♦ IP Multimedia Subsystem Online Session Charging Call Control

Yigang Cai, Xian Yang Li, Yile Wang, John B. Reid, and Peng Wang

An efficient IP Multimedia Subsystem (IMS) online charging system is important for operator revenue generation. However, 3rd Generation Partnership Project (3GPP) specifications do not adequately address how online session charging shall be accomplished for IMS networks, especially how IMS network elements such as the application server and the serving call session control function (S-CSCF) interact with the online charging server (OCS). To remedy the shortcoming of 3GPP online charging standards, this paper presents a policy-based IMS call control system that converges the multiple application servers and the IMS gateway functionality into one IMS node for online session charging. The IMS session charging call control system employs a session charging trigger mechanism that enables a real-time report of session information and provides budget control for online quota monitoring. It also enables service logic for multiple applications to be executed in a single node to greatly reduce traffic access between the IMS call session control function (CSCF) and the OCS.

Introduction

As set forth by the 3rd Generation Partnership Project (3GPP), an IP Multimedia Subsystem (IMS) provides a common core network having an access-agnostic network architecture for converged networks [1, 2]. Service providers are accepting this architecture in their next-generation network evolution plans. Providing efficient IMS online charging for operator revenue generation is important for the successful deployment of IMS networks.

Several 3GPP technical specifications describe online charging in IMS networks [1–3]. For example, the 3GPP TS 32.240 and TS 32.260 standards describe an online charging server (OCS) with a session charging function [2, 3]. The OCS is coupled to a call session control function (CSCF) through an IMS service control (ISC) interface. The CSCF can control a call session for either a calling party or a called party, and it needs to communicate with the OCS over the ISC interface to provide online charging for the call session. While as a service interface the ISC defines a reference point between a serving call session control function (S-CSCF) and an application server for the Session Initiation Protocol (SIP)-based session signaling control, it does not provide session credit authorization and real-time credit control. The ISC interface cannot support online charging. Therefore, in order to use the ISC interface between the CSCF and the OCS for online charging, additional functionality needs to be added to the OCS [2, 3].

Bell Labs Technical Journal 10(4), 117–132 (2006) © 2006 Lucent Technologies Inc. Published by Wiley Periodicals, Inc.
Published online in Wiley InterScience (www.interscience.wiley.com). • DOI: 10.1002/bltj.20129

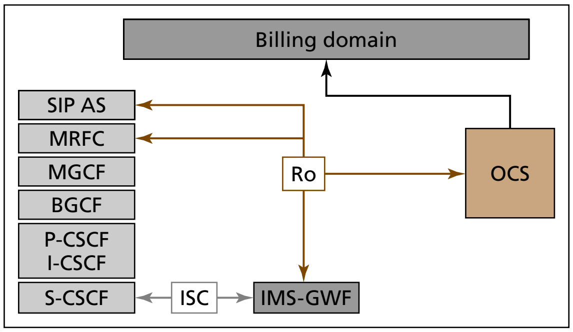
To avoid overloading the OCS with additional functionalities and to keep the online charging architecture consistent, the interface between the CSCF and the OCS may be changed to support online charging instead of adding functionality to the OCS. One option for an interface that supports online charging is to extend the ISC interface to allow for charging mechanisms. The ISC interface would then serve as both a service interface and a charging interface. However, using the ISC interface as a hybrid service/charging interface may not be acceptable for standardization desired by the 3GPP. Another option is to use the reference interface for online charging functions—the Ro interface—instead of the ISC interface because the Ro interface already supports online charging. The 3GPP TS 32.240 and TS 32.260 specifications suggest using the Ro interface for online charging by introducing an IMS gateway function between the CSCF and the OCS (see **Figure 1**) [1, 3]. The IMS gateway function communicates with the CSCF over the ISC interface and with the OCS over the Ro interface. Unfortunately, TS 32.260 and the other 3GPP specifications do not describe how to use the IMS gateway function for online charging for processes such as SIP call session handling, session budget control to supervise the consumption of quota granted by the OCS, or session termination when budget is expended. The specifications state that when the CSCF is directly connected to the OCS via a gateway, the IMS gateway function is beyond the scope of the standardization. Thus, the physical position of the IMS gateway function is not a matter of particular concern to the 3GPP [2, 3].

The 3GPP specifications also describe the IMS network as including a plurality of application servers that are connected to an event-based charging function in the OCS. The application servers communicate with the OCS via the Ro interface and with the serving call session control function (S-CSCF) via the ISC interface. The specifications do not define how the application servers communicate with the OCS to provide session-based online charging for services such as IMS virtual private network (VPN) service [2, 3].

Therefore, the current 3GPP specifications do not adequately address how online session charging may be accomplished in IMS networks. This paper presents a complete, policy-based IMS call control (IMS CC) system that will fill the online charging gaps in the 3GPP standards. The solution includes an IMS session call control architecture, rule-based session call control, budget control, and protocol translation. This IMS session call control architecture converges the multiple application servers and IMS gateway (IMS GW) functionality into one IMS node. The IMS CC enables service logic for multiple applications to be executed in a single node. The rule-based IMS session call control includes rule-based IMS application call control and

Panel 1. Abbreviations, Acronyms, and Terms

3GPP—3rd Generation Partnership Project
ABD—Abbreviated dialing
AS—Application server
AVP—Attribute value pair
BGCF—Breakout gateway control function
CC—Call control
CCA—Credit control answer
CCR—Credit control request
CNF—Conjunctive normal form
CSCF—Call session control function
DCCA—Diameter Credit-Control Application
GW—Gateway
HSS—Home subscriber server
I-CSCF—Interrogating CSCF
IETF—Internet Engineering Task Force
IMS—IP Multimedia Subsystem
IP—Internet Protocol
ISC—IMS service control
IVR—Interactive voice response
MGCF—Media gateway control function
MRFC—Media resource function controller
MSCC—Multiple service credit control
OCS—Online charging server
P-CSCF—Proxy CSCF
PDP—Policy decision point
PEP—Policy enforcement point
QoS—Quality of service
Ro—Reference interface for online charging functions
S-CSCF—Serving call session control function
SDP—Session Description Protocol
SIP—Session Initiation Protocol
UE—User entity
URI—Uniform resource identifier
VPN—Virtual private network



3GPP—3rd Generation Partnership Project
AS—Application server
BGCF—Breakout gateway control function
CSCF—Call session control function
I-CSCF—Interrogating CSCF
IMS—IP Multimedia Subsystem
IMS-GWF—IMS gateway function
IP—Internet Protocol
ISC—IMS service control
MGCF—Media gateway control function
MRCF—Media resource function controller
OCS—Online charging system
Ro—Reference interface o for online charging functions
P-CSCF—Proxy CSCF
S-CSCF—Serving CSCF
SIP—Session Initiation Protocol

Figure 1.
3GPP online charging system architecture in release 6.

rule-based charging point management. IMS CC budget control is included for online quota monitoring. Finally, this paper gives an example IMS session charging scenario that demonstrates the IMS CC rule-based decision process for online session charging.

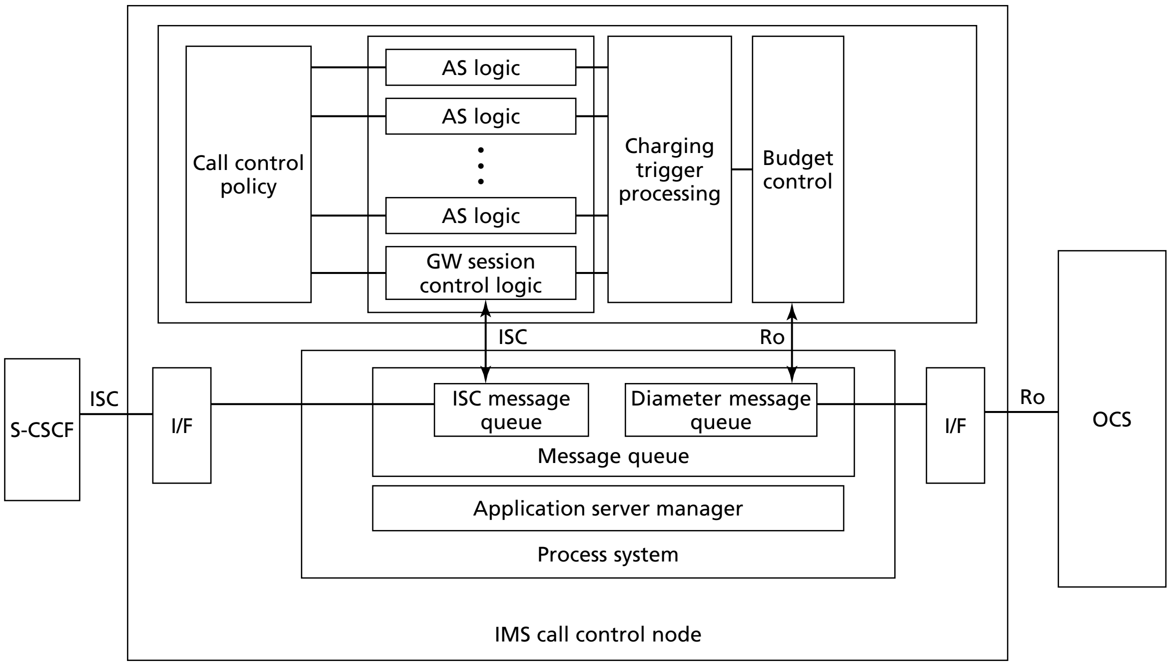
The concept of the IMS CC will be partially implemented as a service application of the Lucent MiLife® SurePay® product suite for online session charging in the IMS network. Currently the IMS CC supports a time-based charging model.

IMS Session Call Control Architecture

The 3GPP specifications describe the IMS GW function as a simple protocol translation element, without considering that session call control and budget control for online charging cannot be simply accomplished via the Ro interface towards the OCS. In 3GPP specifications, application service logic in an application server is separated from the IMS gateway when application servers perform online charging functions. To remedy those shortcomings, a new IMS service control infrastructure converges multiple IMS application server functionalities and IMS gateway functionality into one IMS CC node (see **Figure 2**). From the perspective of the S-CSCF, the converged IMS CC (the call control element with IMS application server and IMS GW functionality) shall exhibit the same ISC interface behavior to the CSCF as a standalone IMS GW or application server. From the perspective of the OCS, the converged IMS CC shall exhibit the same Ro interface to the OCS as a standalone IMS GW or application server (see **Figure 3**). Within this infrastructure, the online charging activity of multiple IMS application servers can be converged into one single IMS call control element.

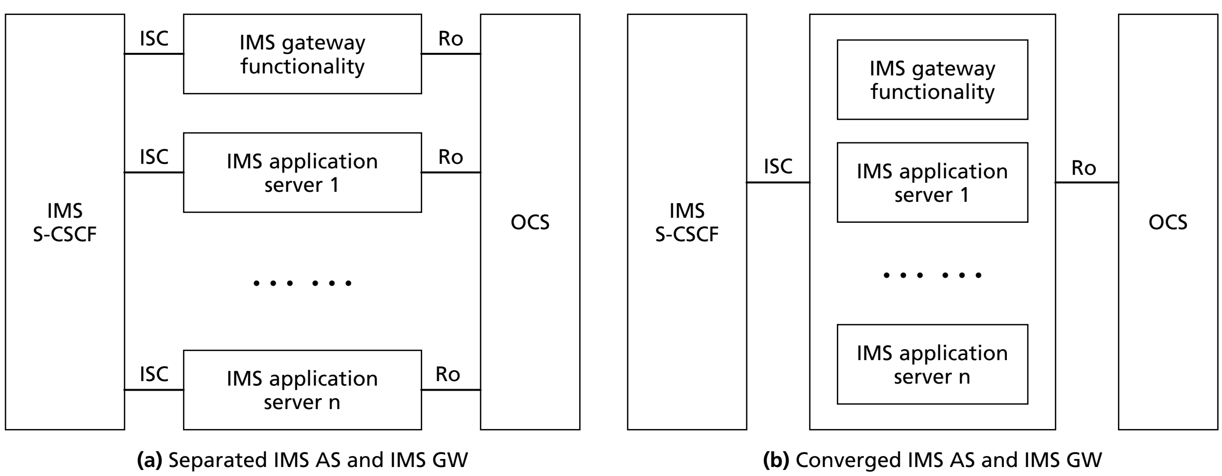
In operation, when the IMS CC processing system receives a call message from the S-CSCF via the ISC interface and puts the message into the message queue, the application manager in the IMS CC processing system determines whether to execute application server logic or gateway logic in response to the call message. If the IMS CC processing system determines that the call message should be processed with application server logic, then the processing system executes application server logic to perform a service. The IMS CC processing system also executes application server logic to contact the OCS for online charging for the service via the Ro interface. If the IMS CC processing system determines that the call message should be processed with gateway logic, then the IMS CC processing system executes gateway logic to perform call session control. The processing system also executes gateway logic to contact the OCS for online charging for the call session via the Ro interface. If the IMS CC processing system determines that the call message should be processed with gateway logic and service logic for multiple applications, this is accomplished according to the configured execution order to perform call session control. The IMS CC processing system also contacts the OCS for online charging for the call session by using multiple service credit control in the same Ro message.

By consolidating application server logic with gateway logic in the IMS CC node, the IMS CC has the capability to execute multiple service session credit control modules within one IMS session. This consolidation enables service logic from multiple applications to be



AS—Application server
CSCF—Call session control function
GW—Gateway
IMS—IP Multimedia Subsystem
IP—Internet Protocol
ISC—IMS service control
OCS—Online charging server
Ro—Reference interface o for online charging functions
S-CSCF—Serving CSCF

Figure 2.
Policy-based IMS call control architecture.



CSCF—Call session control function
IMS—IP Multimedia Subsystem
IMS AS—IMS application server
IMS GW—IMS gateway
IP—Internet Protocol
ISC—IMS service control
OCS—Online charging server
Ro—Reference interface o for online charging functions
S-CSCF—Serving CSCF

Figure 3.
Separated IMS call control vs. converged IMS call control.

executed in one single node, so that it greatly reduces traffic between the IMS CSCF and the OCS. This capability also enhances overall IMS session response time by eliminating the need to route traffic to multiple application server nodes. It simplifies network topology and configuration because subscriber profile and service application data are combined into one concentrated node. This could be a significant cost saving for operators from the perspective of operation and maintenance.

The IMS CC uses one common Diameter credit control (DCC) client to report real-time session or event charging information to the OCS and to reserve the allocated credit unit from the OCS. The Diameter client can control the IMS session/service activity based on allocated credit units from the OCS.

The IMS CC extends the service capability to support tone and announcement interworking with the media resource function controller (MRFC) via the S-CSCF. A specific application server can provide interactive voice response (IVR) capability to support the IMS user interaction. The IMS CC supports pre-call announcement, mid-call announcement, and post-call announcement to notify the subscriber in real time of call charging and service information. When the subscriber's credit is used up, the IMS CC can interact with the MRFC to enable the subscriber to recharge her account. The IMS CC also has the ability to communicate with a home subscriber server (HSS) to download the latest subscriber data via the Sh interface. For instance, when the service executes the originating call charging based on the called party's location information, the calling party sends the request to the HSS to obtain the called party subscriber location. **Figure 4** depicts the IMS CC node in the IMS network.

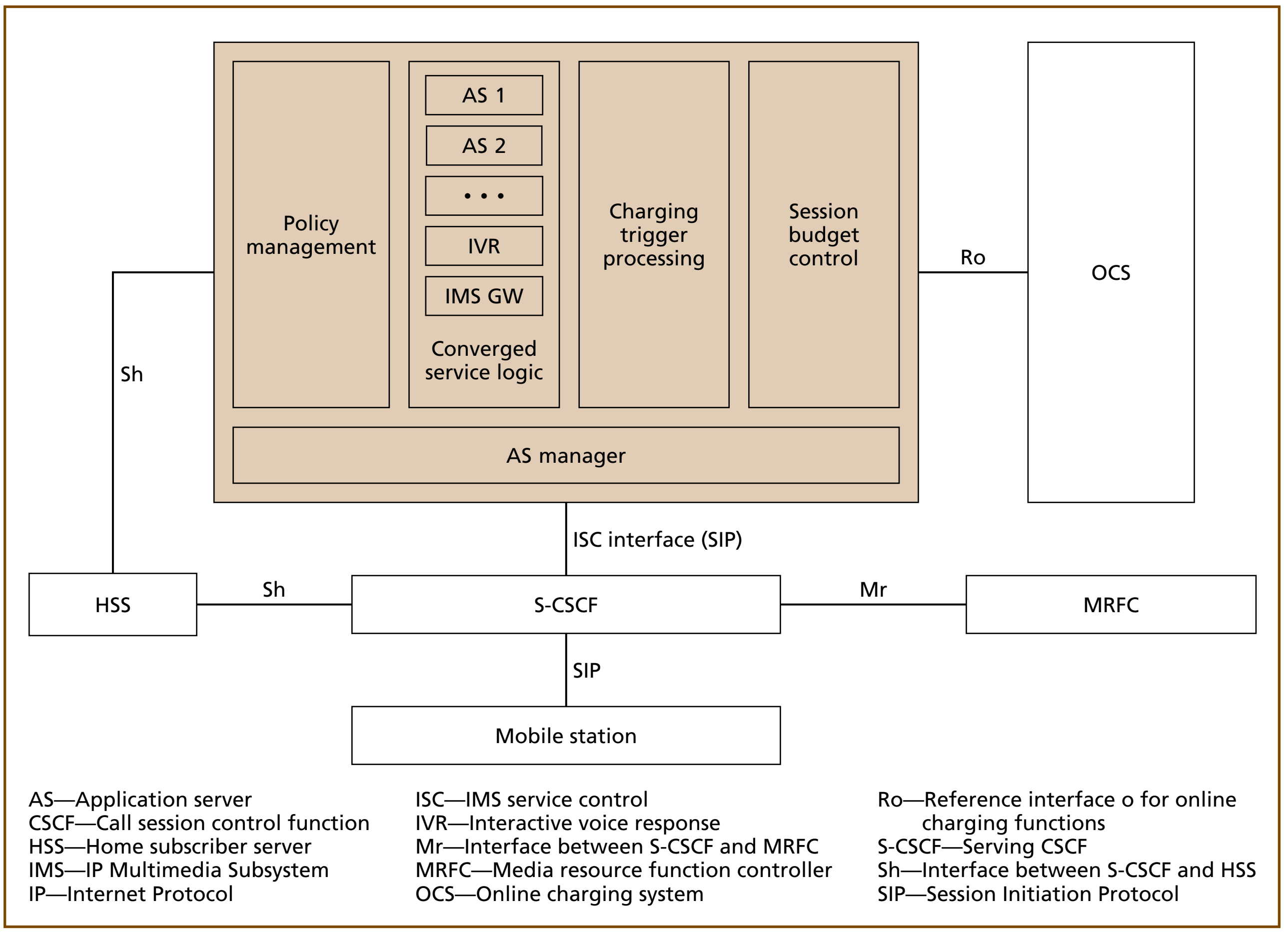
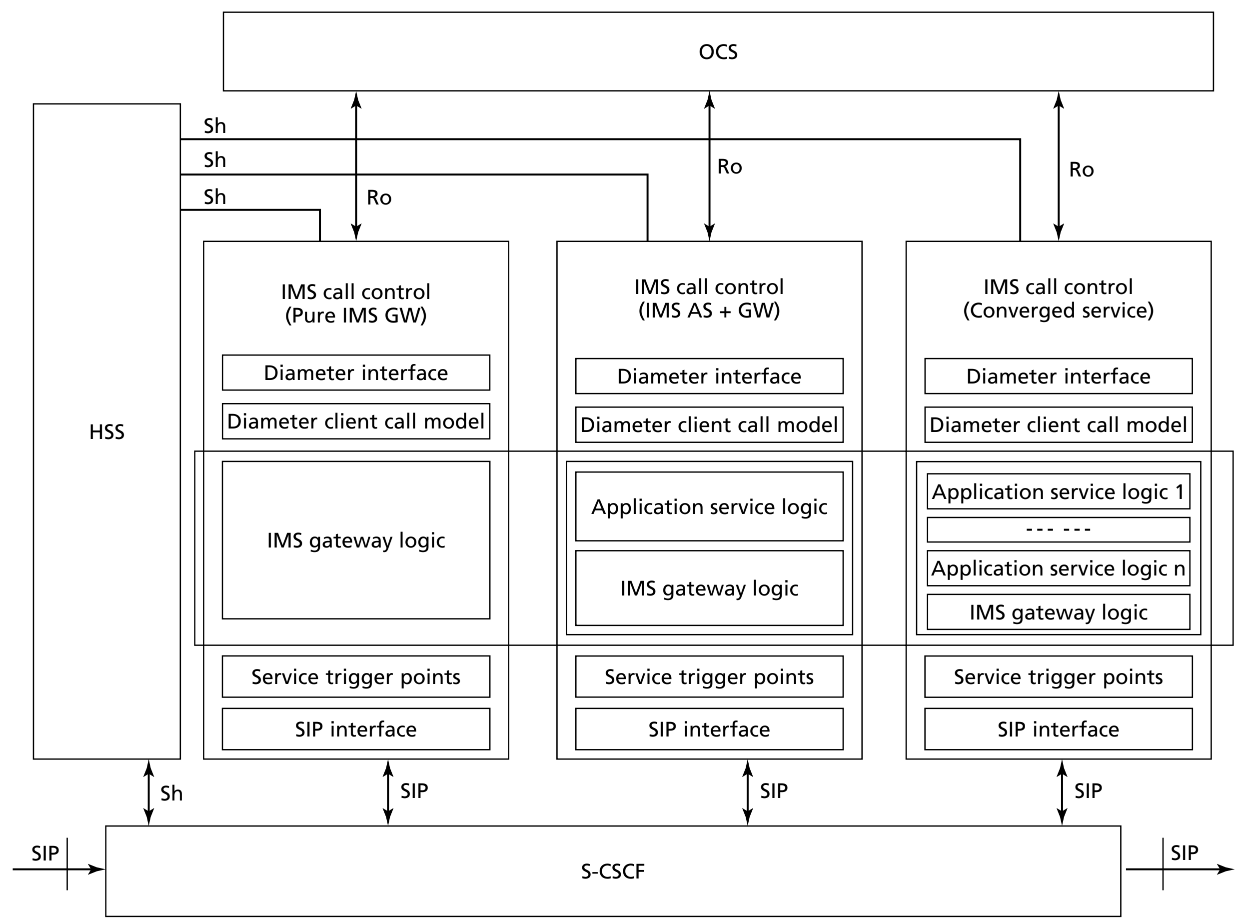


Figure 4.
IMS call control network architecture.

The IMS CC converges the IMS gateway and IMS application server capabilities in a single node. The application service logic for each application server is an independent plug-in component. The IMS CC can disable one service component without impacting other service components. The IMS CC can be configured to support three application types (see **Figure 5**). In the pure IMS GW application, the IMS CC is treated as a single IMS GW functionality; application server capability is disabled in this configuration. In the standalone application (IMS AS + GW), a single application server capability is executed in the IMS CC; other application server capabilities in the IMS CC are disabled. The IMS application reuses IMS GW functionality to execute the ISC interface to the Ro interface message mapping. In the converged service application, the service logic of multiple application servers is executed by one IMS CC node. The output of one application server can be the input of another application server. The execution sequence of application servers is configurable by the service provider.



AS—Application Server
CSCF—Call session control function
GW—Gateway
HSS—Home subscriber server
IMS—IP Multimedia Subsystem
IMS AS—IMS application server
IMS GW—IMS gateway
IP—Internet Protocol
Mr—Interface between S-CSCF and MRFC
MRFC—Media resource function controller
OSC—Online charging server
Ro—Reference interface o for online charging functions
S-CSCF—Serving CSCF
Sh—Interface between S-CSCF and HSS
SIP—Session Initiation Protocol

Figure 5.
IMS call control application types.

Rule-Based IMS Session Call Control

In the IMS call control system, the IMS gateway acts as a SIP proxy for IMS online charging session control. Five states for a session based on the IMS CC concept that have never been introduced in 3GPP standards are defined as follows: *NULL* → *Wait For Call Answer* → *Answered* → *In Progress* → *End Call* (see **Figure 6**).

Before a subscriber makes a call, his IMS session state is *NULL.* When a SIP INVITE message is received, the IMS GW will perform session credit authorization via the OCS. When an INVITE message is successfully handled and sent out to a mobile endpoint, the IMS session state is switched to *Wait For Call Answer.* When the message 200 OK is received, the IMS GW will execute credit re-authorization from the OCS, after which the session state is changed to *Answer.* When an ACK is received, the IMS GW will confirm that the IMS session has been successfully established and the session will transition to the *In Progress* state. While the session is active, when any UPDATE/Re-INVITE messages are received to update the current session, the IMS session remains in the *In Progress* state. When a BYE message is received, the IMS GW will end the current session processing, change the session state to *End Call,* and submit session charging record information to the OCS. At that point, the IMS GW changes the subscriber's session state back to *NULL* and waits for the next new session.

When the IMS GW is in the *Wait For Call Answer* state, if any provisional (1xx) messages are received from the network, the IMS GW will refresh the current session and continue to wait for the call answer. If any type of redirection message (3xx), request failures message (4xx), sever failures message (5xx), or global failures message (6xx) is received, the IMS GW will end the current session and return to the *NULL* state.

To provide the flexibility to control the IMS session, a policy management mechanism is applied in the IMS CC [5]. The charging trigger rules and application server control rules are stored in a policy repository (**Figure 7**). The policy enforcement point (PEP) in the session control logic model will communicate with the policy decision point (PDP) to evaluate the decision request. The PDP will access the policy repository to obtain relevant rules that are evaluated to determine the decision response. Once a decision response is obtained, the IMS CC may invoke functions to carry out the decision for session charging control.

In charging policy management, a rule is expressed as a condition list and a sequence of actions.

For example:

```
IF      Condition_List
THEN
        Sequence_Actions
END IF
```

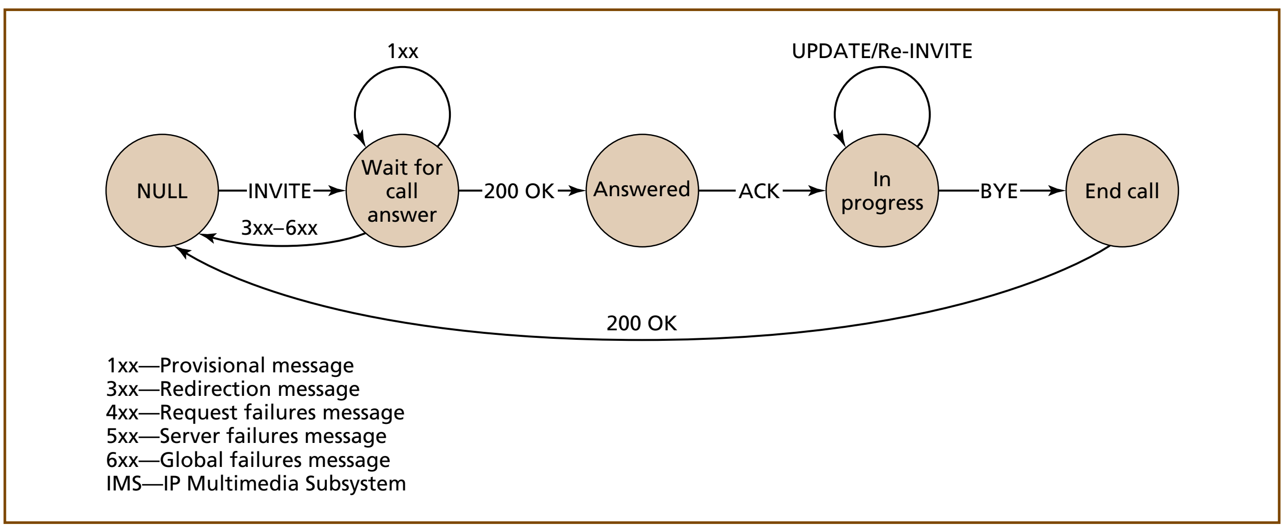


Figure 6.
IMS gateway call state machine.

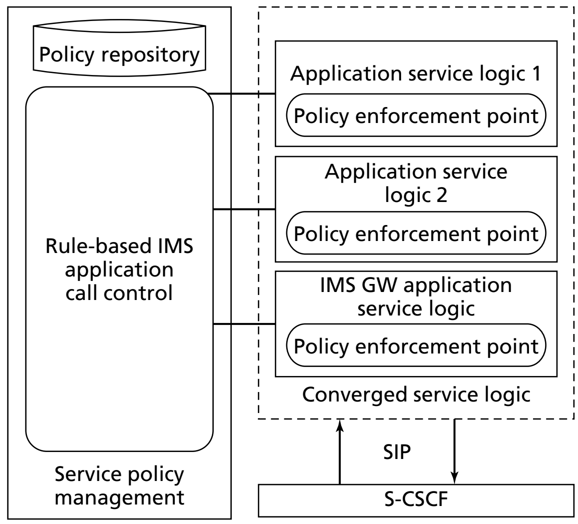


Figure 7.
Rule-based IMS session call control.

The condition list is constructed by a list of conditions linked by the Boolean operators AND, OR, and NOT in conjunctive normal form (CNF). When a rule is invoked, the rule condition will be evaluated at the PDP. If the rule condition is matched, all actions under the rule will be executed in sequential order.

Rule-Based IMS Application Call Control

In the IMS CC, the core service control logic is defined as a set of rules for policy management. The specific application service has its own service rules. All the policy rules are stored in the policy repository. The rules in the policy repository are divided into different categories (e.g., time rules, location rules, calling party rules, called party rules, closer user group rules, session treatment rules, quality of service (QoS) rules, and media component rules).

The policy enforcement point in the application servers communicates with the policy decision point to evaluate the decision request. The PDP accesses the policy repository to obtain relevant rules that are evaluated to determine the decision response. Once a decision response is obtained, the IMS application server invokes functions to carry out the decision for service control and online charging purposes [5].

Using the presence application service as an example, the service routes the subscriber's incoming call to a different location based on day of week, time of day, and calling party role. Rule 1 and Rule 2 in Panel 2 provide the rules to determine the time category. Rule 3 and Rule 4 refer to subscriber 13579848 and determine the calling party role in an incoming IMS call. Rule 5, Rule 6, and Rule 7 determine treatment of calls destined for subscriber 13579848.

Rule-Based Charging Trigger Point Management

In each IMS state, the IMS GW function in the IMS CC will work internally with the session charging trigger processing module to enable subscriber online session charging. **Figure 8** shows the IMS CC session charging trigger mechanism. The charging trigger points are defined as a group of rules to match the SIP/SDP message: SIP method rules, request-uniform resource identifier (URI) rules, SIP header rules, session case rules, and session description rules. The charging trigger point enables the following information to be reported to the OCS by the IMS GW:

- Basic IMS call information,
- Media component update within an IMS session,
- QoS update within an IMS session, and
- Mobile location update within an IMS session.

The IMS GW charging trigger points are defined into three monitor types: INTERRUPT type, NOTIFY type, or NULL type, where the trigger is not armed. When a trigger point is configured in an INTERRUPT session control relationship, the IMS session processing is suspended in the IMS GW and the IMS GW waits for instructions from the OCS. When a trigger point is configured as NOTIFY type, once the trigger criteria are matched, the IMS GW sends session information to the OCS and session processing in the IMS GW continues. When the charging trigger is not armed, the IMS GW returns a SIP message to the S-CSCF to continue the current session without any charging control relationship. Rules 8–10 in **Panel 2** present trigger examples.

Panel 2. Exemplary Rule Sets

```
R1:   IF    Day_of_Week = “Monday” AND Begin_Time = “8:30AM”
            AND End_Time = “5:30PM”
      THEN Time_Category = “Working Hour”
      END IF
R2:   IF    Day_of_Week = “Monday” AND Begin_Time = “5:31PM”
            AND End_Time = “11:30 PM”
      THEN Time_Category = “Family Hour”
      END IF
R3:   IF    Call_Direction = “Incoming” AND
            Called_Party_Number = 13579848 AND
            Calling _Party_Number = 13599090
      THEN Calling_Party_Role = “Boss”
      END IF
R4:   IF    Call_Direction = “Incoming” AND
            Called_Party_Number = 13579848 AND
            Calling_Party_Number = 13599091
      THEN  Calling_Party_Role = “Colleague”
      END IF
R5:   IF    Time_Category = “Working Hour” AND Calling_Party_Category =
      “Boss”
      THEN Ring Call to “Office Phone”
      THEN Ring Call to “Personal Phone”
      THEN Ring Call to “Voice Mail Box”
      END IF
R6:   IF    Time_Category = “Family Hour” AND Calling_Party_Category = “Boss”
      THEN Ring Call to “Personal Phone”
      THEN Ring Call to “Voice Mail Box”
      END IF
R7:   IF    Time_Category = “Family Hour” AND Calling_Party_Category =
      “Colleague”
      THEN Ring Call to “Voice Mail Box”
      END IF
R8:   IF    SIP_Method = “INVITE” AND Call_Status = “NULL”
            AND Trigger_Point_Type = “INTERRUPT”
      THEN
            Hold on the current session
            Send “CCR [INITIAL]” charging report to OCS
            Start timer to wait “CCA [INITIAL]” from OCS
      END IF
R9:   IF    SIP_Method = “200” AND Call_Status = “WAIT_FOR_CALL_ANSWER”
            AND Trigger_Point_Type = “NOTIFY”
      THEN
            Continue the current session.
            Send “CCR [UPDATE]” charging report to OCS
            Start timer to wait for “CCA [UPDATE]” from OCS
      END IF
R10:  IF    SIP_Method = “ACK” AND Call_Status = “ANSWERED”
            AND Trigger_Point_Type = “NULL”
      THEN
            Continue the current session.
      END IF
```

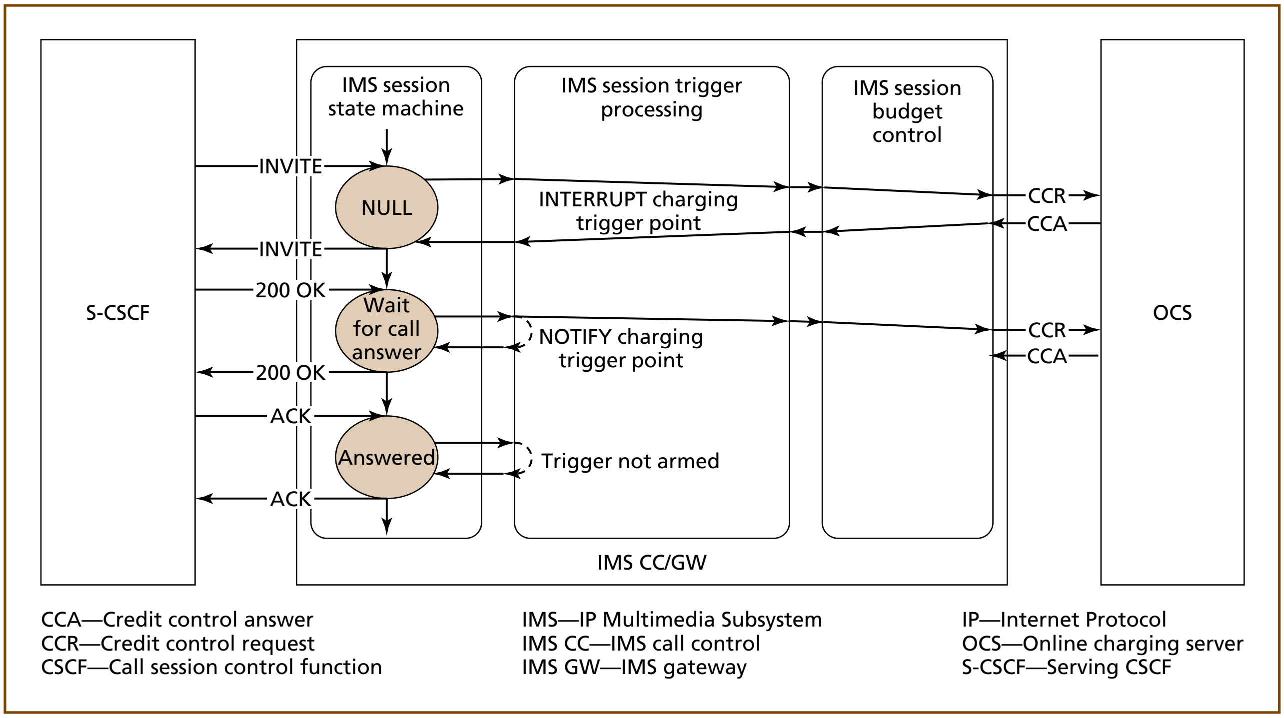


Figure 8.
IMS session charging trigger mechanism.

Session Charging Budget Control

The IMS CC supports the session budget control to supervise the granted quota from the OCS (see **Figure 9**). The IMS session budget control communicates with the OCS via the 3GPP Ro interface, which is the message extension of the credit control request (CCR) and credit control answer (CCA) defined in the draft IETF Diameter Credit-Control Application (DCCA) protocol [4, 6]. The budget control is based on a series of "interrogations" between the IMS GW and the OCS via the Ro interface. These include:

- Initial interrogation;
- Zero, one, or more interim interrogations; and
- Final interrogation.

Each interrogation is composed of a pair of CCR and CCA messages. In the initial interrogation (i.e., CCR [INITIAL] and CCA [INITIAL]), the IMS GW requests to reserve the quota amount from the OCS. When the reserved quota is consumed to the defined threshold or the next charging point is triggered, the IMS GW uses interim interrogation (i.e., CCR [UPDATE] and CCA [UPDATE]) to report the actual number of quota units used as of the current charging point and also to allocate a new quota for the next charging point. The final interrogation (i.e., CCR [TERMINATION] and CCA [TERMINATION]) reports the final total of used units when the IMS session ends.

Protocol Translation

The IMS GW supports message translation between the ISC interface and the Ro interface. Based on the state-defined session control model, the IMS GW translates different SIP messages to an initial, interim, or termination interrogation Ro request.

In addition to normal SIP and Ro protocol translation and field mapping, the IMS GW extends usage of the Ro interface by adding the IMS server trigger parameter attribute value pair (AVP) to enable IMS GW monitoring of IMS server information to be reported to the OCS for session charging. For example, when the IMS GW gets the dynamic charging trigger from the Ro response, the IMS GW dynamically provisions the charging record report filter into the rule repository. For subsequent messages, the PEP in the

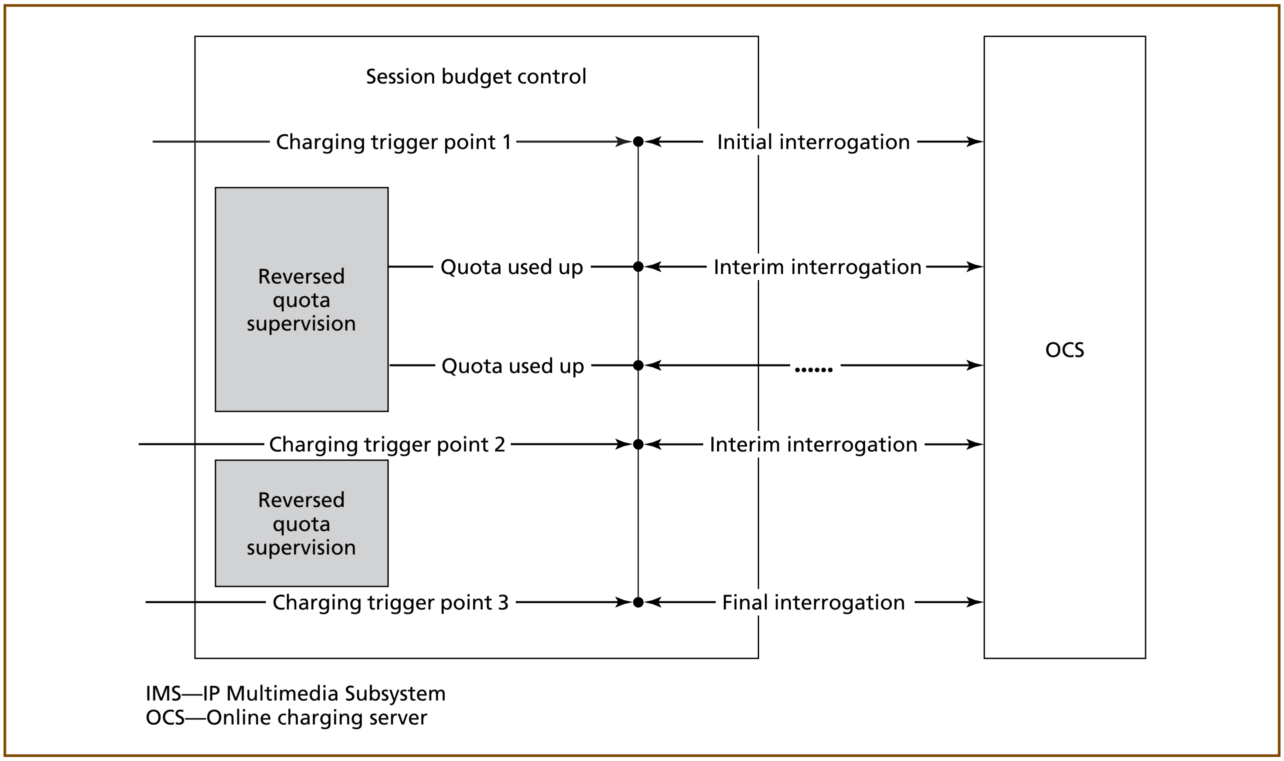


Figure 9.
IMS session budget control.

IMS GW logic can request the PDP to evaluate the IMS call information. When the charging report filter rule is matched, the IMS GW sends a charging report to the OCS.

The IMS CC may also provide IMS correlation information to the OCS via the Ro interface by using the P-Charging-Vector field extension in the SIP header to correlate charging records generated from different entities related to the same IMS session.

In the converged application type, different services may perform different online charging functions. The IMS CC can support independent online charging reports on a per-service basis. To optimally support these scenarios, instead of sending multiple Ro requests for each service's charging request, the IMS CC only sends one Ro request message to the OCS. The Ro message sent to the OCS includes the multiple service credit control (MSCC) group AVP with information for multiple IMS applications. In the IMS CC, there is one service identifier for each service. Multiple services with the same charging characteristic can be grouped into a common rating group. The rule to determine the rating group is based on the service ID and service parameter information. The abstract rating group rule is expressed as the following:

```
IF    Service ID AND IMS_Service
      Parameter Information
THEN  Rating Group
END IF
```

Figure 10 presents converged service online charging support via multiple service credit control.

IMS Session Charging Scenario

The IMS CC supports mobile originated IMS call scenarios, mobile terminated call scenarios, HSS call redirection scenarios (e.g., busy, unconditional, no answer), IMS CC-based call redirection scenarios (e.g., busy, unconditional, no answer), and IMS "rainy day" scenarios for fault recovery. **Figure 11** provides one example of an originating IMS call scenario:

1. The calling party user entity (UE) initiates a SIP INVITE message to the S-CSCF. The S-CSCF sends the INVITE message to the IMS CC. The

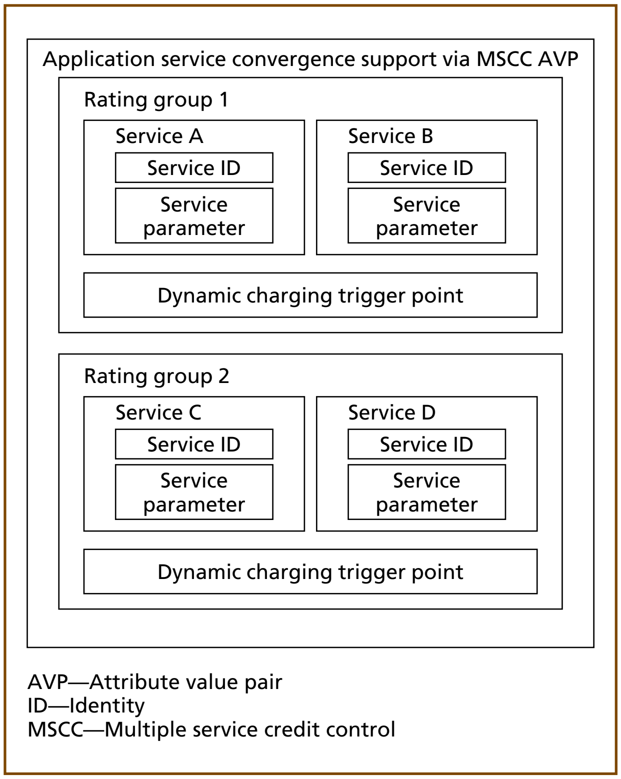


Figure 10.
Converged service online charging support via MSCC.

IMS CC invokes application service logic as follows:

a. The IMS CC determines that the called party number is an abbreviated number and invokes abbreviated dialing (ABD) application logic to convert the abbreviated number to a normal call number.
b. The charging PEP in ABD logic invokes the charging PDP and determines that ABD number conversion shall be charged as rating group 1 (e.g., incur a flat charge for the ABD number conversion).
c. After ABD number conversion, the IMS CC treats this session as a normal session for session control.
d. The IMS CC invokes the IMS GW logic, and the charging PEP for IMS session control invokes the charging PDP and determines session charging to be rating group 2.
e. The IMS CC policy management logic evaluates the first INVITE message of this session, and the charging trigger point is configured as INTERRUPT. The IMS CC starts a timer to hold on the current session. The charging trigger point can be expressed as the following:

```
IF  SIP_Method = "INVITE" AND
    Call_Status = "NULL"
    AND Trigger_Point_Type =
    "INTERRUPT"
THEN
    Hold on the current session
    Send "CCR [INITIAL]"
    charging report to the OCS
    Start timer to wait "CCA
    [INITIAL]" from the OCS
END IF
```

2. The IMS CC sends a credit control request (CCR) [INITIAL] to the OCS for a credit reservation. In the CCR message, two MSCC AVPs are included:
   a. One MSCC AVP for the credit reservation for rating group 1 (e.g., the flat charge for the ABD number conversion);
   b. Another MSCC AVP for the credit reservation for rating group 2 (e.g., session credit pre-authorization to roughly estimate the maximum session duration the calling party can use).
3. The OCS will grant quota units for each rating group, respectively, and set the granted quota in each rating group's MSCC AVP. The OCS populates the service-specific charging trigger sub-AVP under each MSCC AVP. After that, the OCS sends CCA [INITIAL] to the IMS CC.
4. When the IMS CC receives the CCA, it determines that the session is allowed, continues the current session, and forwards the INVITE request to the called party via the S-CSCF.
5. The called party answers the call via a 200 OK message to the S-CSCF, and the S-CSCF forwards the 200 OK response to the IMS CC.
6. When the IMS CC receives the answer message (200 OK), it invokes charging policy

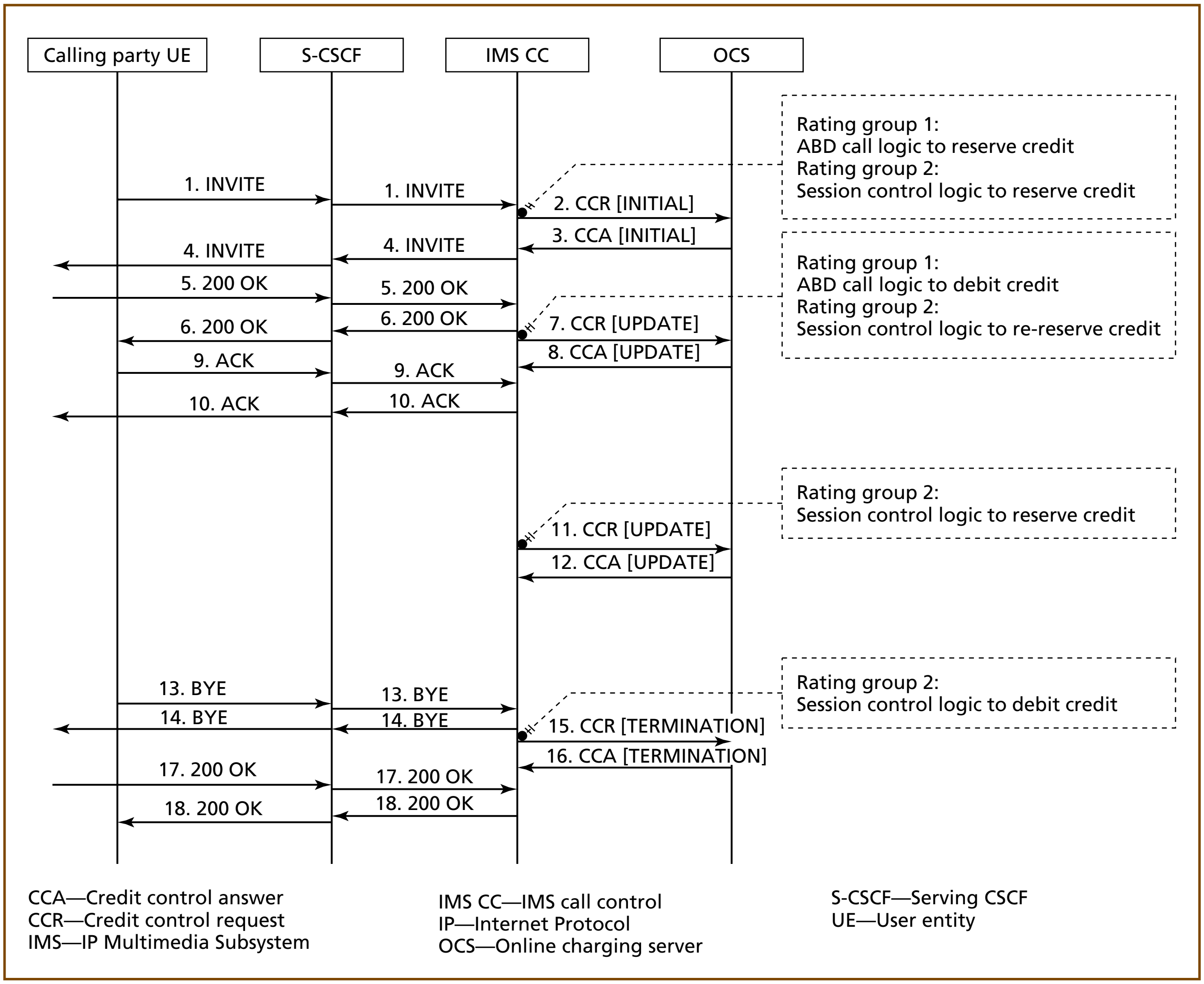


Figure 11.
Originating IMS call scenario.

management, and charging rules are evaluated as follows:

```
IF  SIP_Method = "200" AND Call_
    Status = "WAIT_FOR_CALL_ANSWER"
    AND Trigger_Point_Type =
    "NOTIFY"
THEN
    Continue the current session.
    Send "CCR [UPDATE]" charging
    report to the OCS
    Start timer to wait for a "CCA
    [UPDATE]" from the OCS
END IF
```

Because the charging trigger type is NOTIFY, the IMS CC lets the existing session continue and forwards the 200 OK message to the calling party via the S-CSCF to allow the session to continue.

7. The IMS CC sends a CCR [UPDATE] to report the charging record to the OCS:
   a. The MSCC AVP of rating group 1 indicates the OCS is to debit the reserved credit because the session is successfully answered. An ABD flat charge shall be debited from the balance.
   b. The MSCC AVP of rating group 2 indicates the OCS is to re-authorize session credit

because the session is in the *answered* state. The OCS shall re-reserve the credit from the current session answer time.

8. The OCS responds with a CCA [UPDATE] to the IMS CC. The granted unit and expiry time are included in the MSCC AVP for rating group 2. The OCS populates the extended trigger point AVP in MSCC AVP. When the IMS CC receives the CCA response, it dynamically provisions these charging filter criteria in its policy repository. The IMS CC starts a session control timer to monitor the session's elapsed time based on the reserved quota.
9. When the calling party UE receives a 200 OK answer message, the UE responds with a SIP ACK message, which is forwarded to the IMS CC by the S-CSCF. After the IMS CC receives the ACK message, its PEP will invokes the PDP to evaluate whether to send a charging report to the OCS. In this example, the following charging filter rule is matched:

```
IF  SIP_Method = "ACK" AND Call_
    Status = "ANSWERED"
    AND Trigger_Point_Type =
    "NULL"
THEN
    Continue the current session.
END IF
```

10. Because this message is not armed, the IMS CC lets the SIP message continue and forwards the ACK message to the called party via the S-CSCF.
11. At this point, the allocated quota is used up and the timer is expired. The IMS CC reports the used quota to the OCS via a CCR [UPDATE] message and requests allocation of a new quota.
12. The OCS determines that the calling party has enough credit and allocates another new quota for rating group 2. The OCS sends the new quota back to the IMS CC via a CCA [UPDATE] response. The IMS CC resets the session control timer with the newly allocated quota to monitor the session's elapsed time from this point forward.
13. The calling party initiates the termination of the current session via a BYE message sent to the IMS CC via the S-CSCF. The IMS CC PEP invokes the PDP and encounters the following charging filter rule:

```
IF  SIP_Method = "BYE" AND
    Call_Status = "In_Progess"
    AND Trigger_Point_Type =
    "NOTIFY"
THEN
    Continue the current session.
    Send a "CCR [TERMINATION]"
    charging report to the OCS
    Start timer to wait for a "CCA
    [TERMINATION]" from the OCS
END IF
```

14. The IMS CC lets the SIP message handling continue and sends the BYE response to the S-CSCF.
15. The IMS CC calculates the used quota until the time when the BYE message is received, then stops the session control timer, and sends a CCR [TERMINATION] message to the OCS to report the consumed quota.
16. The OCS returns a CCA [TERMINATION] message to the IMS CC to indicate the message has been received.
17. The called party returns a 200 OK SIP message to the IMS CC via the S-CSCF; this indicates the session resource of the called party is released.
18. The IMS CC's PEP determines there is no rule for this 200 OK message under the current session status, so no action is taken to control the session. The IMS CC sends a 200 OK message to release the calling party's session resource.

Conclusions

This paper describes a new and innovative concept for a policy-based IMS call control system and solutions for providing online session charging in IMS networks that will remedy online charging gaps in current 3GPP specifications, including lack of definition of IMS gateway functionalities and call control mechanisms. The IMS CC solution presented here provides a detailed online session charging mechanism and functions as a gateway element encompassing call state machine, call control logic, budget control, and protocol translation.

In 3GPP specifications, application service logic in an application server is separated from the IMS gateway when the application server performs an online charging function. However, the IMS CC system presented here converges multiple application servers and the IMS gateway functionality into a single node for online session charging. The IMS CC enables service logic for multiple applications to be executed in a single node. When performing online call session control, the IMS CC can execute gateway logic, application service logic (for one or more applications), or a combination of both in a predetermined sequence based on service needs and the rule set configured by the service provider in order to greatly reduce traffic access between the IMS CSCF and the OCS.

With its rule-based architecture, the IMS CC supports many time-based online session charging scenarios: originating IMS call, terminating IMS call, IMS CC-based call redirection on busy, terminating with insufficient credit balance, free calls, mid-call low balance, mid-SIP session timeout, mid-SIP session OCS unavailable, mid-SIP session change, failed SIP session setup, and other IMS CC error processing. Further investigation and research will be conducted in the near future to extend the IMS CC solution to support volume-based session credit control, flow based credit control, and QoS-based charging for IMS online charging.

References

[1] 3rd Generation Partnership Project, “Charging Principles,” 3GPP TS 32.200, V 5.8.0, Mar. 2005, <http://www.3gpp.org/ftp/Specs/html-info/32200.htm>.

[2] 3rd Generation Partnership Project, “Charging Architecture and Principles,” 3GPP TS 32.240, V 6.1.0, Mar. 2005, <http://www.3gpp.org/ftp/Specs/html-info/32240.htm>.

[3] 3rd Generation Partnership Project, “IP Multimedia Subsystem (IMS) Charging,” 3GPP TS 32.260, V 6.1.0, Mar. 2005, <http://www.3gpp.org/ftp/Specs/html-info/32260.htm>.

[4] H. Hakala, L. Mattila, J. Koskinen, M. Stura, and J. Loughney, “Diameter Credit-Control Application,” IETF Internet Draft, Aug. 2004, <http://www.ietf.org/internet-drafts/draft-ietf-aaa-diameter-cc-06.txt>.

[5] R. B. Hull, B. B. Kumar, S. Qutub, M. R. Unmehopa, and D. W. Varney, “Policy Enabling the Services Layer,” Bell Labs Tech. J., 9:1 (2004), 5–18.

[6] J. Rosenburg, H. Schulzrinne, G. Camarillo, A. Johnston, J. Peterson, R. Sparks, M. Handley, and E. Schooler, “SIP: Session Initiation Protocol,” IETF RFC 3261, June 2002, <http://www.ietf.org/rfc/rfc3261.txt>.

(Manuscript approved August 2005)

YIGANG CAI is a distinguished member of technical staff in the Application Solutions Business Unit of Lucent Technologies’ Network Solutions Group in Naperville, Illinois. He holds B.S., M.S., and Ph.D. degrees in engineering from Zhejiang University in Hangzhou, China. Dr. Cai is currently a system engineer for Lucent’s MiLife® SurePay® suite of products.

XIANG YANG LI is a member of technical staff for systems engineering in the Application Solutions Business Unit in Lucent Technologies’ Mobility R&D unit in Beijing, China. He received his B.S., M.S., and Ph.D. degrees in computer science from Zhejiang University in Hangzhou, China. Dr. Li is currently a system engineer for Lucent’s MiLife® SurePay® suite of products.

YILE WANG is a distinguished member of technical staff in the Application Solutions Business Unit of Lucent Technologies’ Network Solutions Group in Holmdel, New Jersey. Dr. Wang is currently a system engineer for Lucent’s MiLife® SurePay® suite of products. He holds a B.S. degree in computer science from Peking/Beijing University in Beijing, China, and M.S. and Ph.D. degrees in computer science from Michigan State University in East Lansing, Michigan.

JOHN B. REID is a technical manager in the Application Solutions Business Unit of Lucent Technologies’ Network Solutions Group in Naperville, Illinois. He received his B.S. degree in computer engineering from the University of Michigan in Ann Arbor and an M.S. degree in computer science from Stanford

University in California. Mr. Reid currently manages a team responsible for product tier 1 systems engineering for emerging solutions applications.

PENG WANG is technical manager for the MiLife® SurePay® systems engineering and performance team within the Application Solutions Business Unit of Lucent Technologies' Mobility R&D unit in Beijing, China. He holds a B.S. degree in computer science from Northern Jiao Tong University in Beijing, China, and an M.S. degree in computer science from the Beijing Institute of Control Engineering. ◆