IMS-TV: An IMS-Based Architecture for Interactive, Personalized IPTV

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ABSTRACT

This article describes a novel architecture for delivering personalized IPTV experiences to end users. The framework leverages the IP Multimedia Subsystem to quickly enable new innovative, multi-media services. We describe the session flows for important use cases, such as accessing the electronic service guide, VoD, fast channel changing, and enhanced parental control services. Important parameters are quantified for the session experience in each of these use cases.

INTRODUCTION

Internet Protocol Multimedia Subsystem (IMS) is a service subsystem within the next-generation network (NGN) architecture currently planned for mobile and fixed multimedia services, standardized by the 3rd Generation Partnership Project (3GPP) [1]. IMS promises a scalable integrated platform that enables new services and provides for the combination of telecommunications and Internet services.

Standardization organizations such as the Alliance for Telecommunications Industry Solutions-IPTV Interoperability Forum (ATIS-IIF) [1], European Telecommunications Standards Institute Telecoms and Internet Converged Services and Protocols for Advanced Networks (ETSI TISPAN) [2, 3], and International Telecommunication Union-Focus Group (ITU-FG) IPTV [4] have proposed an architectural framework for incorporating an end-to-end IPTV subsystem. They have recognized dual approaches, namely:

- A dedicated subsystem for IPTV NGN services (dedicated-IPTV)
- Extending IMS within NGN to deliver selected IPTV services (IMS-IPTV)

The first approach (dedicated-IPTV) focuses on standardizing IPTV functional entities and reference points within the NGN. In some scenarios, a dedicated-IPTV subsystem offers performance improvements by eliminating the extra control messages that are required to communicate with the IMS core during the service control. For example, extra control messages can degrade the user experience for a use case such as park-and-pickup live TV that requires switching between unicast and multicast delivery modes. In this article, we explore the second approach (IMS-IPTV), which makes use of the NGN IMS to deliver selected IPTV services. Specifically, we show in detail (with call flows and measurement timings in a typical deployment) how IMS-TV can support interactive and personalized IPTV services like enhanced parental control services, voting, and so on.

All of the Session Initiation Protocol (SIP) methods used in our system are compliant with RFC 3261 and companion RFCs from the Internet Engineering Task Force (IETF). However, the specific procedures described in the article are under consideration for standardization in TISPAN. Specifically, the start-up and resource management procedures (with slight modifications) are being proposed in the IPTV working groups of TISPAN and in the Open IPTV Forum [5].

The attributes of a NGN IMS subsystem include:

- Access agnostic infrastructure — services are independent of the underlying access network
- Full mobility — transparent connectivity across heterogeneous networks, protocols, and access mechanisms
- Always on, always available capabilities, through sessions that cross networks and devices automatically and transparently
- User-centric context, both device and context-sensitive
- Personalized context-aware applications catered to the needs of an individual or a group of individuals
- Privacy, safety, and security of information to safeguard business and consumer integrity and protect the digital rights of content creators

Market demand necessitates innovation and is driving operators to provide a highly integrated solution for seamless, networked-based media over three screens (TV, mobile devices, and personal computers). The objective of this research is to enable such video services through IMS, integrating multimedia with rich communication services to deliver personalized, interactive television no matter where the viewer is, when the content is requested, or what kind of device is

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used. In particular, several hand-off scenarios between wireline set top boxes (STBs) and wireless handsets are described. We show the advantages of this architecture in the rapid market introduction of new services by reducing the dependence on proprietary vendor solutions. In addition, this architecture introduces the flexibility required to cope with the emerging 3GPP requirement changes and delivers advanced features in a timely fashion. There are several reasons for using an IMS core:

- Core service network that is independent of access technology
- Same application and service is available from any access method or device
- Ability to migrate and deploy across fixed and mobile users
- Standards allow scalable deployment of new services

Note that the scalable deployment of new services is not IMS-IPTV specific. The IETF Real Time Streaming Protocol (RTSP) standard (RFC2326, April, 1998) allows scalable deployment for dedicated-IPTV using RTSP redirect for load balancing during content on demand.

- Evolution to combined services for enhanced user experience (presence, messaging, address book)
- Security is built in — identity management, authentication, authorization, and service access
- Centralized user profiles shared between applications
- Architecture designed for scalability and redundancy
- Common solution to achieve quality of service
- Flexible charging for multimedia and combined services. For interactive features like voting by short message service (SMS) for a watched IPTV program, IMS will allow service providers to unify billing as part of a triple play bundled service.
- Common provisioning

We then discuss the specifics of the IPTV infrastructure using an IMS core. The following section investigates service details, including typical session flow scenarios and timing measurements that we believe are novel in the context of IMS-IPTV. Our IMS-TV implementation is based on the Ericsson IMS core, which provides the basic call state control function (CSCF) functionality, as well as the home subscriber server (HSS) and related databases [6]. The implementation then adds an IPTV application server with functionally that is split into two blocks, namely, the IPTV application platform and the IPTV controller. In addition, we provide protocol level measurements to highlight valuable insights in this framework and suggest possible bottlenecks and improvements from a service provider's standpoint.

Related Work

IPTV Architectures

Different IPTV architectures have been proposed by international standardization bodies in an effort to encourage novel services to be deployed. As mentioned previously, [3] proposes a dedicated IPTV functional area within the NGN framework to alleviate performance bottlenecks for some IPTV features. [2] proposes a framework that enables IPTV functions to be routed through IMS. In particular, authentication, authorization, and signaling for the set up of service provisioning and content delivery are performed using IMS.

Redundancy and Scalability Using IMS

Bodzinga *et al.* [7] discuss how IMS and IPTV service platforms can be interworked and integrated to reduce network complexity and provide a flexible network for novel differentiated services. An important aspect that IMS addresses is redundancy and scalability; these issues within IMS are addressed in [8]. This is particularly attractive for operators that deploy services that scale to a large subscriber base. Traditional telecommunications networks (time-division multiplexing [TDM] architecture) are optimized to have dedicated network functions at specific locations. Load sharing of spread network functions are difficult to realize in TDM networks. Networks must be specifically optimized at network nodes to accommodate peak traffic demands. With IMS, some of these engineering optimizations are alleviated. It is based on the IP protocol-carrying bearer and signaling/control traffic. Whereas bearer traffic functions still must be optimized with respect to best location, the signaling and control functions of the network could be spread somewhat arbitrarily over the network.

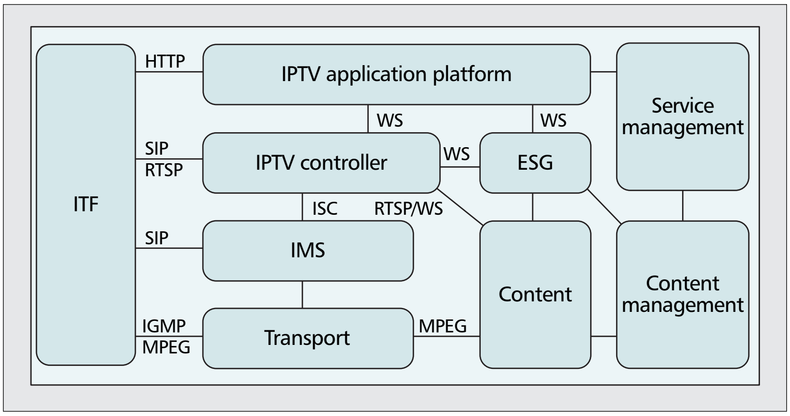

Figure 1. *High-level architecture.*

System Architecture

Figure 1 shows a high-level IPTV network architecture that is supported by an IMS infrastructure. Three functional layers exist, namely the service layer (composed of service management and IPTV application platform), the control layer (composed of IPTV controller), and the media layer (composed of transport, content, and content management), as shown in Fig. 1. The layered architecture facilitates interoperability among different vendor solutions and maintains ease of service creation. The IPTV service layer provides multimedia services to the end user by means of the IPTV application platform (IAP). The IAP implements the portal with

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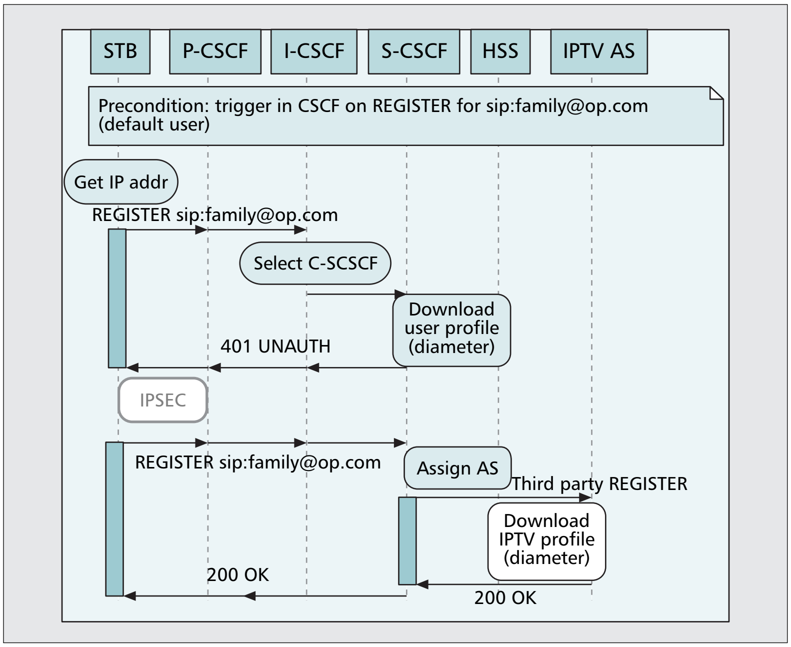

Figure 2. *STB registration.*

which a user interacts and includes functionalities like the electronic service guide (ESG), video on demand (VoD), and so on. The IAP interacts with the IPTV terminal function (ITF), which handles display and interactivity functions for users. The IPTV application server (AS) contains another functional block, the IPTV controller, which implements the interfaces to the IMS core and to all session control functionality (i.e., SIP and RTSP). The ITF also performs functions such as content encoding/decoding and buffering for both unicast and multicast streams. The system deployment is divided into a number of logically separated parts, namely, the home network, access network, aggregation network, and the service provider domain. The home network comprises the STB and the access modem. In a typical fiber-to-the-node (FTTN) environment, the access network is made up of digital subscriber-line access multiplexers (DSLAMs), where each DSLAM can accommodate about 200 homes. Upstream of each DSLAM is an aggregator central office (CO), that connects back to the IP core network. A CO can have several tens of DSLAMs subtending from it. All IMS entities (HSS, CSCFs, IMS-TV application servers) reside in the service provider IP core network. Content is acquired and prepared in video hub offices (VHOs) before transmission into the IP network.

IPTV User Profiles

In the IMS IPTV architecture, personalization is an important feature. To achieve personalization at the application level (i.e., personalized electronic program guides [EPGs], advertisements, or even personalized blended communication services), every user has an IPTV profile. The relation between the IPTV profile and the IMS profile depends on the availability of a home IMS gateway (HIGA) [9]. The HIGA is a functional block with an attached IP multimedia services identity module (ISIM) card reader, which can be deployed in the residential gateway or any other networked consumer equipment. The HIGA translates home signaling, whether SIP, universal plug and play (UPnP), or perhaps pure hypertext transfer protocol (HTTP), to IMS signaling. It also handles network address translation (NAT) traversal and secure connectivity with the proxy-CSCF (P-CSCF) in the IMS domain, as well as identity, device subscription, and management inside the home domain and toward the IMS core.

In a home network domain without an IMS gateway, every IPTV account must have IMS public/private ID pairs for the users of the system; these are used to log in to the IMS domain. However, because the TV can be a social device, in which many users often are watching TV together, the IMS IPTV STB has a default user that represents the household itself (for example, sip:family@op.com). In this way, the STB can be configured to use the default household user to log in to the IMS domain, personalizing itself with the default values for the whole family, or it can be configured to make the initial log-in of a personal user (i.e., sip:dad.family@op.com). Of course, personal user profiles can be protected with a personal identification number (PIN) that must be typed in using the remote control to select a particular profile.

If the household contains a HIGA, the family members can choose to have full IMS identity, one that enables them full communication capabilities supported by IMS, or to have just an IPTV profile that uses the default IMS household identity for authentication purposes. The IPTV profile information that must be shared between different IMS services is stored in the IPTV extensible markup language (XML) document management server (XDMS) database. The XDMS stores profile information in IMS [10]. This database is accessed using the XML Configuration Access Protocol (XCAP) [11], which works over HTTP. These profiles can be shared by different users and other stakeholders within the IPTV system. The HIGA concept is gaining popularity among service providers and currently is being proposed in the open IPTV forum standardization body [5].

The Multicast Data Channel

The multicast data channel (MDC) is a special IP multicast pipe that enables the IPTV application server (or any other authorized node) to transmit information to all STBs registered with the IPTV service. Each STB joins this special multicast group after receiving the first NOTIFY for the SIP SUBSCRIBE and keeps listening to it for as long as it is powered up. The MDC can be separated on different multicast groups for special purposes.

The MDC carries information wrapped in an XML schema that provides the capability of differentiating the various pieces of information, such as:

- EPG information, a link to download the EPG from a server, the EPG itself in XML form, or even EPG updates
- Interactivity triggers, in the form of sched-

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uled actions to be displayed/executed in the STB; an HTML page, showing a pop-up with information or triggering a special interactivity mode in the STB
- Firmware upgrades. The MDC can carry an order for all STBs to download an upgrade immediately or to schedule to an appropriate time
- Alert or emergency messages, which should be shown as immediate pop-ups in the STB; these may not disappear until the user acknowledges them

For each piece of information in the MDC, there is a tag with a timestamp that marks the validity of the information; there is also a tag that marks whether the information is included in the XML content (i.e., the EPG is contained inside the XML-wrapped content) or whether it should be obtained by some other means (i.e., an HTTP GET to a particular server or a file transfer of some type). The XML wrapper contains a set of tags to identify the desired receivers of the content. In this way, the MDC can contain information that it tagged to be received by a subset of the STB population. Typical tags include the following:
- Channel being watched: only STBs currently displaying that channel react upon the information
- Age: only STBs whose active user falls into the age range react
- Region: only STBs located in the specified region react
- Gender: only STBs with an active user of the desired gender react (if that field is populated)

The filtering of the received information according to the XML tags occurs in the STB. In this way, users can decide how much personal information they want configured in their personal profiles in the STB.

IPTV Control Plane

The control plane of the IPTV architecture can be divided into a set of functions, such as session set up, media flow set up, and media flow control. The choice of protocols for each function tries to re-use existing defacto standards or IETF standardized protocols when possible. The key components of the IMS control layer are the x-CSCFs and the HSS. The serving (S)-CSCF evaluates all originating and terminating messages and can link in during session set up, based on information of the service, any number of IMS ASs to perform wanted IPTV services. In all IPTV-related SIP messages originating from the ITF, the IPTV control function is linked in. For IPTV, the HSS keeps triggers and filter information for the IPTV public service ID (PSI) or the service identifier. The information is stored and conveyed on a per IMS AS basis. This means that IMS ASs are allocated dynamically and that SIP messages will be routed to the same IMS AS all the time. The S-CSCF downloads rules and triggers, upon user registration, from the HSS.

IPTV Application Plane

All functions that are not media related and that cannot be provided by SIP methods occur over an HTTP connection from the ITF to the IAP. For example, the delivery of personalized EPGs or extra information to interactive content happens over this channel. The HTTP channel is authenticated using a mutual authentication mechanism, which is bootstrapped by the IMS registration. By using the HTTP transport, XCAP can be used for subscriber management functionality as well.

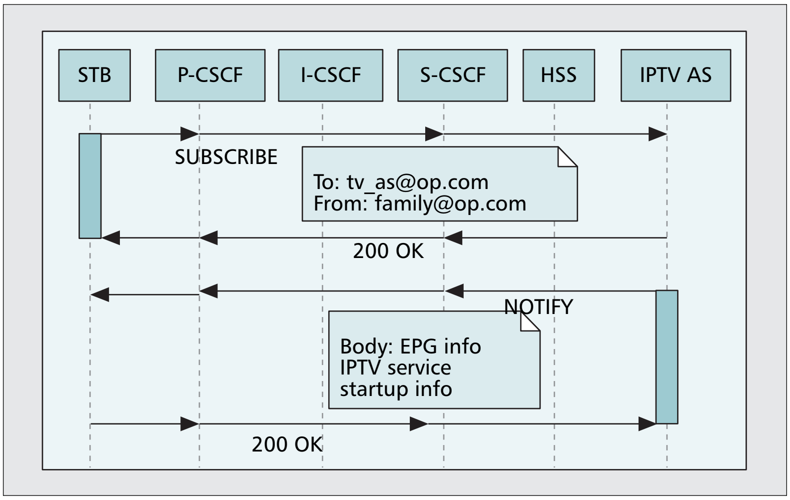

Figure 3. *Subscription to the IPTV service.*

Session Flow Sequence Diagrams

The STB in the IMS IPTV architecture is a full back-to-back IMS user agent that performs the default IMS registration upon start up. When the STB is switched on, it first obtains IP connectivity, which can be statically configured or obtained through the Dynamic Host Configuration Protocol (DHCP). As part of the IP configuration, the STB discovers the IP address or domain name system (DNS) name of the P-CSCF, which is the entry point to the IMS layer.

After the STB obtains IP connectivity, it performs an IMS registration with the predefined default profile. The default profile can be a family user IMS public ID, common for the household, or a personalized public IMS ID. Figure 2 shows the simplified steps of the IMS registration. An important aspect of the registration is that the S-CSCF performs a third-party registration of the user in the IPTV AS, triggered by the information on the IMS user profile stored in the HSS. After registering the user, the STB sends a SIP SUBSCRIBE toward the IPTV AS, as shown in Fig. 3. The body of the SIP SUBSCRIBE contains the last set-up information that the STB has cached, with a timestamp on it, wrapped in the same XML schema in which the information within the MDC was sent.

The information included contains the following:
- IP address of the MDC
- URL to the valid EPG (and interactive program guide if not the same) for the user
- The latest profile information of the user
- Any other required common set-up information

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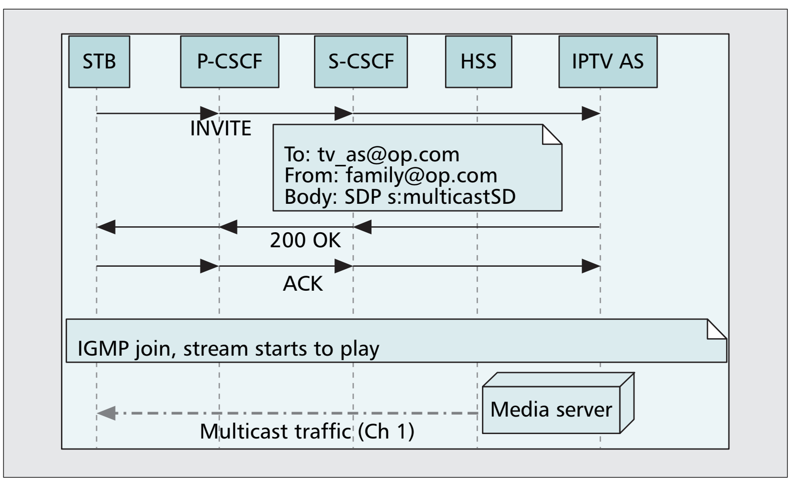
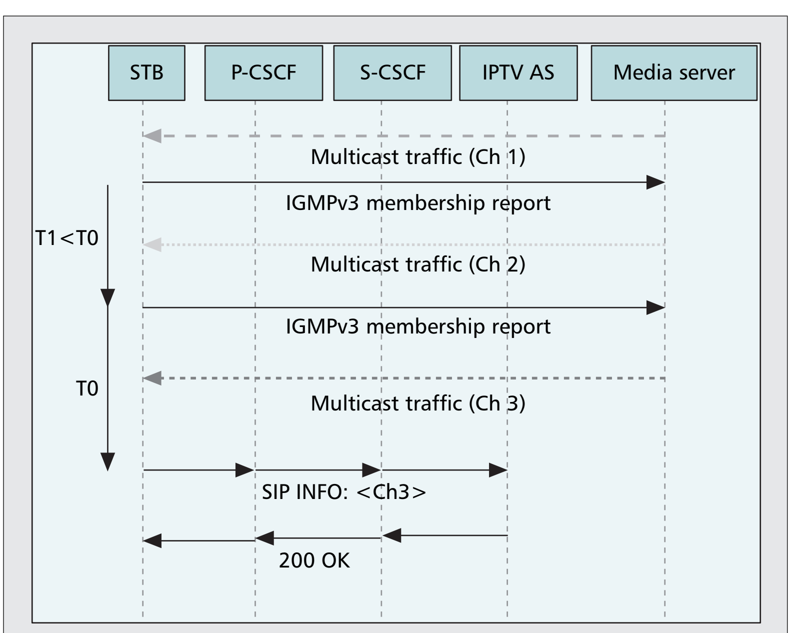
When the IPTV AS receives the SUBSCRIBE, it confirms the SIP dialog and checks the validity of all the information in the XML body. Then, the AS generates a SIP NOTIFY with the updated information wrapped in the same schema, with a tag indicating whether it is the same as the STB sent or the client must update it.

The SUBSCRIBE/NOTIFY SIP session dialog is active as long as the STB is actively watching or connected to IPTV. This SIP session offers an extremely effective personalization mechanism to reach a particular user (or a small group of users) in the IPTV system. By having homogeneous XML to send metadata information over the MDC or over a SIP NOTIFY, the IPTV AS has the ability to reach a single user individually or in a broadcast distribution, without changing the content of the metadata being sent. The same type of filters that are applied in the client when receiving information over the multicast data channel can be applied to the received NOTIFYs; therefore, the STB can filter out undesired information, without compromising the privacy of the registered user, by providing an extra layer of filtering that is not network-based (i.e., based on the IPTV profile stored in the network). A possible use case is sending a notification for all ITFs with registered users in the 20-to-30-year-old range, which when arriving to a particular ITF is filtered out because the user has configured the system to receive only notifications addressed to people living in the user's area.



■ **Figure 4.** *Tuning to a broadcast channel.*



■ **Figure 5.** *Channel changing.*

The last step of the start-up procedure is tuning in to the last broadcast channel that the registered profile was watching. Figure 4 describes the simplified flow. The STB triggers a SIP INVITE toward the IPTV AS. This INVITE contains simplified Session Description Protocol (SDP) information that refers to the type of TV channel being received, in this case multicast in standard definition. The goal of the SIP INVITE is to set up a "media pipe" to the STB to deliver the required set of channels. The AS responds with a full SDP that describes the type of media to be received. Finally, when the INVITE dialog is completed, the STB joins the required multicast channel by performing an Internet Group Management Protocol (IGMP) join.

The figures shown in this article do not describe the procedure for resource management. However, it suffices to say that resource reservation can be performed either by the IPTV control function when receiving the SIP INVITE, sending the 200 OK only when the resources are confirmed, or by the P-CSCF, which only forwards the 200 OK for the INVITE when the resources are confirmed. Our prototype implemented the former approach, by creating a back-to-back (B2B) interface with a fine-grained per-flow reservation system. The reservation system performs dynamic per-flow reservations and can monitor the quality of the access line and notify the IPTV control function (CF) of changes on the available bandwidth.

It is important to note that an update to the SIP dialog only occurs when the characteristics of the media pipe change, but not when the channel changes. In this manner, changing between multicast channels with the same bandwidth characteristics happens via IGMP, without SIP intervention. Figure 5 illustrates the procedure. This behavior is required to achieve a fast channel-changing experience, which would be encumbered if the SIP session had to be updated with every channel change. The behavior is consistent with available IPTV solutions, which do not use IMS as service control layer. If we were to update the SIP dialog every time a channel change is requested, the channel zapping times would increase notably, due to the SIP interaction over the IMS core. Moreover, involving a SIP interaction every time the user zaps in the same channel bundle would create a much higher load of messages for the IMS core.

When the user changes the channel to a multicasted media stream with different characteristics, the SIP dialog is updated through a SIP UPDATE. This mechanism is important because it allows the IMS system to know the proper quality of service (QoS) requirements requested

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by the media flow being sent to the user. Of course, updating the SIP dialog may introduce a small delay in the channel-changing experience, but this update provides for assured media delivery of the requested standard or high-definition live channel.

Nevertheless, to provide targeted advertisements or any type of media-related value-added services, it is important for the IPTV provider to know which channels the different STBs are watching. This occurs when the channel-changing timeout of the STB is triggered, which occurs when the user does not change the channel for "x" seconds (for example, five seconds). When the timeout is triggered, the STB sends a SIP INFO toward the IPTV AS, which contains an XML body with the status information of the media. In the case of multicast live channels, this status information is simply the channel being watched.

Accessing Video on Demand

As described in the previous section, the SIP INVITE dialog remains unchanged as long as the media characteristics do not change. In this way, when the user decides to watch a VoD movie or any other on-demand media item, a new SIP session is created after finalizing the previous one. Figure 6 shows the process. The first step is finalizing the previous SIP INVITE dialog by sending a SIP BYE. This SIP BYE also triggers the release of the resources for the multicast delivery. After the BYE, the STB sends a new SIP INVITE toward the IPTV AS, in this case requesting unicast session description (SD). The response from the IPTV AS contains an SDP describing the required media and transport control protocol, such as RTSP URL. Then, the STB can utilize the proper media transport control protocol (in this case, RTSP) to start the desired VoD item.

When the user is watching VoD, the SIP INFO has another important function. If the user decides to pause or stop the media, then a SIP INFO is triggered toward the IPTV AS. The INFO message contains the status information of the VoD being consumed, for example, the time position or frame number and payment information status, if needed. This information then can be used to retrieve the VoD item that the registered user was watching from another device and continue the program from where it was stopped. If the user decides to go back to live TV, the procedure is repeated. First, a SIP BYE finalizes the unicast SIP media pipe, and then a new SIP INVITE sets up the multicast delivery again.

Change of User Profile

Personalization is a key feature in the IMS IPTV solution. In this sense, we already described how the STB contains a default user for the family entity, as well as personalized users for the different members of the household. The process of changing a user profile implies replicating the start-up procedure for the STB, with a new user IMS identity. The STB first sends a SIP BYE to finalize the SIP dialog that creates the media pipe, a SIP SUBSCRIBE with Expire = 0 to the AS, terminating the subscribe dialog, and then

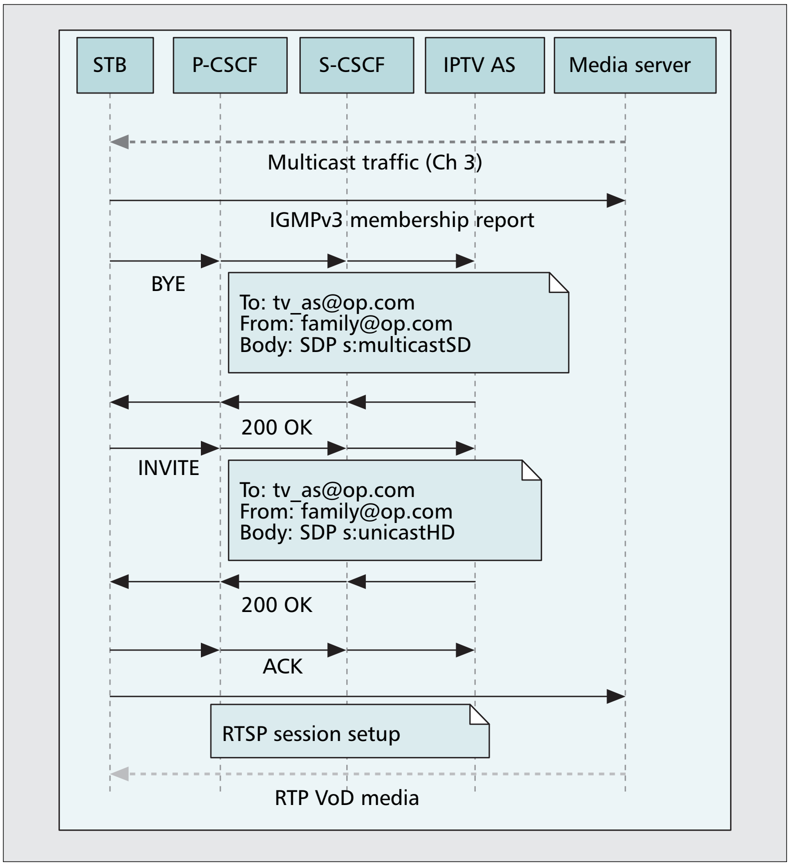

Figure 6. *Video-on-demand.*

unregisters the old user profile. After that, the register, subscribe, and invite procedures are repeated for the new user. Note that if the new user can watch the same channel as the old user, and there is no active channel change from the user, the media transport control protocol is not used, that is, no IGMP message is sent to leave and join, or no RTSP STOP and new SETUP is issued. It is up to the logic in the AS to update the state information of the media flows to belong to the new user instead of the old one. However, if the new user profile does not have rights to watch the current channel, then the default live channel for the new user is set up, using the procedure described in the start-up mechanism. It is worth noting that the SIP BYE sent to finalize the dialog with the previous user would have caused a release of the QoS resources allocated to that session and that a new SIP session must be initiated to establish the required resources. There is a possibility, however, that there may not be adequate resources available if they were utilized completely during the user profile change.

Remote Authorization

Remote authorization service enables TV end users to request permission to order video content that does not have a rating that is designated as acceptable in their current profile. The service can be activated from the VoD guide, which displays an option for requesting remote authorization after users have selected video content that has an age designation rating that is

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Functionality	Elapsed Time (seconds)
STB registration	0.83 sec (Fig. 2)
IPTV service subscription	1.31 sec (Fig. 3)
VoD access	< 5 sec (Fig. 6)
Fast channel change	0.41 sec (Fig. 5, leave-join)
Parental authorization	< 20 sec (depending on network delays and SMS delivery times)

Table 1. *Timing measurements for typical VoD functionalities.*

higher than is allowed in their user profile. An SMS message is sent to the authorizer's mobile device, which contains information about the request, such as the requestor's name, content title, and rating. Following the instructions provided in the request message, the authorizer either can approve or decline the request and reply back. A pop-up message appears on the requestor's TV screen, notifying whether the request is approved or not. If approved, the user can choose to view immediately or later by accessing the content from the user's VoD list. If the approver cannot be reached after a number of retries, a default policy can be used (e.g., reject the request). Note that, in general, other content rating policies (not tied to age) also can be managed in a similar call flow.

INTERACTIVITY

The duplex communication characteristic of the Internet Protocol enables the IMS IPTV to provide excellent interactivity features, which coupled with the personalized aspect of having an IMS registration, offers a complete two-way communication channel between content providers and consumers. The IMS IPTV system uses a combination of methods to deliver interactivity triggers, like the MDC, personalized SIP NOTIFYs, or in-band media related triggers. The feedback channel can be configured in the trigger itself; therefore, for example, a voting message can be sent by a SIP MESSAGE, an HTTP PUT, or even with an SMS triggered from the STB. SIP provides all the required functionality to set up specialized media channels, such as voice-over-IP (VoIP) or videoconference, chatting, or gaming, which further enrich the TV experience to transform it into a social event, based on rich, interactive, multimedia communications.

In prototyping the system, some measurements regarding the time it takes to perform STB registration, VoD access, fast channel change, and parental authorization were captured. Table 1 lists some of the initial performance data.

CONCLUSIONS

This article investigates an IMS-based architecture for the delivery of IPTV services. In particular, session flows for linear TV, video on demand, remote parental authorization, and interactive services were some of the use cases that were discussed. We describe how SIP signaling and IMS can be used to provide entertainment video services.

This article demonstrates the great promise that IMS-TV has and its potential to deliver differentiated services, which offer attractive, interactive, rich multimedia experiences to the end user. We are currently investigating several extensions of IMS-TV, namely, personalized advertisement insertion by means of intelligent multimedia service routers at the network edge and the seamless portability of IPTV sessions across three screens on different access networks.

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BIOGRAPHIES

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