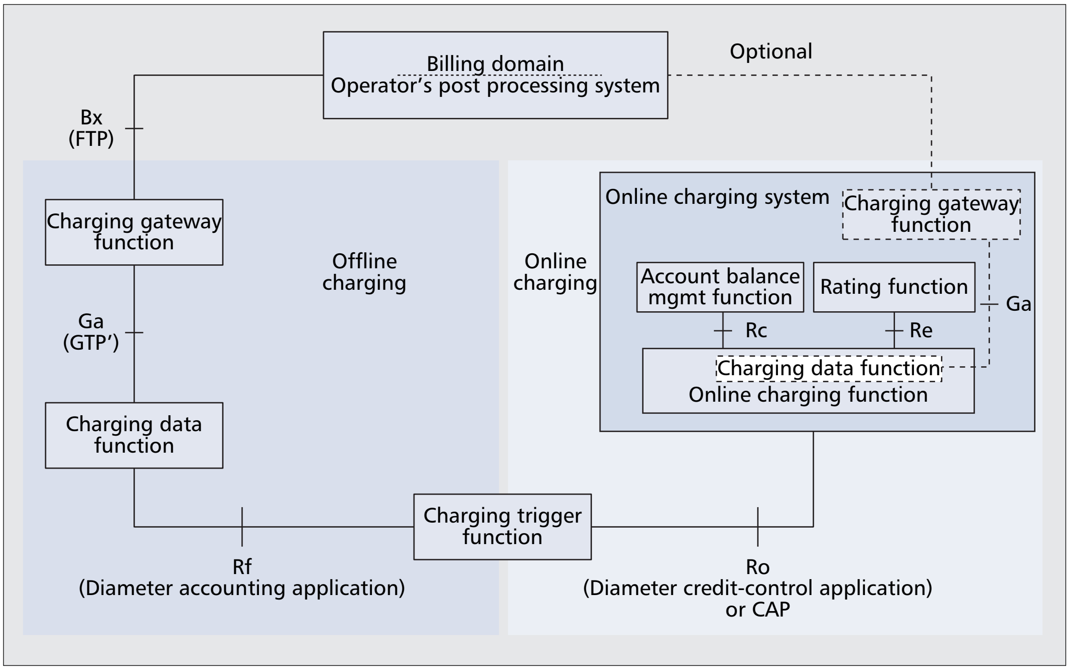



**Figure 1.** *Simplified 3GPP Release 6 logical charging architecture.*

*The CTF is an integrated component of any charging-relevant resource or service element and generates charging information when a so-called chargeable event occurs, that is, user activities that utilize or consume resources of the network or of a related service.*

work identified common logical charging functions that provide the different aspects of the required functionality for all charging-relevant parts of a 3GPP network and combined them into a common logical charging architecture, as shown in Fig. 1.

Within this frame, the subsequent technology- and service-specific specifications then define and describe the exact details of the charging processes that must take place in order to charge the respective technology or service usage. These subsequent specifications are divided into three groups that describe the charging processes of the three different charging levels that were identified by the 3GPP: bearer-level charging (circuit-switched, packet-switched domain, and the 3GPP interworking WLAN), subsystem-level charging (i.e., the IMS), and service-level charging (e.g., multimedia messaging service, push-to-talk over cellular, multimedia broadcast, and multicast service). As a whole, they form the so-called *middle tier* specifications.

Regarding the charging processes in a 3GPP network, two different charging mechanisms can be distinguished: offline charging and online charging. In offline charging, the network reports the resource usage to the billing domain (BD) via a series of logical charging functions after the resource usage occurred. Therefore, no direct interaction with the service being rendered is included in this process, which is the characteristic feature of offline charging. Although it is most often used for this purpose, the offline charging mechanism should not be confused with post-paid billing, since the latter represents a payment method or billing arrangement. In contrast, online charging comprises a real-time interaction between the charging process and the service being rendered to realize credit-control or budget supervision. Therefore, it is not sufficient to only recognize chargeable events, but also to authorize them before the actual resource consumption occurs in the network. The granting of this authorization depends on the requesting subscriber's available account balance, as well as on the rating of the occurred chargeable event. Online charging often is used to realize pre-paid billing, but nevertheless should not be equated with this payment method.

## Charging in the IP Multimedia Subsystem

Based on this logical charging architecture, the middle tier specification for IMS [4] describes in detail the online and offline charging mechanism in IMS, as well as the IMS elements involved therein.

### IMS Offline Charging

As depicted in Fig. 1, in the common logical charging architecture of 3GPP Release 6, three logical charging functions are involved in offline charging: the charging trigger function (CTF), the charging data function (CDF), and the charging gateway function (CGF).

The CTF is an integrated component of any charging-relevant resource or service element and generates charging information when a so-called chargeable event occurs, that is, user activities that utilize or consume resources of the network or of a related service. Possible chargeable events defined in the respective middle tier specifications and described below are manually pre-configured into or dynamically provided to the CTF. Upon recognition of a chargeable event, the CTF generates a charging event, that is, a data record containing a set of charging information characterizing the corresponding chargeable event. By employing the accounting application of the Diameter Base Protocol [5], the charging event is transferred to the CDF over the so-called Rf reference point.

*It should be noted that the Diameter interface provided by the CDF (Rf reference point) is an intra-domain interface, such that in cases of roaming, IMS elements located in foreign networks will send their charging events to a CDF in their own network.*

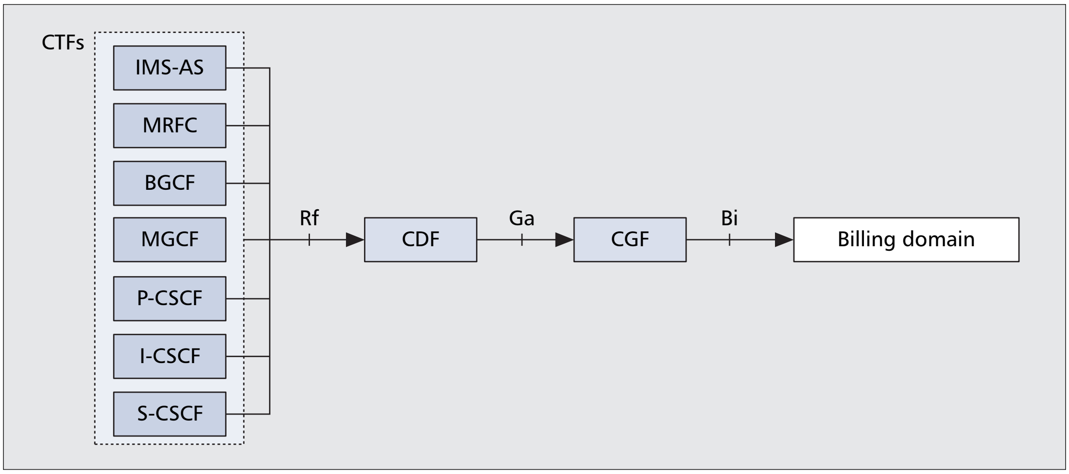



**Figure 2.** *IMS offline charging architecture [4].*

All IMS functional entities shown in Fig. 2 — the IMS application server (IMS-AS); the media resource function controller (MRFC); the border gateway control function (BGCF); the media gateway control function (MGCF); and the call state control functions, that is, the proxy (P-CSCF), the interrogating (I-CSCF), and the serving (S-CSCF) — participate in IMS offline charging by means of an integrated CTF monitoring the signaling traffic for the occurrence of Session Initiation Protocol (SIP) and integrated service digital network user part (ISUP) messages that have been defined to trigger the generation of accounting information. These elements report the captured charging-relevant information to the CDF (i.e., in this case the reception of SIP messages to be monitored).

Therefore, the charging-relevant information is conveyed in Diameter messages in the form of attribute value pairs (AVP). The Diameter messages that are generally employed for IMS offline charging are the accounting request (ACR) and accounting answer (ACA) messages as defined in the Diameter base protocol. ACRs of type [start], [interim], and [stop] and the appropriate answer messages are used for successful SIP sessions, and ACRs of type [event] for failed SIP sessions and session-unrelated procedures.

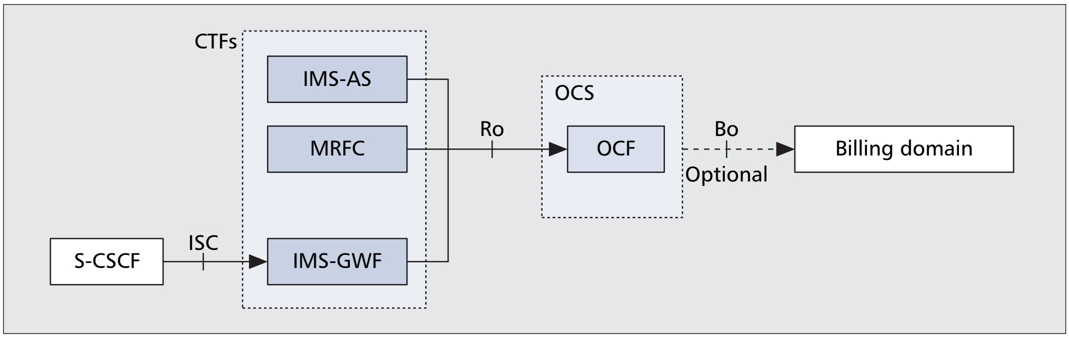
The address of the CDF to be used can either be provided as part of the SIP signaling (in the *P-Charging-Function-Addresses* field) or is locally configured by the operator in the respective IMS element.

The signaling messages (ISUP messages for the MGCF; SIP messages for all other charging-relevant IMS elements) that trigger the sending of ACRs, including the corresponding accounting metrics sets, are a question of operator configuration in the different IMS elements. The 3GPP IMS charging specification [4] requires that in cases of collecting session-related charging information, the beginning and end of these sessions must be demarcated by the appropriate Diameter messages.

The specification [4] lists all signaling messages that the operator might take into consideration as chargeable events (charging triggers). For example, the different CSCFs and the BGCF send an ACR [start] message to the CDF for a SIP 200 OK that: acknowledges an initial SIP INVITE, may send an ACR [interim] when a SIP re-INVITE (i.e., a SIP INVITE sent within an ongoing SIP session) or a SIP UPDATE (e.g., when media components change) is acknowledged by a SIP 200 OK, and again sends an ACR [stop] when a SIP BYE message is encountered terminating the respective session. The MGCF must generate the same start and stop requests when it receives the corresponding ISUP messages. Furthermore, an ACR [interim] is sent by all these IMS network elements when an optional interim interval expires. ACR [event] messages may be sent to the CDF by the CSCF and the BGCF when receiving SIP messages that are not related to sessions, such as SIP NOTIFY, SIP MESSAGE, SIP REGISTER, and SIP SUBSCRIBE, or that pertain to unsuccessful sessions and their abnormal end, respectively.

The CDF as a logical function makes use of the received information to generate so-called charging data records (CDR) that have a standardized content and format. By employing the GTP′ protocol, the charging derivation of the general packet radio service (GPRS) Tunneling Protocol (GTP), it sends the CDR to the CGF. The latter acts as the gateway of the 3GPP network to the BD, carries out a preprocessing of received CDR, and reliably stores them in one of (potentially) several CDR files that it maintains. These CDR files are finally transferred to the BD either employing a push or pull mode of operation. The BD, in which the rating takes place for offline charging, is out of the scope of standardization in 3GPP Release 6.

In the logical charging architecture of 3GPP Release 6, the combination of CDF and CGF replaces the charging collection function (CCF) of 3GPP Release 5, but both may be co-located for the IMS, such that GTP′ will not be used, and there is no difference to having a CCF, either functionally nor regarding the reference points to be implemented. However, it should be noted that the Diameter interface provided by the CDF (Rf reference point) is an intra-domain interface, such that in cases of roaming,




■ **Figure 3.** *IMS online charging architecture [4].*

*The number of functional entities that may take the role of an online-enhanced CTF and therefore can participate in the online charging process is reduced to a total of three: the S-CSCF, the MRFC, and the IMS-AS.*

IMS elements located in foreign networks will send their charging events to a CDF in their own network.

The CDF, as recipient of these messages, creates CDR (corresponding to the accounting request issuing network element type), that is, P-CSCF-CDR, I-CSCF-CDR, S-CSCF-CDR, BGCF-CDR, MGCF-CDR, MRFC-CDR, and AS-CDR. These are created with content common to all CDR (such as the triggering SIP method and the calling and called party addresses) and fields specific to the CDR type at hand, such as the Bearer Service field of a MGCF-CDR that contains the employed bearer service for the PSTN (public switched telephone network) leg of the charged connection.

## IMS Online Charging

As can be seen from Fig. 1, only two logical entities take part in the online charging process, namely the CTF and the online charging system (OCS) [3, 8]. The OCS is comprised of three logical functions, the online charging function (OCF), the rating function (RF), and the account balance management function (ABMF). The OCF, the only function directly interacting with the CTF itself, consists of two logical modules: the session-based charging function (SBCF) that is responsible for the online charging of all session-related resource usage and the event-based charging function (EBCF) that handles all subscriber activities that relate to events. Both must guarantee the correct execution of the respective charging transactions, that is, they exercise control over the respective session- or event-based resource consumption in the network on the basis of Diameter online charging requests received from the involved CTFs and carry out the corresponding actions on the subscriber's account, based on the determined charges with the help of the RF.

The CTF employed for online charging must be functionally extended to support the real-time interaction with the OCS over the Ro reference point. An online-enhanced CTF must be able to delay the requested resource usage until authorization is acquired from the OCS, to monitor the resource consumption in comparison with the authorized amount (quota supervision), and also to suppress or terminate the resource usage if no initial or no additional quota is granted.

As protocol for the Ro reference point, the IETF Diameter credit-control application [6] is employed and extended by additional AVPs specified by the 3GPP specification [9]. Diameter messages exchanged between CTF and OCF are mainly credit-control request (CCR) messages and as response, the corresponding credit-control answer (CCA) messages. A list of all possible chargeable events that may trigger the generation of CCR messages is given in [4]. In contrast to offline charging, initial SIP requests such as SIP INVITE, SIP NOTIFY, and SIP SUBSCRIBE also are defined for online charging because of the requirement for prior authorization. However, for which of these SIP messages CCRs are generated is completely operator configurable.

The number of functional entities that may take the role of an online-enhanced CTF and therefore can participate in the online charging process is reduced to a total of three: the S-CSCF, the MRFC, and the IMS-AS (Fig. 3). However, the S-CSCF does not really obtain online enhancements. Rather, it employs a special gateway for credit-control interactions with the OCS as shown in Fig. 3. This IMS gateway function (IMS-GWF) acts as online CTF regarding the OCS, but for the S-CSCF, it is an application server with which it interacts using SIP. By the IMS-GWF translating between SIP service control and Diameter credit-control, online charging becomes transparent to the S-CSCF and is invoked like any other service over the IMS service control (ISC) reference point, that is, by defining user-specific initial filter criteria that specify when to invoke the respective services. As an option for a stand-alone solution, the IMS-GWF also may be integrated into either the S-CSCF or the OCS; in these cases the respective reference point (i.e., ISC or Ro) is not used.

The previously mentioned initial filter criteria are defined in the HSS as part of the user profile that is provided to the assigned S-CSCF during user registration. They enable the definition of which IMS-AS to forward to the considered SIP message, based on the occurrence of certain triggers in the message, such as the requested URI, the SIP method, any SIP header field, the session case (originating/terminating, registered/unregistered), as well as session description information, that is, any Session Description Protocol (SDP) field in the considered SIP message body [7]. Filter criteria have a priority assigned to them, such that the order in which they are evaluated can be determined. But as the

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name implies, initial filter criteria are only evaluated for initial requests, such as SIP INVITE or SIP MESSAGE. However, as described previously, possible triggering SIP messages are not always initial events, but subsequent SIP messages, such as a SIP 200 OK that signals the successful establishment of a packet-switched (PS) voice call, for instance. The solution to this question is quite simple, because the initial filter criteria evaluation and the resulting addition of application servers to the signaling path does not only affect the initial SIP request, but all subsequent messages belonging to the same SIP session or transaction. Thus, all these messages will take the same route through the selected IMS-AS (i.e., in the case of online charging, the IMS-GWF).

As the IMS-GWF acts as an online-enhanced CTF, it monitors the signaling for the occurrence of chargeable events (i.e., for specific SIP messages) and reports them to the OCF over the Ro reference point. The same holds for the MRFC and other IMS-AS as they directly act as online-enhanced CTF.

For the interaction between OCF and CTF over the Ro reference point, three credit-control cases can be distinguished that in addition to triggering chargeable events, influence the type of the exchanged CCR messages: immediate event charging (IEC), on the one hand, and event charging with unit reservation (ECUR), as well as session charging with unit reservation (SCUR), on the other hand. IEC and ECUR are handled by the EBCF, and SCUR is handled by the SBCF.

For IEC, exchanged messages are of the type CCR [event] and lead to a direct debiting of the respective amount of units (e.g., money) against the user's account. Thus only one pair of CCR and CCA messages will be exchanged in such a scenario. As a consequence, the network element into which the requesting CTF is integrated must ensure that the corresponding service is successfully delivered.

For ECUR and SCUR, messages are of the types CCR [initial] and CCR [terminate]. SCUR also may have one or more messages of the type [update] exchanged during the respective session when charging conditions change and the granted quota expires or is used up so that a new quota must be requested. As their names imply, both credit-control cases employ a reservation of units on the user's account, that is, the actual debiting against the account is not carried out directly, but after the service has been rendered, and the actual costs can be derived, which may not be possible before hand. With a CCR [initial] message, the CTF requests an initial quota that is either granted or denied by a CCA message of equal type. This request starts a new credit-control session. As already mentioned previously, for SCUR several subsequent CCR [update] and CCA message pairs are possible when the user session progresses and resources are consumed. When the user session is finally terminated or the event-based service has been rendered, a CCR [terminate] / CCA message pair is exchanged that stops the credit-control session as well. This includes a debit transaction on the user account including the potential release of a reserved but not consumed quota.

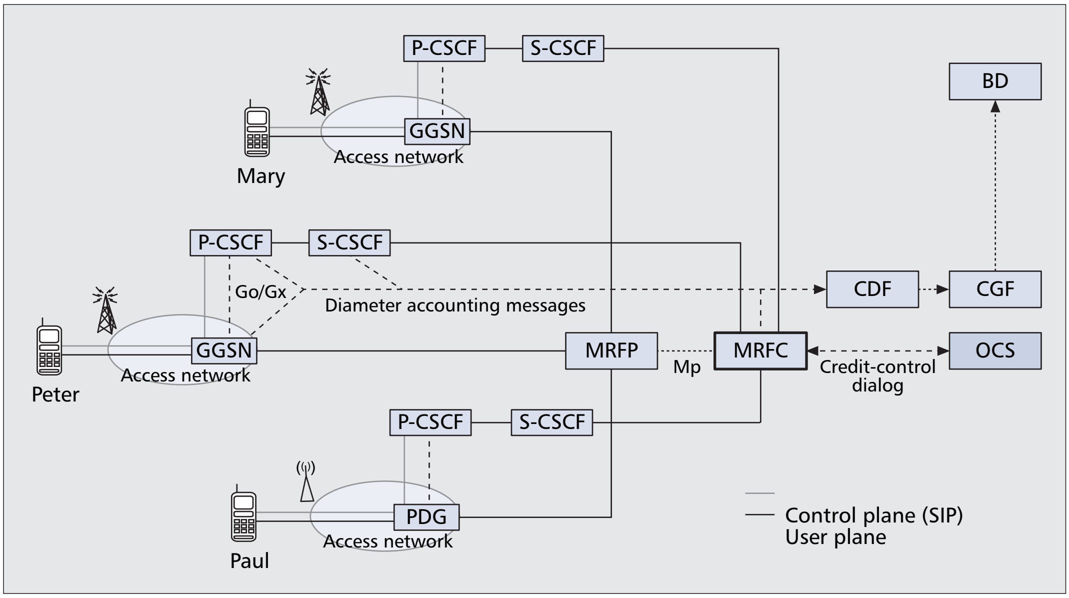
How the online-enhanced CTF will react when no initial or subsequent quota is granted by the OCS (i.e., credit-based authorization is denied by negative answers on CCR [initial] or CCR [terminate] messages) is at the operator's discretion. Also, technically, nothing is specified by the 3GPP. One possibility would be the IMS-GWF acting as a SIP back-to-back user agent (B2BUA), sending SIP BYE messages to the two session end points, thereby terminating the session and effecting the release of all involved resources, which should include a proper indication to the communicating parties why this happened. For the latter to be realized, the OCS includes a final unit indication in its CCA message when it grants the still remaining credit. Suspending the session and re-directing the charged party or parties to a re-charging server could also be an applicable alternative.

The OCS also may generate CDRs as input for operator-defined post-processing purposes. In this case, a CDF is employed by the OCS to generate CDR that may contain rated charging information, that is, the results from the charging and rating processes in the OCS. The CGF also present in the OCS generates CDR files and provides these files to the BD. For the IMS, this information was restricted in 3GPP Release 5. However, in 3GPP Release 6, all information required to create S-CSCF-CDRs is included in the CCR message sent to the OCS by the IMS-GWF. In case of rated CDR, only invoicing must be carried out in the BD. In this respect, a convergent charging by the OCS becomes possible.

## IMS Charging Scenario

In this section, we describe a teleconferencing example to enable a deeper understanding regarding the previously mentioned IMS charging functionality and procedures. In the scenario, three people participate in an IMS teleconferencing session. The first two, Paul and Mary, are pre-paid customers, and the third, Peter, is a post-paid customer of the same operator. According to the operator tariff, all three are charged, based on time for the IP voice call and on the volume of the other media components of the teleconferencing service. Figure 4 shows selected network and charging elements that are involved in such a teleconferencing session, as well as data and signaling flows between them.

Besides the P-CSCF and the S-CSCF that were assigned to the three users during their registration at the IMS, a multimedia resource function controller (MRFC) and a multimedia resource function processor (MRFP) also are involved. The latter provides the required resources for multimedia stream processing and generation and performs tasks such as media stream mixing as well as a potentially required audio transcoding. In addition, the MRFP also performs floor control to manage the usage of shared resources in such a multi-user conferencing environment. The MRFC controls these




■ **Figure 4.** *IMS teleconferencing example.*

*The ICID is always generated by the first IMS element that is involved in a SIP dialog or transaction irrespective of the employed charging mechanism, that is, in the example, the respective user's P-CSCF.*

resources based on SIP request messages received from the respective S-CSCF by translating them into H.248 messages that control the functioning of the MRFP.

As both Paul and Mary are pre-paid customers, the assumed operator OCS is employed to perform credit-control. In the scenario, the operator has pre-configured its online-enhanced CTF in such a way that for the IMS teleconferencing service, only the CTF integrated into the MRFC takes part in the online charging dialog (Fig. 5). Thus, only the latter requests quota and reports the occurrence of session-related chargeable events over the Ro reference point using session-related Diameter credit-control requests to the OCS. Triggering SIP messages received from the participating S-CSCF are SIP INVITE messages that initiate the multimedia conferencing session or connect an additional participant to an on-going session, as well as a SIP BYE that ends this session or a SIP final response with an error code in the 400–600 range, indicating session termination.

The decision whether online or offline charging will occur is contained in the *P-Charging-Function-Addresses* header field of the SIP INVITE message with which the respective user requests the participation in the teleconference. The two parameters are the CDF and OCS addresses referring to the two functional elements responsible for offline and online charging, respectively. They are set by the user's S-CSCF that retrieves these charging function addresses from the HSS as part of the user's profile during user registration at the IMS. This means, that the decision whether online or offline charging is employed for a user is based on his or her subscription, that is, a differentiation based on the service he or she is requesting or using is not possible. Subsequent entities on the SIP signaling path are informed about these addresses by the S-CSCF passing them along in the *P-Charging-Function-Addresses* header field. This information is furthermore restricted to a single operator network and will not be propagated beyond its boundaries. In addition, one of the two charging function addresses must be set, which also indicates the charging mechanism to be employed. Optionally, it is possible that both parameters are set, in which case both interfaces will be served.

For its post-paid customers, we assume for the example that the operator employs the offline charging mechanism. This means that for Peter, all offline charging-relevant CTF involved in his part of the teleconferencing session on the subsystem level will report chargeable events to the CDF over the Rf reference point using ACR messages. Thus, more than one CTF is involved in the charging of the teleconferencing service, and the generated information must be correlated in order to charge Peter correctly and prevent his over-billing, respectively. For this correlation in the BD, a common identifier is used that uniquely identifies the user's service session between all participating elements. Inside the IMS, the IMS charging identifier (ICID) takes this role.

The ICID is always generated by the first IMS element that is involved in a SIP dialog or transaction irrespective of the employed charging mechanism, that is, in the example, the respective user's P-CSCF. This P-CSCF then adds the ICID to the SIP message header *P-Charging-Vector* field with which it is then propagated along the SIP signaling path. All IMS elements that receive the message, extract the ICID for use in both online and offline charging request generation. The ICID also is included in all subsequent SIP messages that pertain to the same SIP dialog.

Furthermore, access network elements (bearer level) also may generate charging information that finally will be reported to the BD where the rating of the user activities eventually will occur. To allow for a correlation of charging information between the subsystem and the IP bearer

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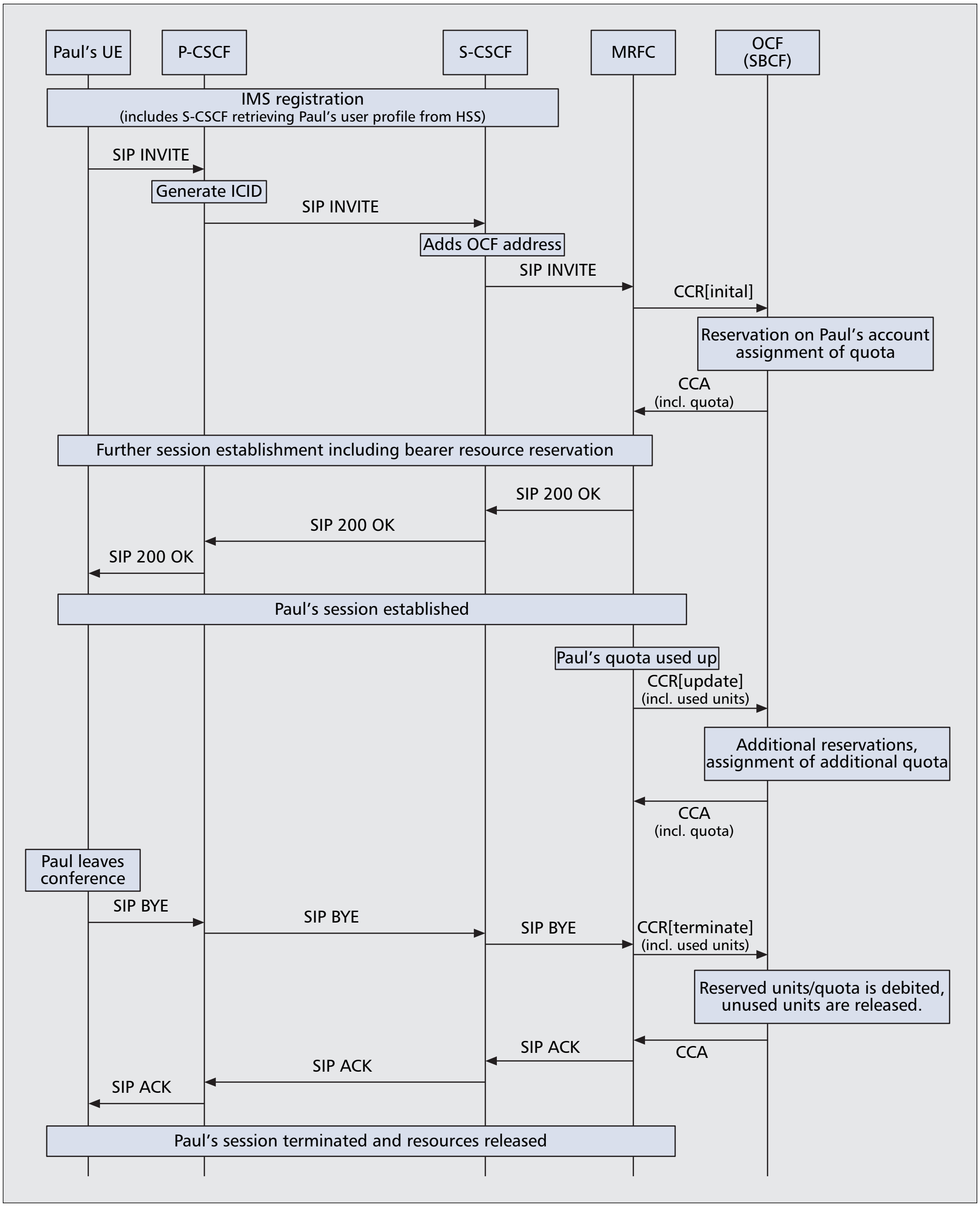
level, another parameter is comprised in the *P-Charging-Vector* header field, namely the access network charging identifier. In the example, it is the GPRS charging identifier (GCID) as Peter is using the PS domain as an access network. For correlation to work, the charging identifiers must be exchanged between these two levels. The service based local policy (SBLP) concept added with the IMS in 3GPP Release 5 and mainly providing bearer quality of service (QoS) and gate control capabilities for the IMS also allows for communicating the GCID to the IMS and the ICID vice versa. This occurs over the Go and Gx reference points as shown in Fig. 4. In 3GPP Release 7, it will be replaced by the so-called policy and charging control (PCC) [10] that integrates SBLP with flow-based charging (FBC) [11] into a single solution to achieve more efficient real-time interactions within the IP bearer domains.

## Conclusion

Charging is one of the crucial functions of any commercial telecommunication system. IMS will be successful only if charging is supported in a flexible and efficient manner. Especially, the charging system must support the rapid introduction of new services as well as arbitrary tariff models. In this article, we provided an overview of the current 3GPP charging architecture and how IMS charging is incorporated into the 3GPP charging architecture. The IMS charging architecture devised by the 3GPP is ready not only to meet these requirements, but also to support a convergent charg-




■ **Figure 5.** *Simplified teleconferencing example message flow for online-charged participant.*

ing solution. Current trends in further development include addressing 3GPP Release 7 enhancements (e.g., voice call continuity, alternate charged parties) and implications of new open mobile alliance (OMA) service enablers (e.g., service identification and correlation) as well as a harmonization with Telecoms & Internet Converged Services & Protocols for Advanced Networks' (TISPAN) IMS-related work within its next generation network (NGN) endeavor.

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