ATIS STANDARD

ATIS-0800018

IPTV LINEAR TV SERVICE

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ATIS-0800018, *IPTV Linear TV Service*

Is an ATIS standard developed by the **Architecture (ARCH)** Committee under the **ATIS IPTV Interoperability Forum (IIF)**.

Published by

Alliance for Telecommunications Industry Solutions
1200 G Street, NW, Suite 500
Washington, DC 20005

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Printed in the United States of America.

ATIS-0800018

ATIS Standard on

IPTV LINEAR TV SERVICE

Secretariat

Alliance for Telecommunications Industry Solutions

Approved December 2008

Abstract

This specification defines the basic Linear TV service operation after the initialization, configuration, service provider discovery, and services discovery documented in ATIS-0800017, *Network Attachment and Initialization of Devices and Client Discovery of IPTV Services*, and ATIS-0800009, *Remote Management of Devices in the Consumer Domain for IPTV Services*.

FOREWORD

The Alliance for Telecommunication Industry Solutions (ATIS) serves the public through improved understanding between carriers, customers, and manufacturers. The IPTV Interoperability Forum (IIF) develops requirements, standards, and specifications that will determine the industry's end-to-end solution for Internet Protocol Television (IPTV).

The mandatory requirements are designated by the word *shall* and recommendations by the word *should*. Where both a mandatory requirement and a recommendation are specified for the same criterion, the recommendation represents a goal currently identifiable as having distinct compatibility or performance advantages. The word *may* denotes a optional capability that could augment the standard. The standard is fully functional without the incorporation of this optional capability.

Suggestions for improvement of this document are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions, IIF Staff, 1200 G Street NW, Suite 500, Washington, DC 20005.

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TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 PURPOSE 1
1.2 SCOPE 1
1.3 ORGANIZATION OF THE DOCUMENT 2

2 NORMATIVE REFERENCES 2

3 DEFINITIONS, ACRONYMS, & ABBREVIATIONS 3

3.1 ACRONYMS & ABBREVIATIONS 3
3.2 DEFINITIONS 5

4 REFERENCE ARCHITECTURE 6

4.1 INTRODUCTION 6
4.2 ARCHITECTURE 8
4.3 FUNCTIONAL DESCRIPTIONS 12
4.3.1 Content Delivery Error Recovery Function 12
4.3.2 Error Recovery Client Function 13
4.3.3 Multicast Transport Function 13
4.4 GEOGRAPHICALLY DISTRIBUTED FUNCTIONAL ARCHITECTURE 15

5 OVERVIEW 16

5.1 OVERVIEW OF CONTENT DISTRIBUTION AND CONTROL PATHS THROUGH THE NETWORK 16
5.2 MESSAGE SEQUENCE CHARTS 18

6 NETWORK AND SERVICE ATTACHMENT PRE-CONDITIONS 19

7 LINEAR TV SERVICE ATTACHMENT AND INITIAL RESOURCE ACQUISITION 19

7.1 STATIC AGGREGATE ALLOCATION OF NETWORK RESOURCES FOR NON-IMS LINEAR TV 21
7.1.1 Application Layer with Static Resources 21
7.1.2 Application Layer Resource Management 21
7.2 DYNAMIC AGGREGATE ALLOCATION OF NETWORK RESOURCES FOR NON-IMS LINEAR TV 23
7.2.1 Coupled 24
7.2.2 Resources Unavailable 25
7.3 IMS SERVICE CONTROL 26
7.3.1 Public Service Identifier (PSI) as Linear TV Service URL 26
7.3.2 Linear TV SIP Session Setup 26
7.3.3 Set-Up and Maintenance of Linear TV SIP Session 28

8 CHANNEL CHANGES WITH LINEAR TV RESOURCES MANAGED IN THE TRANSPORT LAYER ONLY 32

8.1 NULL OR STATIC RESOURCE MANAGEMENT 33
8.2 ADJUSTABLE RESOURCES BETWEEN UNICAST AND MULTICAST 34
8.3 FULLY SHARED RESOURCES BETWEEN UNICAST AND MULTICAST 36
8.4 RESOURCES UNAVAILABLE ERROR CONDITION FOR TRC MULTICAST ADMISSION CONTROL 37

9 CHANNEL CHANGES REQUIRING MODIFICATION OF LINEAR TV SERVICE RESOURCES 37

9.1 NON-IMS COUPLED 38
9.1.1 Resources Unavailable 39
9.2 IMS-BASED RESOURCE MANAGEMENT DURING CHANNEL CHANGE 40
9.2.1 ITF-initiated SIP Session Modification 40
9.2.2 IPTV Control Function Initiated SIP Session Modification 44

10 IPTV SERVICE TERMINATION 44

10.1 NON-IMS COUPLED 44
10.2 IMS 46

11 CONTENT STREAM MEDIA FORMATS AND PROTOCOLS 47

11.1 VIDEO AND AUDIO ENCODED MEDIA 47
11.1.1 Standard Definition Profile 47
11.1.2 High Definition Profile 48
11.1.3 Picture in Picture Profile 48
11.1.4 Video Formats 48

11.1.5 General AVC and Transport Stream Bitstream Constraints *52*
11.1.6 Bitrate Restrictions *52*
11.2 MEDIA METADATA AND DATA 53
11.3 MEDIA ENCAPSULATIONS 53
11.3.1 MPEG-2 Transport Streams *53*
11.3.2 RTP *53*

12 REFERENCE POINTS 53

12.1 A1 53
12.2 E1 54
12.3 E3 (IMS USAGE) 55
12.4 E3 (NON-IMS DECOUPLED USAGE) 55
12.5 E4 55
12.6 E5-CM AND E6-CM 55
12.6.1 Multicast requirements for IPv4 ..... *56*
12.6.2 Multicast requirements for IPv6 ..... *56*
12.7 MD 56
12.7.1 Application Layer FEC *57*
12.7.2 Application Layer Retransmission *57*
12.8 MULTICAST TRANSPORT RESOURCE CONTROL: RP 57
12.9 DNG POLICY ENFORCEMENT CONTROL: RH' (INFORMATIVE) 57
12.10 S3 (RS) 57

APPENDIX A: NON-IMS DECOUPLED SERVICE CONTROL [INFORMATIVE] 59

A.1 REFERENCE ARCHITECTURE 59
A.2 SERVICE ATTACHMENT AND INITIAL CHANNEL ACQUISITION 60
A.2.1 Resources Unavailable *61*
A.3 CHANNEL CHANGE 62
A.3.1 Resources Unavailable *63*
A.4 TERMINATION 64

TABLE OF FIGURES

FIGURE 1: KEY METADATA RELATIONSHIPS FOR THE LINEAR TV SERVICE (INFORMATIVE) 8
FIGURE 2: HIGH LEVEL ARCHITECTURE 9
FIGURE 3: FUNCTIONAL ARCHITECTURE FOR NON-IMS LINEAR TV 11
FIGURE 4: FUNCTIONAL ARCHITECTURE FOR IMS LINEAR TV 12
FIGURE 5: GEOGRAPHICALLY DISTRIBUTED FUNCTIONAL ARCHITECTURE FOR LINEAR TV 15
FIGURE 6: OVERVIEW OF BASIC LINEAR TV PROCESSES 16
FIGURE 7: NON-IMS SERVICE ATTACHMENT AND INITIAL CHANNEL ACQUISITION – STATIC NETWORK LAYER WITH APPLICATION LAYER RESOURCE MANAGEMENT 22
FIGURE 8: NON-IMS SERVICE ATTACHMENT AND INITIAL CHANNEL ACQUISITION – COUPLED 24
FIGURE 9: LINEAR TV SIP SESSION SETUP AND INITIAL CHANNEL ACQUISITION 27
FIGURE 10: CHANNEL CHANGE - NO BANDWIDTH CHANGE NEEDED 33
FIGURE 11: CHANNEL CHANGE WITH ADJUSTABLE RESOURCES IN THE ACCESS NETWORK 35
FIGURE 12: CHANNEL CHANGE WITH FULLY SHARED RESOURCES IN THE ACCESS NETWORK 36
FIGURE 13: NON-IMS CHANNEL CHANGE - COUPLED 38
FIGURE 14: IMS-BASED RESOURCE MANAGEMENT DURING CHANNEL CHANGE – RE-INVITE CASE 41
FIGURE 15: IMS-BASED RESOURCE MANAGEMENT DURING CHANNEL CHANGE – UPDATE CASE 43
FIGURE 16 : NON-IMS IPTV SERVICE TERMINATION – COUPLED 45
FIGURE 17: IMS LINEAR TV SERVICE TERMINATION 46
FIGURE 18: FUNCTIONAL ARCHITECTURE FOR NON-IMS LINEAR TV WITH DECOUPLED SERVICE CONTROL 59
FIGURE 19: NON-IMS SERVICE ATTACHMENT AND INITIAL CHANNEL ACQUISITION – DECOUPLED 60
FIGURE 20: NON-IMS CHANNEL CHANGE – DECOUPLED 62
FIGURE 21: NON-IMS LINEAR TV SERVICE TERMINATION – DECOUPLED 64

TABLE OF TABLES

TABLE 1: SDP NORMATIVE FIELDS AND VALUES 29
TABLE 2: HD VIDEO FORMATS – 30 HZ SYSTEMS 49
TABLE 3: SD VIDEO FORMATS – 30 HZ SYSTEMS 49

TABLE 4: PIP HD VIDEO FORMATS – 30 HZ SYSTEMS 50
TABLE 5: PIP SD VIDEO FORMATS – 30 HZ SYSTEMS 50
TABLE 6: HD VIDEO FORMATS – 25 HZ SYSTEMS 51
TABLE 7: SD VIDEO FORMATS – 25 HZ SYSTEMS 51
TABLE 8: PIP HD VIDEO FORMATS – 25 HZ SYSTEMS 52
TABLE 9: PIP SD VIDEO FORMATS – 25 HZ SYSTEMS 52
TABLE 10: AVC AND TRANSPORT STREAM CODING CONSTRAINTS 52
TABLE 11: AVC BITRATES 53

ATIS Standard on –

IPTV Linear TV Service

1 INTRODUCTION

As noted in ATIS-0800002, *IPTV Architecture Requirements* [1], the Linear/Broadcast TV service on the IPTV platform corresponds to the classic form of television service offered by cable operators, terrestrial broadcasters, and direct broadcast satellite providers. The key characteristics of a television service are that:

- The constitution of the stream's content is determined by the content provider (a.k.a. *broadcaster*).
- The stream does not have a fixed beginning or end point; it is temporally infinite in both directions.

The TV service provides an essentially continuous stream flowing from the content provider to the terminal device in the home network. A key difference in the delivery of similar services via an IPTV platform is that the IP infrastructure used a packet network technology based on a multicast (rather than broadcast) data transfer mode.

1.1 Purpose

The purpose of this document is to describe the use of the components identified in ATIS-0800007, *IPTV High Level Architecture* [2], for delivery of an IPTV service with a consumer experience similar to that of a traditional television service.

1.2 Scope

This specification defines the basic Linear TV service operation after the initialization, configuration, service provider discovery, and services discovery documented in ATIS-0800017, *Network Attachment and Initialization of Devices and Client Discovery of IPTV Services* [5] and ATIS-0800009, *Remote Management of Devices in the Consumer Domain for IPTV Services* [3]. Note that those specifications may enable an IPTV Terminal Function (ITF) to access additional IPTV services beyond the basic Linear TV service described in this specification.

This specification defines the interfaces required between the Service Provider Domain to the Consumer Domain, as well as the essential Network Stratum interfaces. The Service Provider can provide additional processing of the video stream -- e.g., insertion of local content channels, advertising, etc. -- but such mechanisms are beyond the scope of this specification. Section 4 identifies the specific interfaces to be specified in this document in relation to the IPTV High Level Architecture components and interfaces.

The scope of this specification ends with the delivery of the content to the ITF. Further distribution beyond the ITF, user interface controls for presentation on a television set, etc., are beyond the scope of this specification.

The Service Provider can replicate the content stream to multiple Delivery Networks, and the Delivery Networks can replicate the content stream for multiple home networks. This specification covers a client-server architecture (i.e., not peer-to-peer) with delivery via IP multicast (i.e., not unicast) techniques. This specification describes a basic acquisition mechanism for Linear TV content channels with options for various network resource allocation mechanisms.

This specification can be used for low bandwidth and/or wireless infrastructures, but it is not optimized or explicitly addressed for those purposes.

Content can be received by the service provider via satellite or other means, but hybrid delivery (i.e., via mechanisms other than an IP network infrastructure) of content to the consumer domain is beyond the scope of this specification.

The content delivered via the Linear TV service may be either secured or unsecured. Where content security is required to ensure confidentiality of the content and constrain its further distribution, appropriate Digital Rights Management mechanisms are used. These mechanisms are beyond the scope of this specification.

This specification assumes the ITF is authorized to access one or more service packages. Mechanisms to restrict or modify the set of available authorized service packages are beyond the scope of this specification.

1.3 Organization of the Document

Sections 2 and 3 address external references, acronyms, and defined terms. Sections 4 and 5 describe a functional architecture and overview for Linear TV from ATIS-0800007, *IPTV High Level Architecture* [[2]] as a reference for the specifications in the following sections. Section 6 defines the pre-conditions between the attachment state as defined in ATIS-0800017, *Network Attachment and Initialization of Devices and Client Discovery of IPTV Services* [[5]] and this document. Section 7 then addresses the initial resource acquisition for both IMS and non-IMS service control. Sections 8 and 9 address the channel change resource management, and section 10 addresses release of resources being used for the Linear TV service. Section 11 addresses the media payload details (video, audio, etc). Section 12 defines numerous system reference points. Informative Appendix A addresses non-IMS, decoupled service control.

2 NORMATIVE REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this ATIS Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

[1] ATIS-0800002, *IPTV Architecture Requirements*, May 2006. [1]
[2] ATIS-0800007, *IPTV High Level Architecture*, April 2007.[1]

[1] This document is available from the Alliance for Telecommunications Industry Solutions, 1200 G Street N.W., Suite 500, Washington, DC 20005. <http://www.atis.org>

[3] ATIS-0800009, *Remote Management of Devices in the Consumer Domain for IPTV Services*, March 2008. [1]

[4] ATIS-0800013, *Media Formats and Protocols Specification*, due January 2009. [1]

[5] ATIS-0800017, *Attachment and Initialization Specification for IPTV Services in the Consumer Domain*, September 2008. [1]

[6] ATIS-0800019, *Multicast Network Service Specification*, not yet published. [2]

[7] ATIS-0800020, *IPTV EPG Metadata Specification*, June 2008. [1]

[8] ATIS-0800022, *IPTV Consumer Domain Configuration Metadata*, January 2008. [1]

[9] ATIS-0800027, *IPTV Glossary*, not yet published. [2]

[10] ITU-T Y.1910, *IPTV Functional Architecture*, May 2008.[3]

[11] ITU-T Y.2021, *IMS for Next Generation Networks*, September 2006.[3]

[12] ITU-T Y.2111 Revision 1, *Resource and Admission Control Functions in Next Generation Networks*, 2008. [3]

[13] *UPnP-QoS Architecture:3* for UPnP Version 1.0, Standardized DCP, November 2008.[4]

[14] ITU-T Q.3301.1, *Resource control protocol - Protocol at the Rs interface*, March 2007. [3]

3 Definitions, Acronyms, & Abbreviations

3.1 Acronyms & Abbreviations

AVC	Advanced Video Coding
BSS	Business Support System
CBR	Constant Bit Rate
CDER	Content Delivery Error Recovery
CSCF	Call Session Control Function
DLNA	Digital Living Network Alliance
DNG	Delivery Network Gateway
DNS	Domain Name Service
DRM	Digital Rights Management
DVB	Digital Video Broadcasting
EAS	Emergency Alert System
EPG	Electronic Program Guide
ERC	Error Recovery Client
ES	Elementary Stream
FEC	Forward Error Correction
GOP	Group Of Pictures
HD	High Definition

[2] This document will be available from the Alliance for Telecommunications Industry Solutions, 1200 G Street N.W., Suite 500, Washington, DC 20005. <http://www.atis.org>

[3] These documents are available from the International Telecommunications Union. < http://www.itu.int/ITU-T/ >

[4] This document is available from the Universal Plug and Play Forum.
< http://www.upnp.org/standardizeddcps/default.asp >

HDMI	High Definition Multimedia Interface
HE-AAC	High Efficiency Advanced Audio Coding
iFC	initial Filter Criteria
IGMP	Internet Group Management Protocol
IMS	IP Multimedia Subsystem
IP	Internet Protocol
ISC	IMS Service Control
ISCF	IPTV Service Control Function
ITF	IPTV Terminal Function
LTV	Linear TV
LTVA	Linear TV Application
MC	Multicast Client
MCF	Multicast Control Function
MDF	Multicast Delivery Function
MLD	Multicast Listener Discovery
MPEG	Moving Picture Experts Group
MTF	Multicast Transport Function
NACF	Network Attachment Control Functions
NACK	Negative Acknowledgement
NGN	Next Generation Network
OSS	Operations Support System
P-CSCF	Proxy Call Session Control Function
PE	Policy Enforcement
PES	Packetized Elementary Stream
PiP	Picture in Picture
PSI	Public Service Identifier
QoE	Quality of Experience
RACF	Resource and Admission Control Function
RTP	Real-time Transport Protocol
S-CSCF	Serving Call Session Control Function
SPDIF	Sony/Philips Digital Interconnect Format
SCF	Service Control Function
SD	Standard Definition
SDP	Session Description Protocol
SHE	Super Head End
SIP	Session Initiation Protocol
SPD	Service Provider Domain
SPTS	Single Program Transport Stream
SSM	Source Specific Multicast
TRC	Transport Resource Control
UNI	User-Network Interface
UPSF	User Profile Server Function
URI	Uniform Resource Identifier
URL	Uniform Resource Locator

VBR	Variable Bit Rate
VHO	Video Hub Office
VOD	Video On Demand
VSO	Video Serving Office

3.2 Definitions

The definitions of ATIS-0800027, *IPTV Glossary* [9], are incorporated by reference.

Terms in italics are data type elements defined here, in ATIS-0800013, *Media Formats and Protocols Specification* [4], or in ATIS-0800022, *IPTV Consumer Domain Configuration Metadata* [8].

3.2.1 Content: Electronic or mechanical representation, in analog or digital form, of audiovisual data consisting of individually or in composite form still or moving images, audio, text, or graphics to include related data and metadata.

3.2.2 Electronic Program Guide (EPG): The Electronic Program Guide is a means of presenting or querying information about the available content to the consumer, allowing interactive selection of desired content.

3.2.3 Linear TV Application Session: A Linear TV application session provides association between a service provider and one or more active ITFs of a subscriber on a particular delivery network. A Linear TV application session is established and maintained by the Linear TV application and can be used for purposes of network resources reservation, accounting, etc.

3.2.4 Linear TV SIP Session: A Session Initiation Protocol (SIP) session typically used for IMS-based Linear TV service.

3.2.4 Linear TV Service: A television service in which a continuous stream flows in real time from the service provider to the terminal device and where the user cannot control the temporal order in which contents are delivered.

3.2.5 IP Multicast: A process of transmitting IP packets from one source to many destinations. An example of a multicast application is Linear TV.

3.2.6 Physical Interface: The transport layer between two physical systems.

3.2.7 Program: Content limited to a specific instance or event, typically associated with a linked instance of video and accompanying audio.

3.2.8 Service Information (SI) – The information that is necessary for the ITF to **access and parse** the Content. An SI Record (a.k.a., a Programming Source) reflects distribution of Content by the IPTV system and allows the ITF to acquire the selected content.

3.2.9 Television (TV) System: The IPTV Glossary describes television as a communication system for the broadcast, reception and display of pictures (stationary or moving) and audio.

3.2.10 Television Service: A consumer receives a Television Service when a Television System is operated to deliver program content to that consumer.

3.2.11 IP Unicast: A process of transmitting IP packets from one source to one destination. An example of a unicast application is VoIP.

3.2.12 Virtual Channel Description Table: A Virtual Channel Description Table contains the parameters necessary to acquire and consume the streaming content from a Virtual Channel (a Virtual Channel Service Stream). A Virtual Channel Description Table contains one or more Programming

Sources and their Programming Source Description(s). In addition, where possible, a priori knowledge is given of certain parameters required to receive and decode the Virtual Channel. The metadata definition of a Virtual Channel Description table is provided in ATIS-0800022, *IPTV Consumer Domain Configuration Metadata* [8].

3.2.13 Virtual Channel Map Table: Each ITF has a Virtual Channel Map Table assigned to it as part of the Service Information. This channel mapping *may* be based on geographic location, entitlements, or other mechanisms. Each Virtual Channel Map Table will be assigned a unique identifier. A Virtual Channel Map Table contains multiple Virtual Channel Description Table(s). The metadata definition of a Virtual Channel Map Table is provided in ATIS-0800022 [8].

3.2.14 Virtual Channel Service Stream: A Virtual Channel Service Stream is a stream of content. For the purposes of this specification, a Virtual Channel Service Stream is Linear TV content -- e.g., the stream of video and audio programming distributed under the brand, "TreeTV". Virtual Channel Service Stream will have a specific media format and protocol. Section 11 of this specification describes media formats and protocols further.

3.2.15 Programming Source: A Programming Source is the network information the ITF requires for acquisition of a specific Virtual Channel Service Stream. For a Linear TV service, this information includes multicast address and port number as well as any network resource allocation requirements (e.g., bandwidth). The metadata definition of Programming Source is provided in ATIS-0800022, *IPTV Consumer Domain Configuration Metadata* [8].

3.2.16 Programming Source: Description: The Description provides metadata to aid in the selection of the appropriate version of a Programming Source. As an example, the "TreeTV" virtual channel may be streaming High Definition (HD) and Standard Definition (SD) versions from different Programming Source(s). This metadata may also be used to identify other codec parameters. In some cases, multiple streams (and therefore multiple Programming Sources) may be required for purposes such as error control (FEC/retransmission) or layered video encoding. The metadata definition of Programming Source Description is provided in ATIS-0800022, *IPTV Consumer Domain Configuration Metadata* [8].

4 Reference Architecture

4.1 Introduction

ATIS-0800002, *IPTV Architecture Requirements* [[1]], defines IPTV as a suite of secure, reliable managed services. Linear TV is one service from the suite of IPTV services. From a user perspective, this Linear TV service is intended to provide similar capabilities to existing broadcast, satellite, or cable TV distribution services. The Linear TV service enables the user to access a number of Linear TV content streams.

The same Linear TV content stream is assumed to be available to multiple users on a multicast basis. Delivery of Linear TV content streams via unicast mechanisms is not covered.

A client-server architecture is assumed where the ITF is the Client and the Linear TV content channel is streamed from a server of the Service Provider accessed through the IP network infrastructure.

This specification assumes the existence of an IP infrastructure and the location of the ITF device in a Consumer Domain home network.

This specification describes a basic acquisition mechanism for Linear TV content streams with options for various network resource allocation mechanisms. Optimizations of this basic acquisition mechanism are for further study.

Figure 1 is taken from section 13 of ATIS-0800022, *IPTV Consumer Domain Configuration Metadata* [8]. It shows the relationships among the key metadata elements associated with the Linear TV service. The rectangular boxes with rounded corners represent the primary metadata tables. The rectangular boxes with square corners represent the primary elements in the tables. Links to the files containing the tables are shown in solid black lines. Links to the individual elements within the tables are shown in dotted red lines. Data elements that are used as the keys for lookup are shown in red bold. The formal XML definitions of these metadata elements are specified in ATIS-0800022, *IPTV Consumer Domain Configuration Metadata* [8].

An Electronic Program Guide (EPG), shown on the left side of Figure 1, can be used to select Linear TV content streams for presentation. ATIS-0800020, *IPTV EPG Metadata Specification* [[7]], specifies the data model and delivery mechanisms for data to populate such an EPG. The user interactions related to presentation and selection of a Linear TV content stream for presentation are beyond the scope of this specification.

For the purposes of this specification, it is sufficient to note that when a user selects a Linear TV content stream for presentation, an EPG data element "ServiceDescription" is bound to an index *VirtualChannelServiceId*.

This *VirtualChannelServiceId* index is used to look up the entry for the selected Linear TV content stream within the set of *Virtual ChannelMapTables* (which can be found via links from the *MasterSITable*). The links shown in Figure 1 can then be followed to find the corresponding entry within a *VirtualChannelDescriptorTable* and the corresponding entry within a *SourceTable*, which provides the network related parameters (e.g., multicast address, port, bandwidth, etc.) required to acquire the desired LinearTV content with the appropriate rate and format.

With the network related parameters, the ITF has the information required to acquire a specific *VirtualChannelServiceStream* (e.g., TreeTV in HD). The initial acquisition, change, and termination of a specific *VirtualChannelServiceStream* are the subject of this specification.

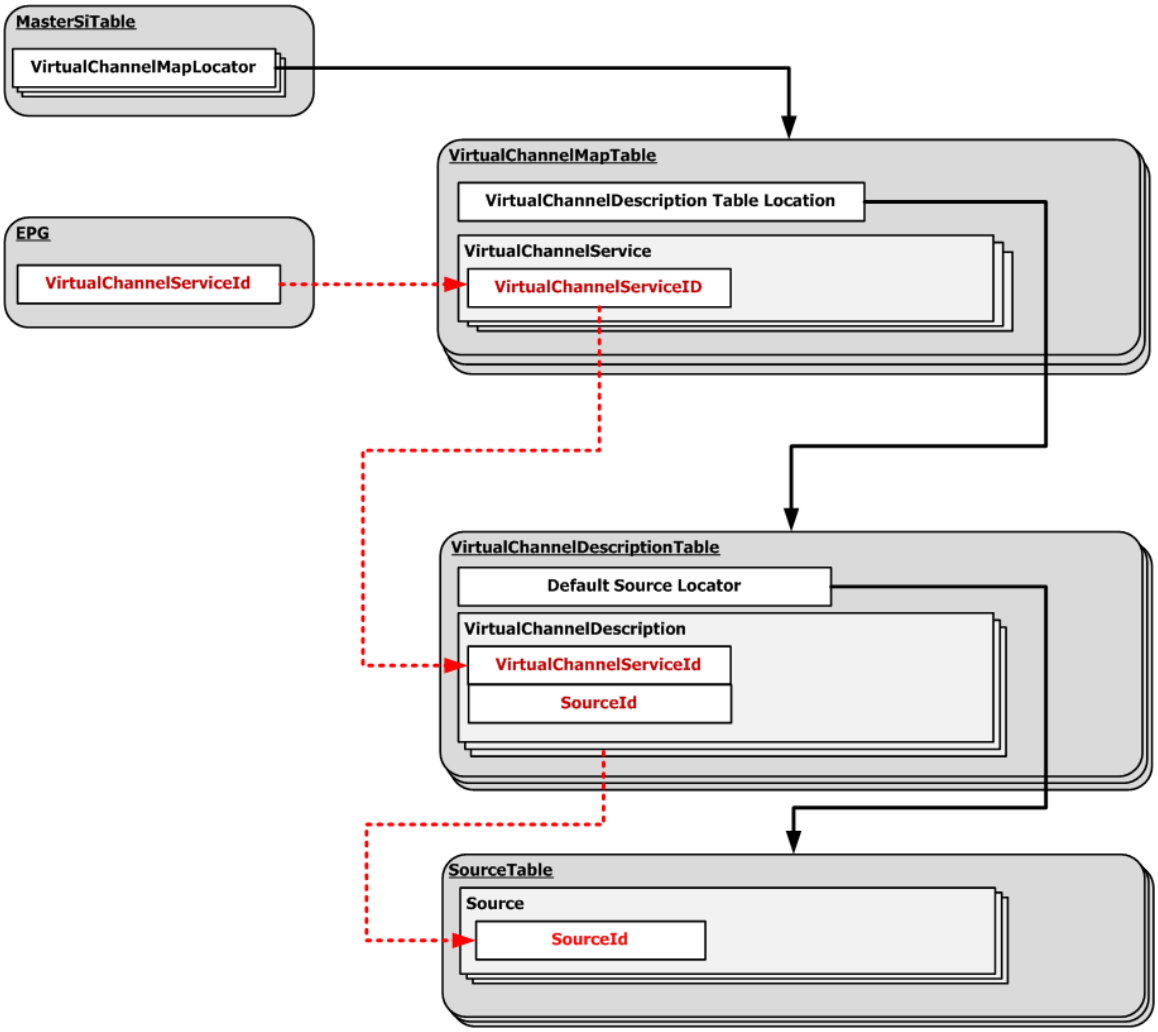

Figure 1: Key Metadata Relationships for the Linear TV Service (Informative)

4.2 Architecture

Figure 7 from ATIS-0800007, *IPTV High Level Architecture* [2], is reproduced here slightly reformatted as Figure 2 and shows a typical IPTV system, which includes the delivery of various IPTV services including a Linear TV service. The architecture supports both non-IMS and IMS-based services in an NGN environment.

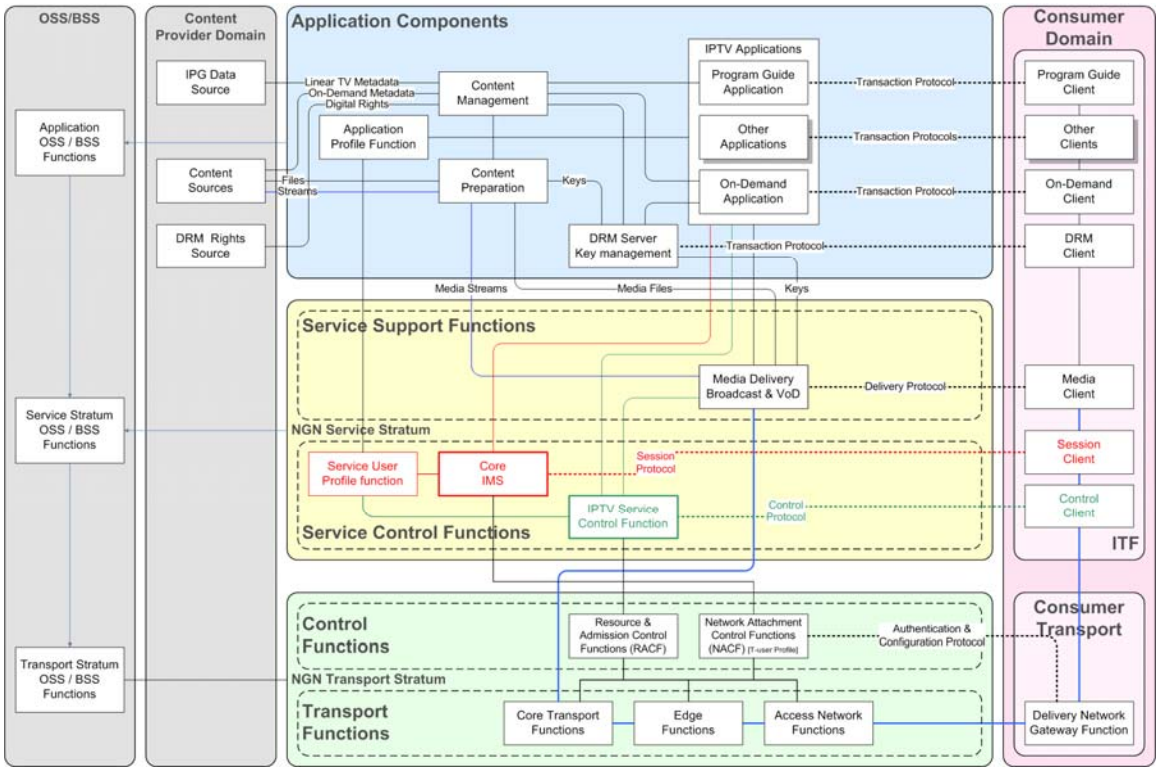

Figure 2: High Level Architecture

Figure 2 highlights the functional entities and interfaces directly involved with the delivery of the Linear TV service to the ITF. These functions and interfaces are described in more detail in the following sections of this specification.

A device implementing the ITF functions for the Linear TV service may also implement a number of additional applications for other purposes beyond the scope of the basic Linear TV operational capabilities. One such application of general interest is a Time of Day distribution application that is expected to be of value to the user in conjunction with EPG information for the user to select a virtual channel to access. This information flows between the "Other Applications" and "Other Clients" boxes of Figure 2.

The ITF *shall* implement a Network Time Protocol (NTP) client in accordance with ATIS-0800013, *Media Protocols Specification* [4].

Note that other services and applications beyond the scope of this specification -- e.g., key distribution mechanisms -- may place more stringent requirements on the security or accuracy of the time distribution mechanism beyond the use case indicated above.

Figure 3 and Figure 4 show functional architectures for NGN-based Linear TV service. Figure 3 and Figure 4 are the same except for the service control function used and the interfaces involved. Figure 3 uses a dedicated IPTV service control function. Figure 4 uses an IMS service control function.

In order to reduce the degree of complexity, Figure 3 and Figure 4 eliminate the following from Figure 1:

- Functions that are part of an IPTV network but out of scope for this document:
  - OSS/BSS functions.
  - Content provider domain functions.

- Functions that are involved with Linear TV service but out of scope for this document:
  - EPG-related functions.
  - DRM-related functions.
- Functions related to IPTV services other than Linear TV:
  - Content on Demand service related functions.
  - Other application functions.

Figure 3 and Figure 4 provide detail beyond that shown in Figure 2 on functions that are particularly important to Linear TV service. These include:

- Multicast transport functions including multicast replication and its control.
- Transport resource control, particularly related to multicast traffic.
- Distributed policy enforcement.
- Packet loss recovery functionality for improving the Quality of Experience (QoE).

Functions that are involved in Linear TV service and described in this specification are shown in boxes with thick borders and bold text. Similarly, interfaces that are involved in Linear TV service and described in this specification are shown with thick lines and bold text. Other Linear TV functions and interfaces that provide a context or clarity but are not specified in this document are shown with thin grey borders, lines, and text.

The solid blue line from Content Preparation, through the Multicast Delivery Functions, through the core, edge, access and customer Multicast Transport Functions, and on to the Multicast Client in the ITF represents the physical path of the Linear TV content. Linear TV requires a managed IP network that is not further specified in this document. The thick dashed lines are virtual interfaces. Information exchanged between end-points of the virtual interfaces are delivered over the IP transport network along with the Linear TV content and other IPTV and non-IPTV services not considered in the specification. Reference point identifiers are used to identify various virtual interfaces.

Figure 3 identifies the functions and interfaces involved in Linear TV service using non-IMS IPTV service control. Figure 4 identifies the functions and interfaces involved in Linear TV service with IMS-based service control. These functions and interfaces provide the framework for the flow diagrams in sections 7, 8, 9, and 10. Section 11 specifies the media formats for the Linear TV content (Virtual Channel Service Stream) crossing the Md interface. Section 12 specifies the protocols used on the remaining in-scope interfaces.

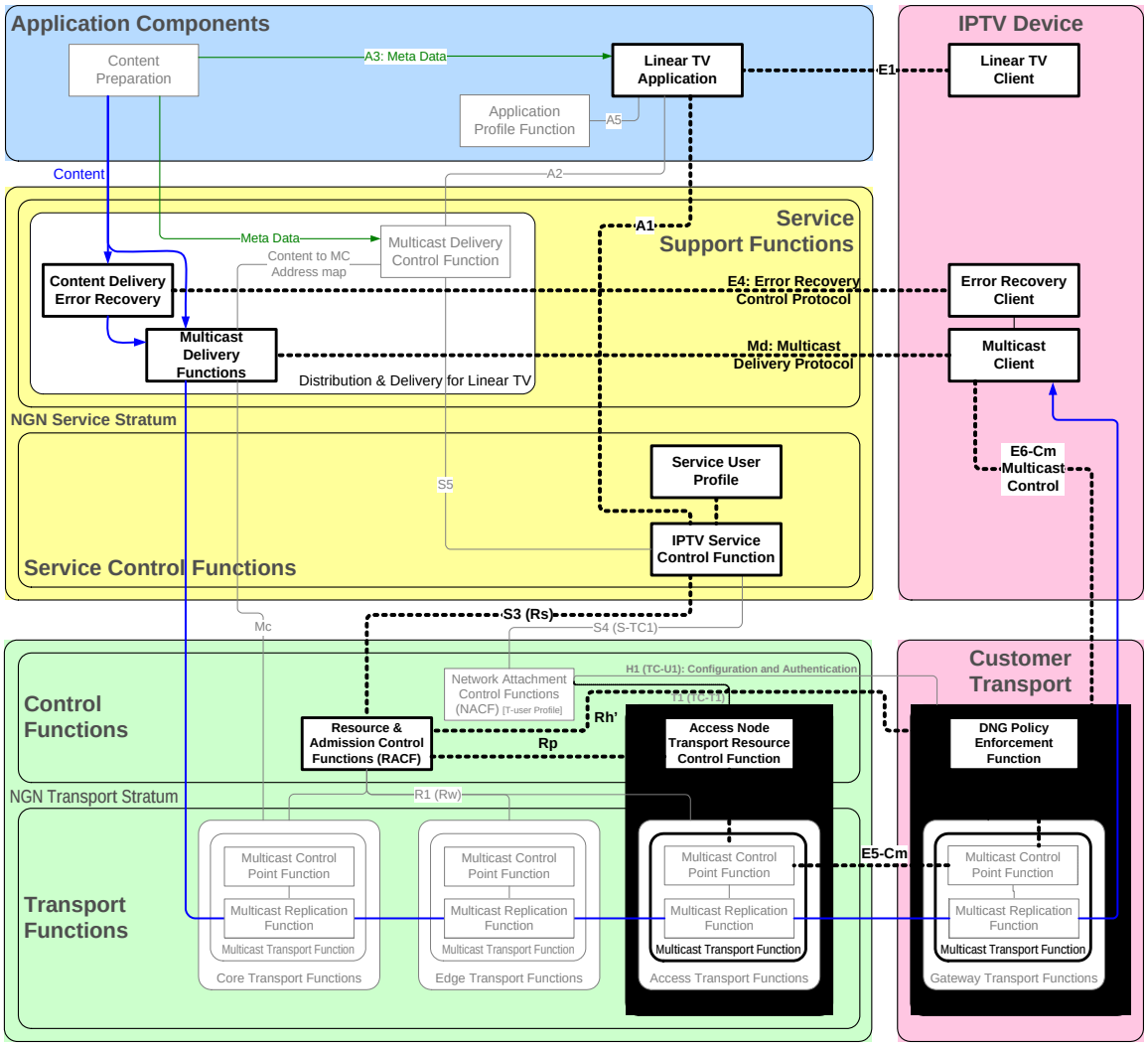

Figure 3: Functional Architecture for non-IMS Linear TV

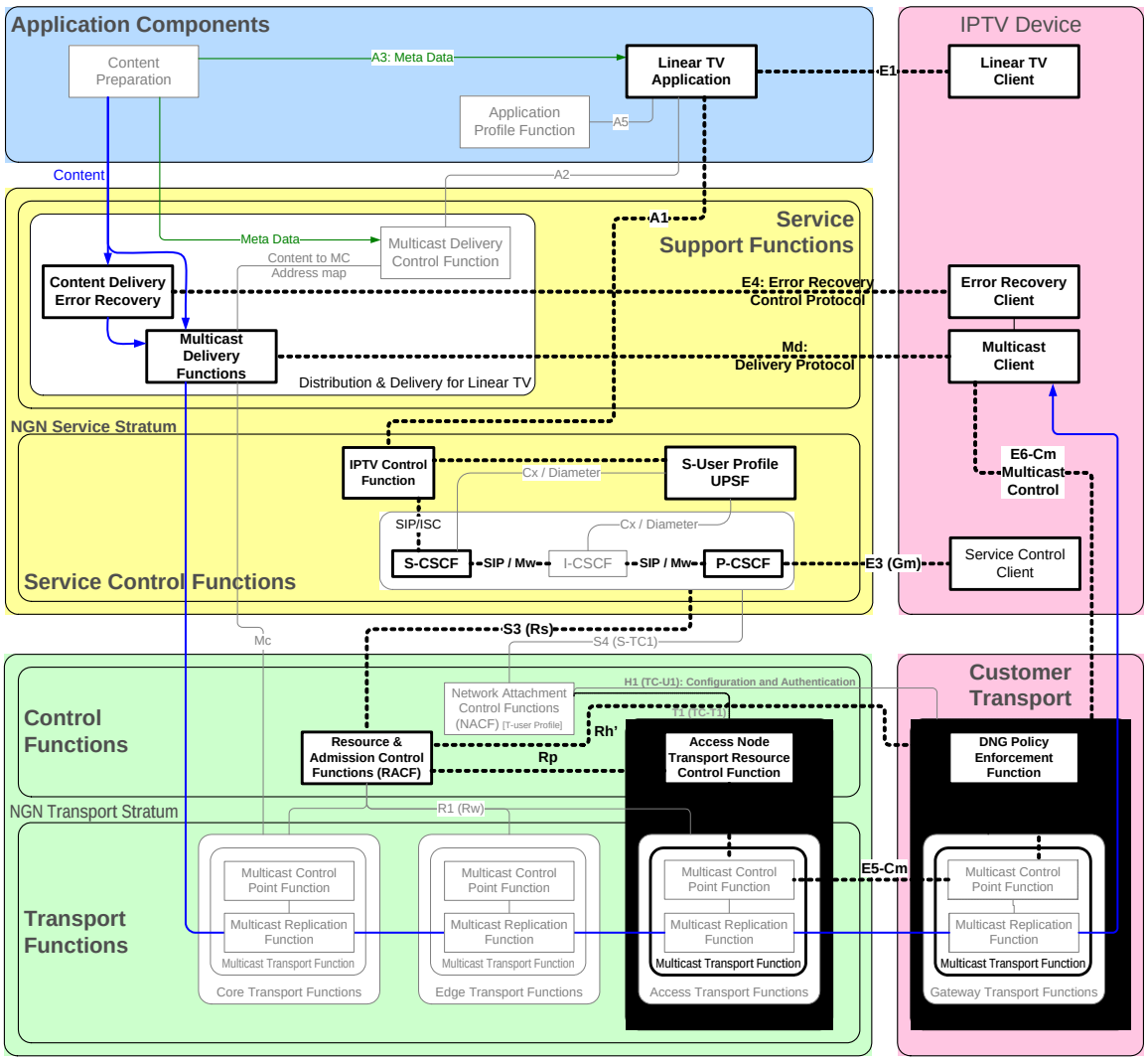

Figure 4: Functional Architecture for IMS Linear TV

4.3 Functional Descriptions

4.3.1 Content Delivery Error Recovery Function

The Content Delivery Error Recovery (CDER) function supports the reliable delivery of media stream packets. When reliable delivery is accomplished by application-layer Forward Error Correction (FEC), the CDER is responsible for the generation of the repair packets blocks of original packets in the Multicast Delivery Function (MDF). The repair packets *may* be sent with the original packets in the same multicast group or the repair packets *may* be sent in one or more additional multicast groups to facilitate conditional or multiple degrees of error protection. When reliable delivery is accomplished by packet retransmission, the CDER is the retransmission source. The CDER maintains a buffer of recent Real-time Transport Protocol (RTP) packets that have been sent by the MDF and transmits selected packets from this buffer based on feedback from the Error Recovery Client (ERC).

4.3.2 Error Recovery Client Function

The ERC in the ITF supports the reliable delivery of media stream packets. When reliable delivery is accomplished by application-layer FEC, the ERC uses received repair packets to attempt to recover any missing or erroneous original packets arriving at the Multicast Client (MC). The MC must provide sufficient buffering to store all source packets in the block protected by the repair packets. When reliable delivery is accomplished by packet retransmission the ERC detects missing packets and requests the CDER to retransmit those packets.

4.3.3 Multicast Transport Function

Multicast Transport Functions (MTFs) are functions within transport nodes (core, edge, and access nodes and delivery network gateways) that replicate and control the replication of Linear TV and other multicast streams. The MTF is composed of a Multicast Replication Function (MRF) and a Multicast Control Point Function (MCPF).

4.3.3.1 Multicast Replication Function

The Multicast Replication Function replicates packets of a multicast group based on the membership tracked by the Multicast Control Point Function (MCPF). For more information see ATIS-0800019, *Multicast Network Service Specification* [6].

4.3.3.2 Multicast Control Point Function

The Multicast Control Point Function processes the requests (e.g., IGMP, MLD) for joining or leaving a multicast group and tracking the group membership.

The MCPF may interact with the Resource and Admission Control Function (RACF) for the following purposes:

- Request the RACF to perform resource and admission control based on the initial processing of multicast requests -- e.g., when the transport node is not already part of the requested multicast group.
- Request the RACF to release related resources when all end users leave an existing multicast group.

For more information, see ITU-T Y.2111 [12].

4.3.4 Transport Resource Control Function

The RACF consists of two types of entities: the Policy Decision Functional Entity (PD-FE) and the Transport Resource Control (TRC) functional entity. This decomposition enables the RACF to support a variety of network configurations within a general resource control framework.

The TRC is responsible for transport technology dependent resource control including:

- Resource status monitoring and network information collection.
- Resource-based admission control.
- Transport dependent policy control.
- QoS mapping.

Multiple TRC instances can be interconnected in the same transport network, and one or more of those instances may be co-located with transport functions. For Linear TV it is advantageous to co-locate a TRC with the MTF in transport nodes to improve the performance of the Linear TV service. The TRC instance that is directly connected to the PD-FE is called the top-tier TRC. The TRC instance that is connected to the top-tier TRC and co-located with transport functions is called a co-located TRC. The following operation modes are supported by the TRC and the Rp reference point:

- **Outsourcing mode**

  The co-located TRC makes the resource admission decision for both unicast and multicast services. The top-tier TRC queries the co-located TRC for resource admission in the relevant network segment (i.e., access network). The outsourcing mode can be performed at either media flow level or aggregate level. The outsourcing mode is used for fully-shared resources between unicast and multicast (see section 8.3).

- **Designating mode**

  The co-located TRC performs resource admission control for unicast and/or multicast services respectively within the pre-provisioned threshold of aggregate resources; the top-tier TRC is entitled to adjust the threshold of aggregate resources based on the resource utilization or upon the request of co-located TRC. The designating mode can only be performed at the aggregate level. The designating mode is used for adjustable resources between unicast and multicast (see section 8.2).

For more information see ITU-T Y.2111 [12].

4.3.5 Delivery Network Gateway Policy Enforcement Function

The DNG Policy Enforcement Function enforces the network policy rules instructed by the RACF. It performs the following functions based on flow information such as classifier (e.g., IPv4 5-tuple) and flow direction, as well as transport interface identification information (e.g., VLAN) as needed:

- Enabling or disabling packet filtering for a media flow.
- Rate limiting and bandwidth allocation.
- Traffic classification and marking.
- Traffic policing and shaping.
- Mapping of IP-layer QoS information onto link layer QoS information based on pre-defined static policy rules (e.g., setting 802.1p priority values).
- Collecting and reporting resource usage information (e.g., start-time, end-time, and octets of sent data).

Use of the DNG Policy Enforcement Function is for further study.

For more information see ITU-T Y.2111 [12].

4.4 Geographically Distributed Functional Architecture

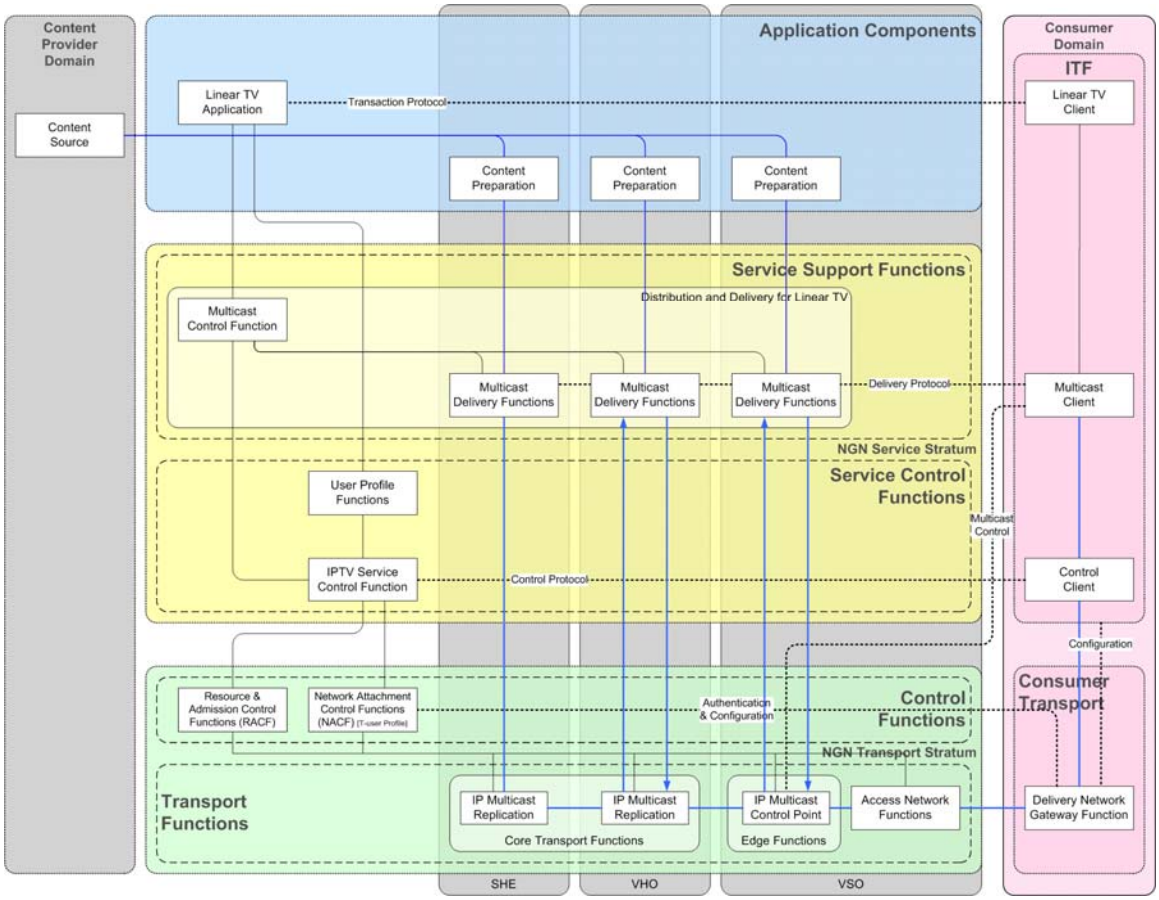

Figure 5: Geographically Distributed Functional Architecture for Linear TV

The functional elements of the network architecture can be mapped to the physical network as shown in Figure 5, which is a reformatted version of Figure 10 from ATIS-0800007, *IPTV High Level Architecture* [2].

This figure includes a network hierarchy as media and control flows from the content provider to the consumer. This hierarchy is intended to be typical, with larger networks having more levels and smaller networks having fewer. The content provider interfaces are included for context and are not specified here.

- *Super Head End (SHE) network node(s) with the broadest content scope*. The SHE sources content to an entire IPTV network. Intended uses include primary storage for off-line content and transmission of region-independent off-air content -- e.g., premium and specialty programming. For the Linear TV service, the content is comprised of Virtual Channel Service Streams.
- *Video Hub Office (VHO) network node(s) with a local/regional content scope*. The VHO sources region-dependent off-air content (e.g., local programming) and houses local off-line storage of content.
- *Video Serving Office (VSO) network node(s) connect consumers (via access systems) to the IPTV network*. The VSO (typically a Central Office) hosts or connects all access systems for

interconnection to consumers. In addition, the VSO contains aggregation equipment to enable efficient interconnection of access systems to the IPTV network. The option to locate content interconnection and/or content processing equipment is shown, though perhaps not typical.

5 OVERVIEW

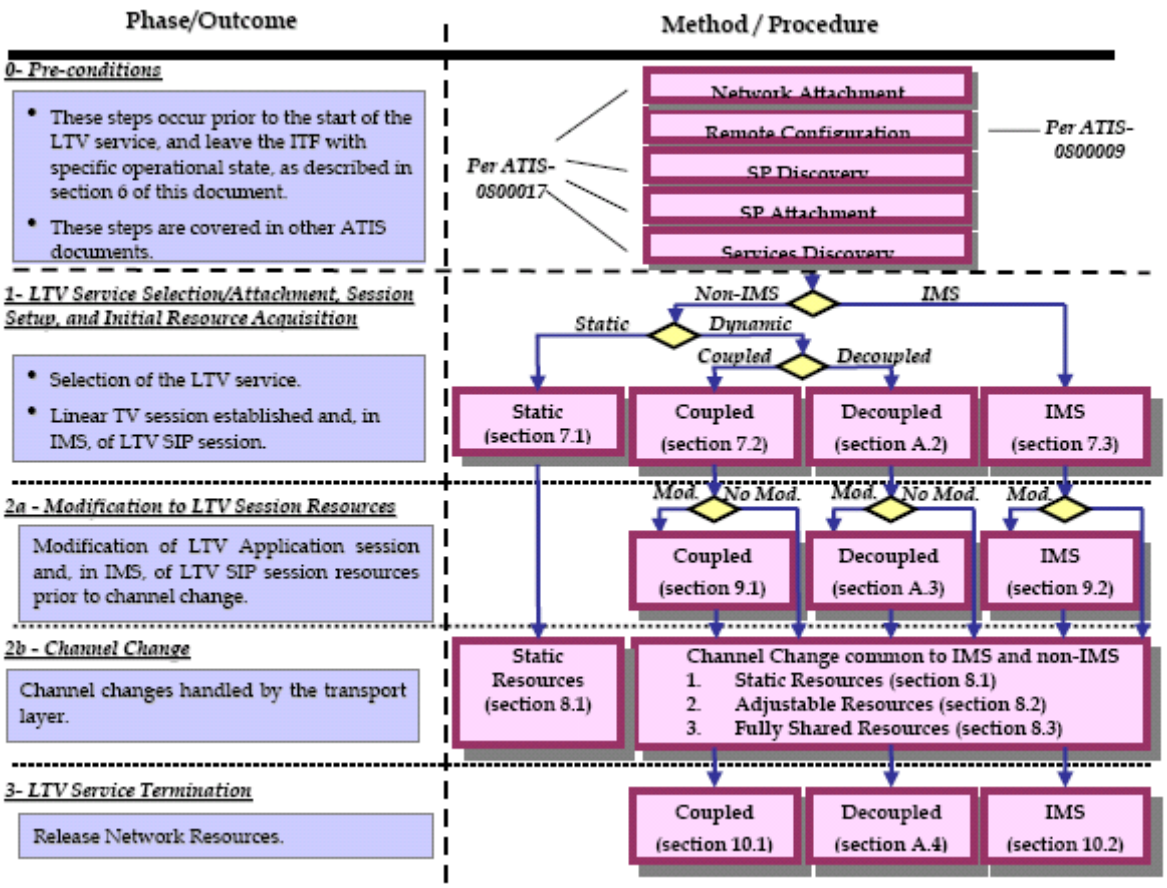

Figure 6: Overview of Basic Linear TV Processes

5.1 Overview of Content Distribution and Control Paths through the Network

The description of the protocols used in Linear TV is classified into two categories: *content (Virtual Channel Service Stream) flow* and *control paths*. All the major reference points in Figure 3 and Figure 4 are described and specified.

The following sections describe the flows taken through the network for the program content, its metadata attributions, and the control protocols used for controlling and monitoring those paths. The path descriptions and specifications are organized principally by reference points as being the major logical interconnections of interest.

The following sections also cover the control flows between the various domains for Linear TV. These flows control the distribution of the Linear TV content including the selection of channel, mapping of logical channels to physical channels, resource allocation and monitoring, error recovery, and the connection with the end user.

Prior to Linear TV Service attachment, an IPTV network may be engineered and deployed with a certain amount of network resources available for Linear TV service and other services sharing the transport layer. The aggregate amount of network resources available for Linear TV (multicast) service and other (unicast) services may be static and determined by anticipated traffic patterns. The resource budget may be configured into transport nodes via network management mechanisms or pushed into transport nodes from the RACF. Alternatively, network resources may be dynamically allocated when the Linear TV Application session or Linear TV SIP session is established.

The control of Linear TV service includes three distinct phases as shown in Figure 6. They are:

- **Linear TV Service Attachment and Initial Resource Acquisition:** In this phase (Phase 1 of Figure 6) a Linear TV Application session or Linear TV SIP session is established, network resources may be allocated, and an initial Virtual Channel Service Stream is acquired. This phase may be triggered by the ITF being powered on or by the action of a user. Linear TV service attachment and initial resource allocation is performed differently for IMS and non-IMS networks. For non-IMS networks, the resources may have been statically allocated prior to service attachment or dynamically allocated when the Linear TV Application session is established. The Linear IPTV Application may use an admission control mechanism to prevent oversubscription. There are two dynamic resource allocation mechanisms: *coupled* and *decoupled*. In the coupled case, network resources are allocated at the request of the application during the establishment of the Linear TV Application session -- e.g., when the ITF is powered on. In the decoupled case, network resources are allocated in response to a request for resources directly from the ITF when the resources are needed. For IMS networks, the Linear TV SIP session establishment is decoupled from the Linear TV application and network resources are dynamically acquired when the Linear TV SIP session is established.

- **Channel Change:** This phase occurs when the user switches between two Linear TV programming sources, thus leaving one Virtual Channel Service Stream for another. Since Linear TV is a multicast service, channel changes may cause an increase, a decrease, or no change in the consumption of network resources on the edge, access, or consumer networks, depending on the particular channels being delivered to the various consumers of the Linear TV service.

  In order to reduce the channel change latency, most channel changes should not require a modification of the Linear TV Application session or Linear TV SIP session. Network resources for channel changes not requiring or following Linear TV session modification are managed by functions exclusively in the transport layer (RACF and transport-node TRC). Network resource usage for these channel changes may be *static* or *dynamic* (Phase 2b of Figure 6). For the static case, an IPTV network can be engineered such that there are sufficient resources for the Linear TV service without network resource management during channel changes. For the dynamic case, there may be times when actual unicast and multicast traffic levels do not match what was anticipated and more efficient use of network resources can be achieved by fully sharing network resources or by adjusting the amount of aggregate network resources allocated to unicast -- e.g., VoIP and VoD -- and multicast (Linear TV) services. This can be accomplished within the transport layer without involvement of service control or application functions.

  When changing from one Virtual Channel Stream to another having different bandwidth requirements -- e.g., from SD to HD -- modification of the Linear TV Application session or Linear TV SIP session may be required before the channel can be changed (Phase 2a of Figure 6). These channel changes allow more efficient use of network resources but increase

the channel change latency. Following the modification of network resources for the Linear TV session, the channel change process continues as described in Phase 2b.

- **Linear TV Service Termination:** This phase (Phase 3 of Figure 6) occurs when the last ITF in a Linear TV application session or, in the IMS case, a Linear TV SIP session, is powered off while the Linear TV application session was still active. It can also occur when a user switches from the Linear TV service to another service. The procedure for Linear TV service termination is different for IMS and non-IMS networks. For non-IMS networks, the Linear TV service termination can be coupled or decoupled from the Linear TV application.

Figure 6 shows the phases of Linear TV service attachment and resource allocation, initial channel acquisition and channel changes, and Linear TV service termination. The figure identifies sections of this document that describe each option of each phase.

5.2 Message Sequence Charts

For the message sequences in this document, the following conventions apply:

Note – The charts show the case where a single ITF is deployed on a home network to simplify the message sequences.

Dashed lines indicate messaging that is conditional or optional in the message sequence.

The header staves represent the following entities:

- **Linear TV Application:** This is the Linear TV Application as appears in Figure 3 and Figure 4.
- **Multicast Delivery Function (MDF):** This is the Multicast Delivery Functions as appears in Figure 3 and Figure 4.
- **IPTV Service Control:** This is the IPTV Service Control Function as appears in Figure 3 and the IPTV Control Function as appears in Figure 4.
- **S-User Profile:** This is the Service User Profile as appears in Figure 3 and the S-User Profile User Profile Server Function (UPSF) as appears in Figure 4.
- **Serving Call Session Control Function (S-CSCF):** This is the S-CSCF as appears in Figure 4. The S-CSCF does not appear in non-IMS flows or those that apply to both IMS and non-IMS systems.
- **Proxy Call Session Control Function (P-CSCF):** This is the P-CSCF as appears in Figure 4. The P-CSCF does not appear in non-IMS flows or those that apply to both IMS and non-IMS systems.
- **Resource & Admission Control Functions (RACF):** This is the RACF as appears in Figure 3 and Figure 4.
- **Access Network**
  - **Transport Resource Control (TRC):** This is the Access Node Transport Resource Control Function as appears in Figure 3 and Figure 4.
  - **Multicast Transport Function (MTF):** This is the Multicast Transport Function as appears in Figure 3 and Figure 4.
- **Delivery Network Gateway (DNG)**
  - **Policy Enforcement (PE):** This is the DNG Policy Enforcement Function as appears in Figure 3 and Figure 4.

- **Multicast Transport Function (MTF):** This is the Multicast Transport Function in the DNG as appears in Figure 3 and Figure 4.
- **ITF Multicast Client:** This is the Linear TV Client in the IPTV Device as appears in Figure 3 and Figure 4.

Signal flows in the message sequence charts include numbers that correspond to descriptive text following each figure. Where applicable, the descriptive text identifies in parenthesis the reference point involved. More detail on the reference points can be found in sections 11 and 12.

6 Network and Service Attachment Pre-conditions

This Linear TV Service assumes that the initialization and attachment, as defined in ATIS-0800017, *Network Attachment and Initialization of Devices and Client Discovery of IPTV Services* [5], has been completed. As described in section 8.1.2, the following data sets have been delivered and are known to the ITF:

- Attachment addressing information (required), in one of the following forms:
  - SP P-CSCF URL through which to connect to the IMS registrar (IMS case);
  - Multicast IP Address or a combination of source and multicast IP addresses; or
  - Application Server URL/IP address.
- SP ID (Note: not required for IMS; whether this is required for non-IMS is for further study).
- SP name (optional, multi-lingual).
- SP description (optional, multi-lingual).
- SP logo (optional).
- Version number of SP information (optional).

After the attachment to the SP, the information needed for subsequent Linear TV service discovery and attachment is provided by the SP to the ITF. This information includes:

- Channel Map Identifier (required).
- Location information (using multicast and/or unicast means) of the:
  - SI data (required) (see ATIS-0800022, *IPTV Consumer Domain Device Configuration Metadata* [8]).
  - Electronic Program Guide data (optional) (see ATIS-0800020, *IPTV EPG Metadata Specification* [7]).
  - Emergency Alert Service (EAS) data (if regionally required).

7 Linear TV Service Attachment and Initial Resource Acquisition

In conformance with ATIS-0800017, *Network Attachment and Initialization of Devices and Client Discovery of IPTV Services* [[5]], section 8, a "Linear TV Service" function *may* be implemented on either the SD Server or it *may* reside on a separate dedicated server. In the latter case, the Linear TV communications are either being routed to and from the Linear TV Application Server transparently to IPTV clients or the Service Provider *shall* provide the clients with the location of the Linear TV Application Server in accordance with definitions in ATIS-0800022, *IPTV Consumer Domain Device Configuration Metadata* [[8]].

This specification assumes all of the ITFs in a home network support the same resource allocation mechanism -- e.g., all ITF devices are compliant with one of sections 7.1.1, 7.1.2, 7.2, or 7.3. Interactions between different resource allocation mechanisms are for further study.

The Linear TV Service utilizes access network resources (that may be reserved) at the interface between the network provider and the home network. Network resources in the home network are beyond the scope of this specification. The details of network resources in the network provider's infrastructure beyond the access network to the home network interface are beyond the scope of this specification.

The Linear TV service may allocate resources for one or more ITFs in the home network.

In the non-IMS case, a Linear TV Application session provides association between the service provider and the active ITFs of an IPTV subscriber for the purpose of network resources reservation.

In the IMS network, network resources reservation is performed in the context of a SIP session. Therefore in IMS, typically a Linear TV Application session contains a single Linear TV SIP session.

During Linear TV Service, the ITF is able to access the program content of one or more specific authorized Virtual Channel Service Streams:

- In non-IMS Linear TV, resources are allocated either statically (section 7.1) or dynamically (section 7.2) when a Linear TV Application service is established.
- In IMS Linear TV, resources are dynamically allocated per single Virtual Channel Service Stream at Linear TV SIP session establishment (section 7.3).

The flow diagrams in sections 7.1, 7.2, and 7.3 show the flows and transactions involved with initial resource acquisition for Linear TV service. The diagrams continue with representative flows for the selection of the initial Virtual Channel Service Stream. Other sequences for joining a Virtual Channel Service Stream are possible such as those described in section 8.

The program content is available as Virtual Channel Service Stream(s) via one or more multicast addresses. For example, the program media may be available from one multicast address and associated FEC information may be available via another multicast address. The streaming of program content as layered video across multiple multicast addresses is beyond the scope of this specification.

The SI provides a virtual channel map table that provides the binding between a virtual channel that identifies the program content and the multicast address information required to access that program content.

Virtual channel metadata provides information including the bandwidth required for access to a specific multicast stream, and, if it exists, the multicast address for any associated FEC stream.

The Linear TV service is not bound to a specific Virtual Channel Service Stream and may change Virtual Channel Service Streams during the life of the Linear TV service.

Recording operations, Trick Mode controls, and Picture-in-Picture features are beyond the scope of this specification.

Content protection for the Virtual Channel Service Streams, such as data encryption techniques, is beyond the scope of this specification. The specific authorization mechanism for access to virtual channels is also beyond the scope of this specification.

7.1 Static Aggregate Allocation of Network Resources for Non-IMS Linear TV

An IPTV network *may* be engineered with sufficient resources statically allocated (to include failure conditions), such that oversubscription will not or is unlikely to occur no matter the mixture of traffic (Unicast/Multicast) or expected/subscribed IPTV service penetration.

In this case, resource admission control *shall* be performed for each ITF as it is powered on to authorize the equipment and check the user profile, but network resources are not dynamically allocated (changed) as part of this process by RACF, TRC, or both.

The network *may* police these resource limits at the network interface and discard any traffic in excess of these resource limits.

Therefore a resource reservation function *shall* be implemented in the application domain to ensure that at any time the total IPTV bandwidth traffic consumed by the household/account on the access link does not exceed the pre-allocated resources.

A Linear TV Application session, which provides association between the service provider and the active ITFs of an IPTV subscriber, is being used for this purpose as described in the two sections below.

Note that the two modes of operation described below can be enhanced by using network dynamic resources allocation as specified in section 9.1 of this document. This combined architecture allows for more efficient system operation and an optimized user experience beyond Linear TV service -- e.g., when IPTV service usage switches from:

- ITF to ITF;
- service to service;
- unicast to multicast.

The network resource modification requests are issued only if the total IPTV bandwidth consumption in the home network or in the access network needs to be updated (subject to the overall QoS Home Network policies).

7.1.1 Application Layer with Static Resources

In this case, each Linear TV client is pre-configured (or is informed at the Linear TV application session establishment stage) about the maximal bandwidth it is allowed to use at any point of time on the access link. Note that this bandwidth is allocated to each ITF device individually. The ITF device *shall* be configurable for remote management access to records of bandwidth consumption.

7.1.2 Application Layer Resource Management

In this case, each Linear TV client is pre-configured (or is informed at the Linear TV application session establishment stage) about the maximal bandwidth its IPTV household account is allowed to use at any point of time on the access link.

Note that in this case, each Linear TV application client *shall* communicate with other IPTV application clients on the Home Network to ensure that at any time the total of bandwidth (both multicast and unicast) traffic consumed by the household/account on the access link does not exceed the pre-allocated resources.

The protocol for bandwidth reservation and management for clients in the Home Network is beyond the scope of this document. For example, the system and the protocols defined in UPnP-QoS

Architecture:3 [13] support the described functionality. The Digital Living Network Alliance (DLNA) is working to define a profile of this UPnP specification.[5]

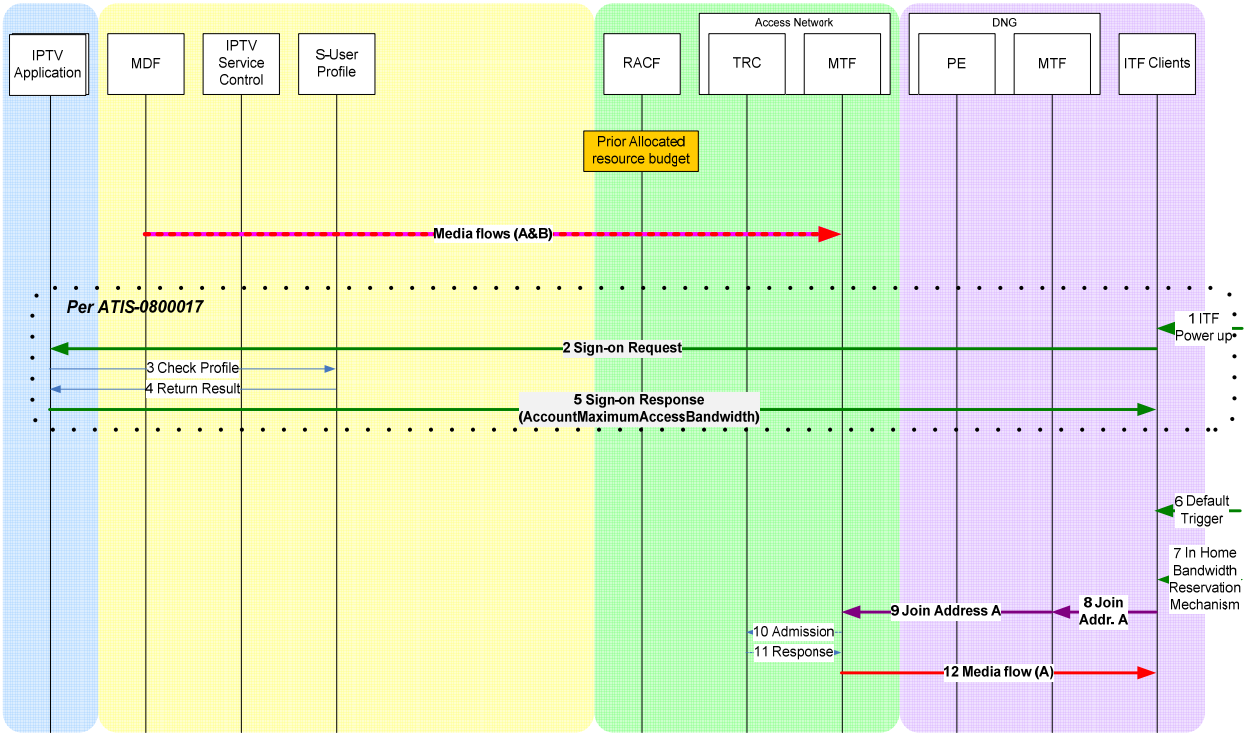

Figure 7: Non-IMS Service Attachment and Initial Channel Acquisition – Static Network Layer with Application Layer Resource Management

1. ITF is powered up and performs "Network Attachment" and "Service Provider Discovery" procedures per ATIS-0800017, *Network Attachment and Initialization of Devices and Client Discovery of IPTV Services* [5], sections 6 and 7 respectively.
2. ITF starts the "Attachment to a Service Provider" procedure per ATIS-0800017, *Network Attachment and Initialization of Devices and Client Discovery of IPTV Services* [5], section 8.3 or 8.4.
3. The IPTV Application validates the ITF's account against the S-User Profile.
4. The S-User Profile returns the profile data which (among other parameters) contains the maximal bandwidth allocated for the account/household on the access link.
5. The ITF completes the "Attachment to a Service Provider" procedure by receiving a successful response from the IPTV Application indicating the maximal bandwidth allocated for the account/household to be used on the access link.
6. The ITF application layer locally invokes the "IPTV Linear TV session" client with the "initial Virtual Channel" parameter. The initial Virtual Channel Service Stream *may* be a home Virtual Channel Service Stream, the last Virtual Channel Service Stream watched or some other "default" Virtual Channel Service Stream.

[5] Work in the DLNA is proceeding on a "Commercial Video Player (CVP) Profile" at the time of the publication of this specification.

7. Using internal to the home network reservation mechanism, the ITF checks whether joining the indicated initial channel wouldn't exceed the access link capacity. If the upper bandwidth limit is exceeded, the ITF *shall* locally display to the user, and remote management, an error message "No Resources Available".
8. Otherwise, the ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the initial Virtual Channel Service Stream. In this figure, the first MTF is in the DNG and the initial Virtual Channel Service Stream is "channel A" (E6-Cm).
9. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
10. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast stream with the TRC. Admission policies *may* include authorization checks such as black lists or white lists constraining which subscribers may be connected to which multicast groups. Admission policies *may* include resource availability checks.
11. If authorized, and resources are available, the TRC signals its approval of the admission request back to the MTF. If not authorized, the Access Network *shall* record an error code indicating to network management that the multicast join request "Failed Authorization". If the resources are not available, the Access Network *shall* record an error code indicating to network management that the multicast join request failed due to "No Resources Available".
12. The MTF configures the multicast forwarding table(s) to deliver the selected channel through the multicast replication function(s) to the ITF. The multicast flow for channel A is delivered to the ITF (Md).

7.2 Dynamic Aggregate Allocation of Network Resources for Non-IMS Linear TV

An IPTV network *may* dynamically allocate resources in order to avoid over-provisioning of network resources, and thus make better use of available network resources. The dynamic allocation of resources *shall* ensure that an over-subscription will not occur no matter the mixture of traffic (unicast/multicast) or expected/subscribed IPTV service (to include failure conditions). However, allocation of network resources for Linear TV *may* be pushed by RACF or provisioned into the transport node TRC to request additional resources. Resources *may* be allocated when the Linear TV service is initiated (coupled case) or when a media control session is established (decoupled case).

1) *Coupled*: The network resources are allocated on request of the application during the establishment of the Linear TV Application session. They are released by a request from the application at the termination of the Linear TV Application session. This approach described in section 7.2.1 is called "coupled" as the application layer is coupled to the control and delivery functions.
2) *Decoupled*: The network resources are allocated in response to a request for resources from the ITF Service Control Client to the IPTV Service Control Function (SCF). They are released when the ITF Service Control Client requests the IPTV SCF to do so. This approach is called "decoupled" as the application layer is decoupled from the control and delivery functions. In this case, the network resources allocation of the Linear TV Application Session is kept synchronized through bi-directional communications between the Service Control Client and the ITF Service Control Client. While decoupled operation is possible for basic Linear TV service, it is more appropriate for Linear TV Service with trick modes (play, pause, fast forward, and rewind) where the ITF already interacts directly with the IPTV SCF to control the media

flows. Since the Linear TV Service with trick modes is out of scope for this document, decoupled non-IMS service control is covered in informative Appendix A.2.

7.2.1 Coupled

Figure 8 shows the flow for Linear TV service attachment and initial resource acquisition in the case of a non-IMS coupled implementation. As a precondition of this flow, the multicast streams for Linear TV channels A and B are being delivered to the Access Node.

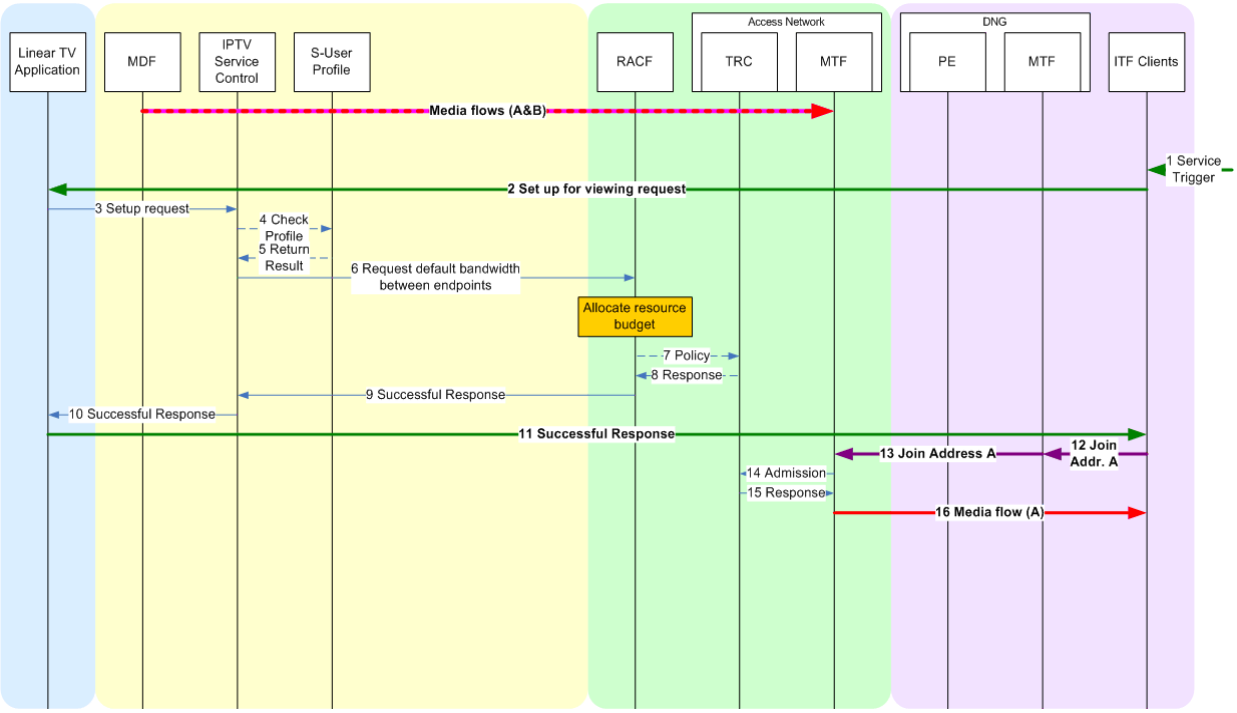

Figure 8: Non-IMS Service Attachment and Initial Channel Acquisition – Coupled

1. The Linear TV service is triggered through user interaction, preset recording instructions, or other means.
2. The ITF requests the Linear TV Application to establish a Linear TV Application session (E1).
3. The Linear TV Application signals the IPTV Service Control Function to request the network resources for the reception of the Linear TV service and the list of multicast addresses for the channels (A1).
4. The IPTV Service Control Function *may* optionally validate the ITF's connection against the S-User Profile.
5. The S-User Profile returns the profile data which the IPTV Service Control Function uses to validate the service connection.
6. The IPTV Service Control Function requests the RACF to allocate the access network resources needed to support the path from the MDF to the ITF. The RACF allocates the bandwidth needed by the multicast delivery function in the access network (S3).

7. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
8. The TRC signals its acceptance of the policy update (Rp).
9. The RACF signals that the bandwidth allocation is complete to the IPTV Service Control Function (S3).
10. The IPTV Service Control Function informs the Linear TV Application that the allocation is complete and the application is now available to the user (A1).
11. The ITF receives a successful response from the Linear TV Application (E1).
12. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the initial Virtual Channel Service Stream. The initial Virtual Channel Service Stream *may* be a home Virtual Channel Service Stream, the last Virtual Channel Service Stream watched or some other "default" Virtual Channel Service Stream. In this figure, the first MTF is in the DNG and the initial Virtual Channel Service Stream is "channel A" (E6-Cm).
13. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
14. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast stream with the TRC.
15. The TRC signals its approval of the admission request back to the MTF.
16. The MTF configures the multicast forwarding table(s) to deliver the selected channel through the multicast replication function(s) to the ITF. The multicast flow for channel A is delivered to the ITF (Md).

7.2.2 Resources Unavailable

If the network architecture allows for the oversubscription of network resources, such as an overabundance of ITFs within the household, then it is conceivable that the RACF may deny the resource request and will send an "INSUFFICIENT_RESOURCES (4041)" Error Code (per ITU-T Q.3301.1) message back to the IPTV Service Control Function over interface S3 during step 9 in the message sequence above. In this event, the following actions *shall* be taken:

1) The IPTV SCF *shall* inform the IPTV Application over the A1 interface that insufficient resources are available. The protocol for this interface is for further study.
2) The IPTV Application *shall* interact with the ITF Linear TV client over the E1 interface to:
    a. Inform the Linear TV client that there are insufficient resources for initial channel acquisition. This message is for further study.
    b. If the Linear TV Application has visibility of all ITFs in the consumer's domain then it may be able to make suggestions or instructions to the other Linear TV clients to release network resources and make them available for the Linear IPTV channel acquisition. This interaction is for further study.
3) If the ITF is unable to acquire the desired channel, it *may* request another channel requiring fewer network resources. For instance, if the ITF is unable to acquire an HD channel, it may attempt to acquire an SD channel. This is for further study.

4) Operational error codes (alarms or logging events) *may* be issued into the OSS/BSS system to notify the service and network operators that a full service denial has occurred due to lack of network resources.

7.3 IMS Service Control

7.3.1 Public Service Identifier (PSI) as Linear TV Service URL

IMS-based PSIs are essentially SIP URIs that are functionally equivalent to IMS public user identities but identify services instead of users.

In that capacity, they can be provisioned in an end-user profile as originating initial Filter Criteria (iFCs) for service access authorization. Users who don't have the IMS-based PSI for a particular service provisioned in their originating iFC will not be allowed to access that service. This also requires that the Service Provider Domain Name Service (DNS) not include such an IMS-based PSI as an entry. This ensures that if no iFC including the IMS-based PSI is detected, normal IMS routing using DNS will fail and result in an error message (4XX) returned to the ITF.

The ATIS IIF names IMS PSIs as identifiers for a Linear TV service. The IMS-based PSI representing the Linear TV service will be included in the Request-URI of the SIP INVITE that establishes the Linear TV SIP session.

For all users who are authorized to access the Linear TV service, the originating iFC will have the IMS-based PSI configured as a trigger point in conjunction with a SIP INVITE. Furthermore, within the same iFC, the Application Server to which the request is routed will be configured to be the IPTV Control server.

For more information on how IMS-based PSIs are used for routing within the IMS domain, refer to ATIS-0800017, *Network Attachment and Initialization of Devices and Client Discovery of IPTV Services* [[5]].

7.3.1.1 Well-Known PSI for Linear TV Service

For Linear TV service, a well-known PSI shall be used. The well-known PSI shall be as follows:

IPTV-LTV-Service@<*domain name*>

Where *domain name* is the service provider domain name obtained during service discovery.

7.3.2 Linear TV SIP Session Setup

Figure 9 shows the flow for Linear TV service attachment and initial resource acquisition for an IMS-based implementation. As a precondition of this flow, the multicast Virtual Channel Service Streams for Linear TV channels A and B are being delivered to the Access Node.

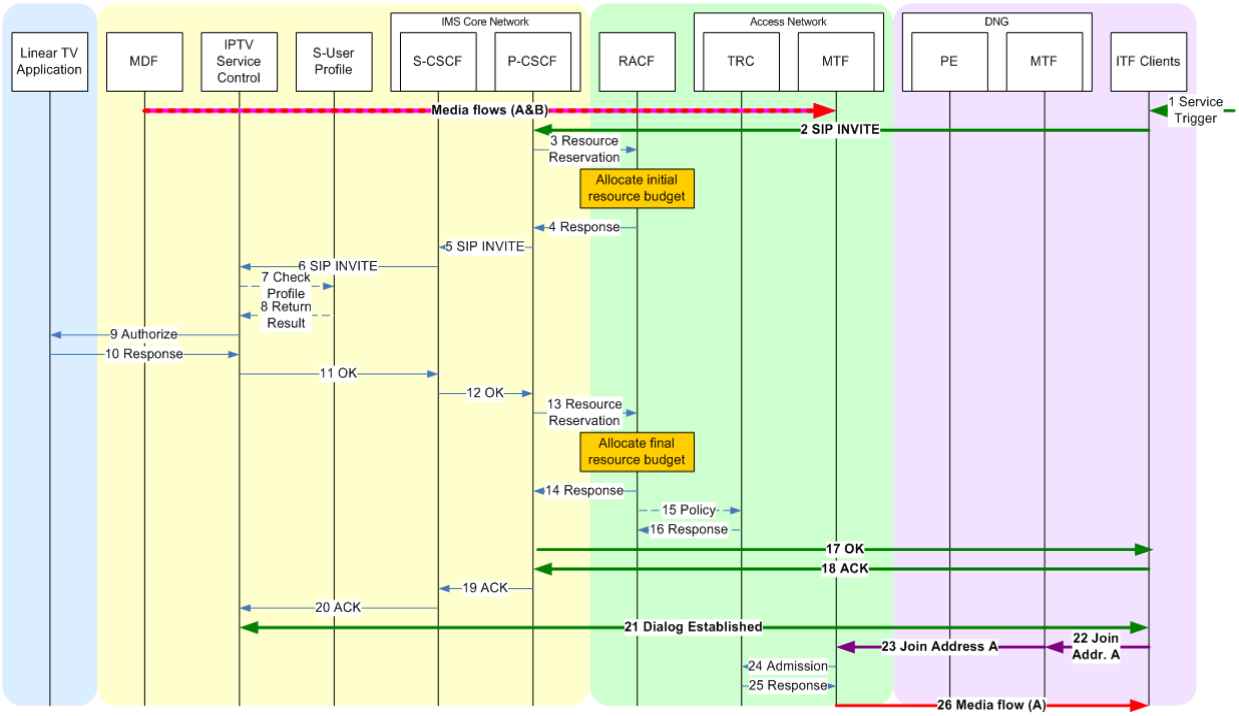

Figure 9: Linear TV SIP Session Setup and Initial Channel Acquisition

1. The Linear TV service is triggered through user interaction, preset recording instructions, or other means.
2. The ITF initiates a SIP session by sending a SIP INVITE to the P-CSCF (E3).
3. The P-CSCF initiates a resource reservation request (reservation phase) to the RACF based on the Bandwidth requested in the incoming INVITE. The RACF allocates the default initial bandwidth (S3).
4. The RACF signals that the bandwidth allocation is complete to the P-CSCF (S3).
5. The P-CSCF forwards the INVITE to the S-CSCF. If the subscriber is not entitled to IPTV services, the S-CSCF rejects the SIP session request.
6. The S-CSCF forwards the INVITE to the IPTV Service Control Function.
7. The IPTV Service Control Function *may* optionally validate the ITF's connection against the S-User Profile.
8. The S-User Profile returns the profile data which the IPTV Service Control Function uses to validate the service connection.
9. The IPTV Service Control Function requests authorization from the IPTV Application for the user to receive Linear TV Service (A1).
10. The IPTV Application signals approval of the user as a recipient of Linear TV. The IPTV Application *may* also return the bandwidth requirement for the requested channel (A1).
11. The IPTV Service Control Function returns 200 OK to the S-CSCF.
12. The S-CSCF returns 200 OK to the P-CSCF.
13. The P-CSCF initiates a resource reservation request (commitment phase) to the RACF based on the Bandwidth for the requested Virtual Channel Service Stream. The RACF allocates the required bandwidth for the service (S3).
14. The RACF signals that the bandwidth allocation is complete to the P-CSCF (S3).

15. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
16. The TRC signals its acceptance of the policy update (Rp).
17. The P-CSCF returns 200 OK to the ITF (E3).
18. The ITF sends an ACK to the P-CSCF (E3).
19. The P-CSCF sends an ACK to the S-CSCF.
20. The S-CSCF sends an ACK to the IPTV Service Control Function.
21. The SIP dialog is now established between the ITF and the IPTV Service Control Function.
22. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the initial Virtual Channel Service Stream. The initial Virtual Channel Service Stream *may* be a home Virtual Channel Service Stream, the last Virtual Channel Service Stream watched or some other "default" Virtual Channel Service Stream. In this figure, the first MTF is in the DNG and the initial Virtual Channel Service Stream is "channel A" (E6-Cm).
23. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
24. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast stream with the TRC.
25. The TRC signals its approval of the admission request back to the MTF.
26. The MTF configures the multicast forwarding table(s) to deliver the selected channel through the multicast replication function(s) to the ITF. The multicast flow for channel A is delivered to the ITF (Md).

7.3.3 Set-Up and Maintenance of Linear TV SIP Session

The Linear TV SIP session *shall* be set up using TS 3GPP 24.229 as specified in ATIS-0800013, *Media Formats and Protocols Specification* [4], section 7.7, and the Session Description Protocol (SDP) as specified in ATIS-0800013 section 7.5. The use of SDP *shall* be between the ITF and the IMS core. The control and communication from the IMS core to the NGN Transport Stratum components *shall* use the S3 reference point (see Figure 4). SDP is also used to modify the resources of the Linear TV SIP session as (and if) required. The SDP fields for a Linear TV SIP Session shall be set in accordance with Table 1 below. It is assumed that this use of SDP applies to the session level and not the individual Virtual Channel Service Streams that may be part of this Linear TV SIP Session. It should also be noted that the described use of SDP in Table 1 is specific to Linear TV; other IPTV services may specify their own use of SDP and ascribe different rules regarding how the fields are derived.

Table 1: SDP Normative Fields and Values

SDP <type>	Description	<value>	Explanation
v=	protocol version	0	As specified in the standard referred to in ATIS-0800013, section 7.5.
s=	session name	"ATIS IIF Linear TV"	Identifies the session as being compliant to the ATIS IIF specifications for Linear TV Service.
i=	session description	Populated with the well known PSI for Linear TV service as specified in section 7.3.1.1 of this document.	The Public Service Identifier (PSI) identifies that the session is an IPTV Linear TV service and who the service provider is.
c=	connection data	IN (IP4 or IP6 set appropriately) <connection address>	IN is defined by IANA as Internet. IP4 or IP6 refers to whether IP protocol version 4 or 6 is being used for the supplied connection address and should be set accordingly. The connection address is the IP Multicast address that will be first accessed. Subsequent SDP messages that are sent to augment the initial values established at setup may refer to some other Virtual Channel Service Stream. The connection address is derived from the Source Table DestinationIpAddress element as defined in ATIS-0800022, *IPTV Consumer Domain Device Configuration Metadata*, for the Virtual Channel Service Stream being referenced. It should be noted that the format of the address varies depending on whether the data is retrieved via a PUSH (e.g., Multicast) or PULL (e.g., Unicast) method, as well as whether IPv4 or IPv6 addresses are used. For information on the proper representation of the connection address value, please refer to the SDP specification.
t=	time the session is active	Typically set to "0 0"	Because Linear TV has no defined beginning or end, the t= type is usually defined as unbounded ("0 0"). Certain devices such as digital video recorders (DVRs) may record Virtual Channel Service Streams based on a time schedule. When this schedule is know the appropriate values *may* be declared.
m=	media descriptions	<media> <port> <proto> <fmt>	At least one media description line is required. The media, proto, and fmt fields of the m= line are constructed from elements of the metadata associated with the Virtual Channel Service Stream that will be accessed first; specifically: the ResourceLocator -> IpmStreamingMediaLocator -> IpmSessionDescriptionType -> IpmChannelType (mediaType, mediaProtocol, and payloadType). The <port> value is set to the IP port bound to the process in the ITF that receives the Virtual Channel Service Stream.

SDP <type>	Description	<value>	Explanation
b=	bandwidth information	AS:(session total bandwidth expressed in kilo bits per second)	The value is at a minimum populated from the tiasBandwidth element of the ResourceLocator, IpmStreamingMediaLocator associated with the first Virtual Channel Service Stream being accessed in the session. However, the value may be adjusted to represent the maximum aggregate bandwidth anticipated to be used during the life of the session. If used in this manner, the value should include in its total the maximum value of any Virtual Channel Service Stream plus any associated support streams such as FEC packets, Packet Retransmissions, picture-in-picture streams, etc. The Linear TV Application is free to update the SDP as often as required to provide a more refined granularity of bandwidth management.
a=	attributes	recvonly	This attribute indicates that the Linear TV session is a receive-only service.
a =	attributes	BCservice:<BCserviceId>	Set to the channel that will first be accessed. This value is derived from the Virtual ChannelShortName (from Virtual Channel Description Table) as defined in ATIS-800022, *IPTV Consumer Domain Device Configuration Metadata*, for the Virtual Channel Service Stream to be initially joined.
a=	attributes	SdpAttributeType:value	This is an optional a= line that is included if the Virtual Channel Service Stream's ResourceLocator/ IpmStreamingMediaLocator/IpmSessionDescription/ IpmChannelDescription contains an SdpAttributeType and value elements.
a=	attributes	<a=rtpmap:>rtpmap	This is an optional a= line that is included if the Virtual Channel Service Stream's ResourceLocator, IpmStreamingMediaLocator/IpmSessionDescription/ IpmChannelDescription contains the rtpmap element. Note: The Metadata element only contains the value that follows the “a=rtpmap:” text on the line. Implementers must be sure to include the “a=rtpmap:” preceding the metadata element's contents.
a=	attributes	<a=fmtp:>fmtp	This is an optional a= line that is included if the Virtual Channel Service Stream's ResourceLocator/IpmStreamingMediaLocator/ IpmSessionDescription/IpmChannelDescription contains the fmtp element. Note: The Metadata element only contains the value that follows the “a=rtpmap:” text on the line. Implementers must be sure to include the “a=rtpmap:” preceding the metadata element's contents.

SDP <type>	Description	<value>	Explanation
m=	Additional optional media description entries	<media type> <port> <proto> <fmt>	Optional m= lines declare other supported media types such as codecs that are outside the scope of ATIS-0800013, *Media Formats and Protocols Specification*. Inclusion of these optional lines is purely declarative and no particular action is associated with their presence or absence.

7.3.3.1 ITF initiated SDP Offer during Linear IPTV IMS Session setup

Upon a request for a Linear TV session initiation, the ITF *shall* generate an initial INVITE request. The Request-URI in the INVITE request *shall* be set to the well-known PSI of the Linear TV Service.

An initial SDP offer *shall* be included in the INVITE request. The required SDP offer shall at a minimum comply with the required fields defined in Table 1. The SDP offer *may* optionally include the following:

- If the ITF does not have knowledge of the bandwidth required (e.g., thin client) based on Table 1, it *shall not* include a b= line in the initial outgoing offer.
- There *may* be additional m-lines in addition to the single mandatory m-line in Table 1. These m-lines could reflect other streams such as picture-in-picture.
- If the ITF intends to join FEC stream(s) associated with the original Virtual Channel Service stream(s), it *may* include additional m-lines in the initial SDP offer in accordance with Table 1 (last entry). More specifically:
  - The ITF *may* include one or more m-line(s) for each FEC stream exposed through the metadata (FecProfileType in SourceTable).
  - Each included m-line for each FEC stream *shall* contain a c-line exposed through the metadata (FecProfileType in SourceTable).
  - In case there are multiple m-lines for Virtual Channel Service streams and/or FEC streams, and for the purpose of associating an FEC stream with a Virtual Channel Service stream, grouping line(s) *shall* be included, one for each Virtual Channel Service m-line that is associated to a FEC stream. The grouping line uses the "FEC" semantic as defined in forward error correction group semantics in SDP as specified in ATIS-0800013, *Media Formats and Protocols Specification,* section 7.5.1:
    - a=group:FEC:<original stream id> <base FEC stream id> <enhancement FEC stream id>
      - The original stream id *shall* reflect the value held by the media description of the Virtual Channel Service stream in its a=mid attribute as specified in ATIS-0800013, *Media Formats and Protocols Specification*, section 7.5.2. This implies when a grouping line is included, there *shall* be an additional media identification attribute within the m-line of the original Virtual Channel Service stream that is within the grouping. The format for that attribute is:
        - a=mid:<original stream id>
      - The base FEC stream id *shall* reflect the value held by the media description of the FEC stream (associated to the original stream) in its a=mid attribute.

- The enhancement FEC stream id *shall* reflect the value held by the media description of the FEC stream (associated to the original stream) in its a=mid attribute.

If the ITF receives a 488 error code with warning 370 Insufficient Bandwidth, the ITF *may* perform a new SIP INVITE with a lower maximum bandwidth for the Linear TV service the ITF intends to join. This procedure *may* be repeated. If no agreement can be reached the ITF *may* display a failure message to the user.

When the ITF receives the SIP final response, the ITF joins the multicast channel identified in the a= BCservice line of the SDP message.

7.3.3.2 IPTV Control Server initiated SDP answer during Linear TV session IMS set up

Upon receipt of a SIP INVITE request, the IPTV control server *shall* examine the Request-URI to determine that it is a Linear TV Session initiation request. The IPTV control server *shall* also examine the SDP parameters in the received offer in conjunction with the user subscription. In particular:

- It *shall* examine the a=BCservice parameter. This parameter contains the channel the ITF intends to join. If the BCservice parameter does not point to a valid channel or a channel the ITF has access to, the IPTV control server *shall not* accept the offer and *shall* answer with a 403 error code.
- It *shall* examine the c-line(s) to determine whether it is a multicast session. It *may* also check that it corresponds to the BCservice parameter. If not, the IPTV control server *may* answer with a 403 error code.
- It *shall* examine the b-line parameter, if present, to verify that it is set to the largest bandwidth of all the BC services and associated support streams (i.e., FEC) the user is subscribed to. If the b-line parameter is not set to that bandwidth value, the IPTV control server *shall* answer with a 403 error code. If there is insufficient bandwidth available, the IPTV control server *shall* answer with a 488 error code with warning 370 Insufficient Bandwidth.

If the SDP parameters are examined successfully and there is sufficient bandwidth, the IPTV control server *shall* answer with a SIP 200 OK, including the SDP answer as follows:

- The c-lines and m-lines *shall* be identical to ones indicated in the SDP offer;
- It *shall* include an a=recvonly attribute; and
- It *shall* include a b-line parameter with the same value as in the offer, or, if the b-line was absent, the IPTV control server *shall* include a b-line parameter with a value set to the largest bandwidth of all the BC services the user has access to.

8 Channel Changes with Linear TV Resources Managed in the Transport Layer Only

Responsive channel changes are important to the quality of the Linear TV experience. To achieve satisfactory performance it is necessary that most channel change requests be processed locally with minimal involvement of remote admission control functions and associated signaling. This section

describes channel change scenarios in which the channel change control is entirely in the transport stratum. These channel change flows are the same for networks using IMS or an IPTV service control function. There are several alternative approaches to channel change involving only the transport stratum. This includes the following cases:

- *Resource admission control is not performed by the network (the network is engineered to have sufficient resources or the Linear TV application doesn't ask for more than the network can provide)*. The network will honor any channel change request.
- *Static (or independent) case where the multicast policies are loaded into transport nodes through management or configuration means*. The transport nodes are responsible for multicast resource management based on these policies and the RACF is responsible for unicast resource management.
- *Adjustable (or synchronized) aggregate resources between multicast services and other resource-managed unicast services*. This is where the Access Node (or other transport node) performs multicast admission control based on aggregate multicast resources that have been allocated to it. When necessary, the RACF can modify the aggregate multicast resources allocated to the Access Node to lend resources to or borrow resources from unicast services.
- *Fully shared (or integrated) aggregate resources between multicast services and other resource-managed unicast services*. This is the case where the Access Node (or other transport node) is responsible for both unicast and multicast resource admission control.

8.1 Null or Static Resource Management

Figure 10 shows the flow for a channel change where no bandwidth change is needed. As a precondition of this flow, the multicast Virtual Channel Service Streams for Linear TV channels A and B are being delivered to the Access Node. Channel A is being multicast to the ITF.

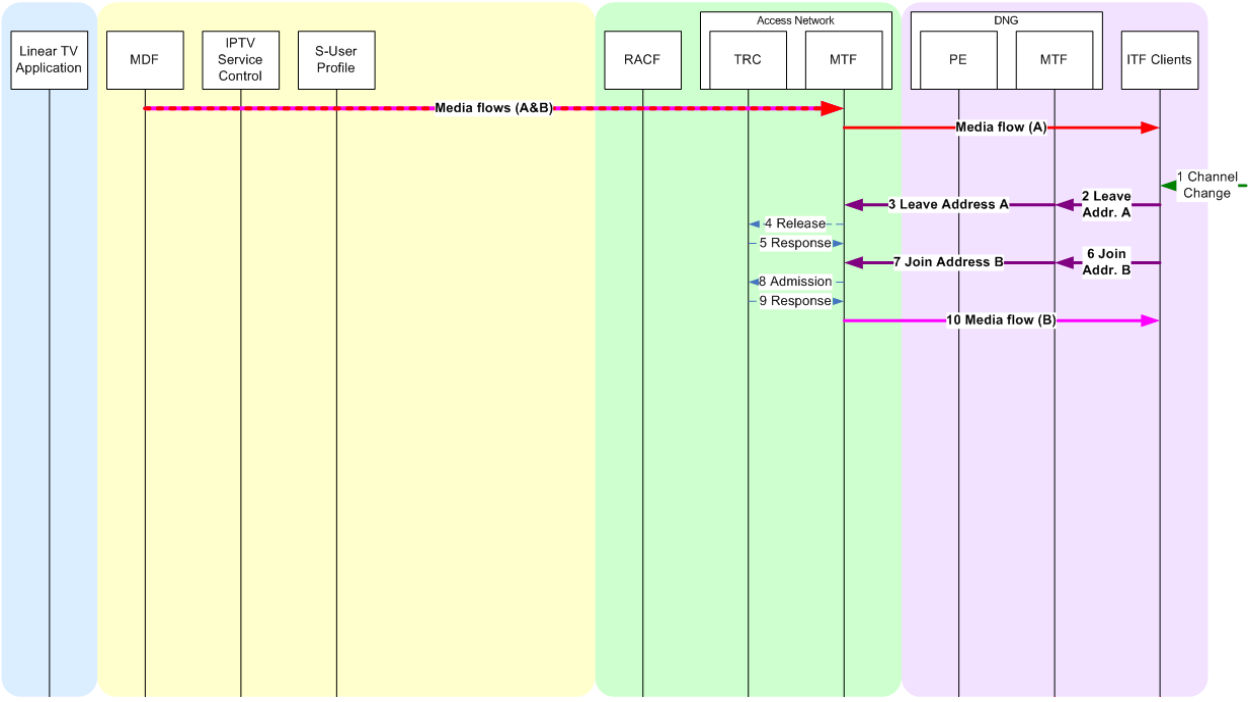

Figure 10: Channel Change - No Bandwidth Change Needed

1. A channel change is signaled to the ITF through user interaction or other means. In this flow, the ITF is selecting Virtual Channel Service Stream B.
2. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active Virtual Channel Service Stream. In this figure, the first MTF is in the DNG (E6-Cm).
3. If the Virtual Channel Service Stream is not being locally replicated, then the Multicast Group "Leave" is forwarded to the preceding Multicast Transport Function. In this figure, the "Leave" is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream A to that ITF is stopped (E5-Cm).
4. When the MTF replicating the Virtual Channel Service Stream receives the Leave request, if the ITF was the last entity receiving the replication, the MTF can request that the TRC deallocate the resources for the replication since it is no longer needed.
5. The TRC signals its completion of the replication deallocation back to the MTF.
6. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the selected Virtual Channel Service Stream. In this figure, the first MTF is in the DNG (E6-Cm).
7. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
8. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast Virtual Channel Service Stream with the TRC.
9. The TRC signals its approval of the admission request back to the MTF.
10. The MTF configures the multicast forwarding table(s) to deliver the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream B is delivered to the ITF (Md).

8.2 Adjustable Resources between Unicast and Multicast

Figure 11 shows the flow for Virtual Channel Service Stream change when the resource allocation between unicast and multicast are adjustable in the access network. As a precondition of this flow, the multicast streams for Linear TV channels A and B are being delivered to the Access Node. Virtual Channel Service Stream A is being multicast to the ITF.

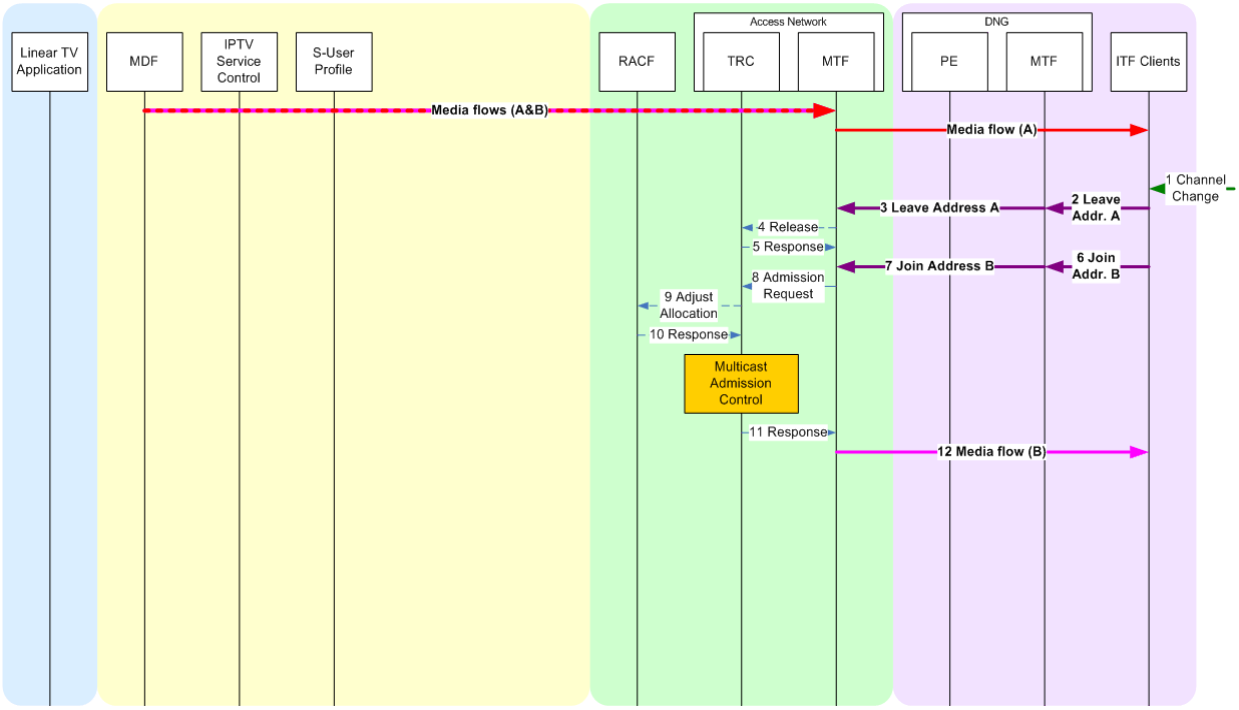

Figure 11: Channel Change with Adjustable Resources in the Access Network

1. A channel change is signaled to the ITF through user interaction or other means. In this flow, the ITF is selecting channel B.
2. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active Virtual Channel Service Stream. In this figure, the first MTF is in the DNG (E6-Cm).
3. If the Virtual Channel Service Stream is not being locally replicated, then the Multicast Group "Leave" is forwarded to the preceding Multicast Transport Function. In this figure, the "Leave" is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream A to the ITF is stopped (E5-Cm).
4. When the MTF replicating the Virtual Channel Service Stream receives the Leave request, if the ITF was the last entity receiving the replication, the MTF can request that the TRC deallocate the access network resources for the replication since they are no longer needed.
5. The TRC signals its completion of the replication deallocation back to the MTF.
6. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the selected channel. In this figure, the first MTF is in the DNG (E6-Cm).
7. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
8. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast Virtual Channel Service Stream with the TRC.
9. The TRC requests the RACF to approve an adjustment to the allocation of bandwidth between unicast and multicast to support the additional needs for the new multicast channel (Rp).

10. The RACF signals its approval to the TRC. The TRC readjusts the bandwidth to support the multicast channel (Rp).
11. The TRC signals its approval of the admission request back to the MTF.
12. The MTF configures the multicast forwarding table(s) to deliver the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream B is delivered to the ITF (Md).

8.3 Fully Shared Resources between Unicast and Multicast

Figure 12 shows the flow for a channel change when the resources for multicast services and other resource-managed unicast services are fully shared in the access network. As a precondition of this flow, the multicast streams for Linear TV Virtual Channel Service Stream A and B are being delivered to the Access Node. Virtual Channel Service Stream A is being multicast to the ITF. Aggregate resources for multicast and unicast services are allocated in the transport node TRC. Multicast admission control is performed locally in the transport node TRC. For reference, unicast admission requests (from services beyond the scope of this specification) are shown as being received by the central RACF and forwarded to the transport node TRC for admission control.

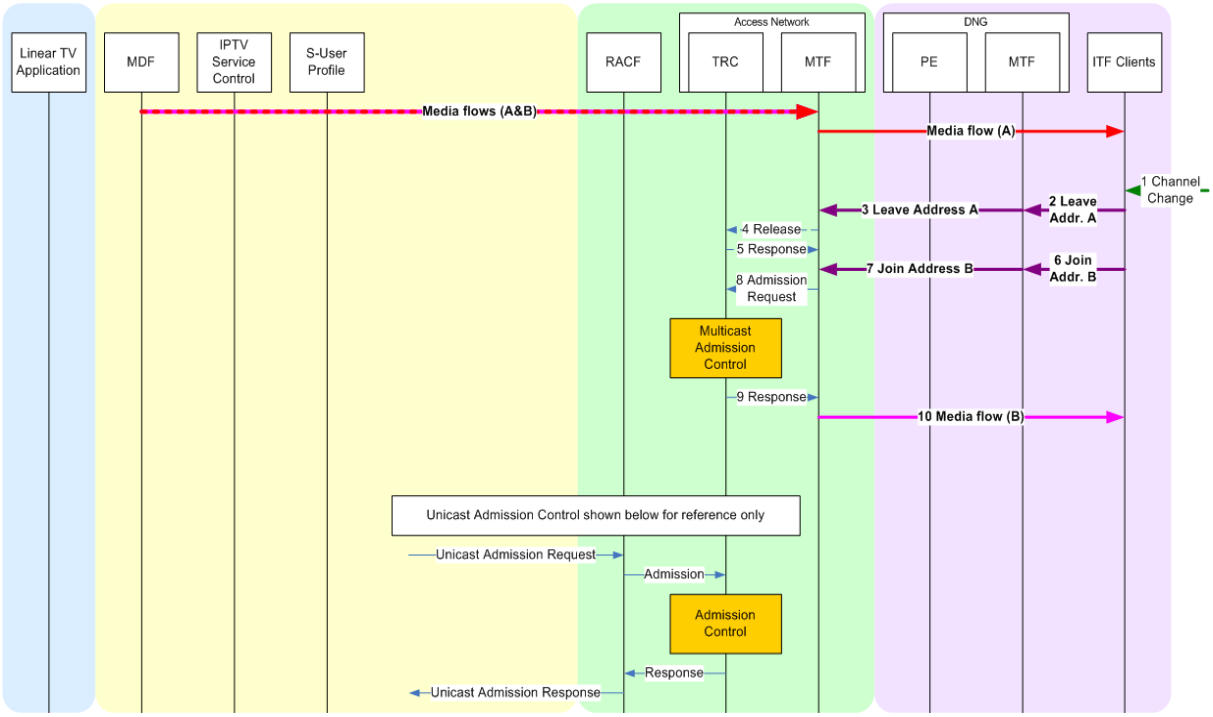

Figure 12: Channel Change with Fully Shared Resources in the Access Network

1. A channel change is signaled to the ITF through user interaction or other means. In this flow, the ITF is selecting channel B.
2. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active channel. In this figure, the first MTF is in the DNG (E6-Cm).
3. If the Virtual Channel Service Stream is not being locally replicated, then the Multicast Group "Leave" is forwarded to the preceding Multicast Transport Function. In this figure, the "Leave"

is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream A to the ITF is stopped (E5-Cm).

4. When the MTF replicating the Virtual Channel Service Stream receives the Leave request, if the ITF was the last entity receiving the replication, the MTF can request that the TRC deallocate the access network resources for the replication since they are no longer needed.
5. The TRC signals its completion of the replication deallocation back to the MTF.
6. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the selected Virtual Channel Service Stream. In this figure, the first MTF is in the DNG (E6-Cm).
7. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
8. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast Virtual Channel Service Stream with the TRC. The TRC readjusts the bandwidth to support the multicast Virtual Channel Service Stream.
9. The TRC signals its approval of the admission request back to the MTF.
10. The MTF configures the multicast forwarding table(s) to deliver the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream B is delivered to the ITF (Md).

8.4 Resources Unavailable Error Condition for TRC Multicast Admission Control

In the previous call flows, the MTF and TRC communicate to validate resource availability on a per multicast join basis. Resource tables in the TRC are kept current based on join/leave state information. If the ITF signals a channel change that would cause the aggregate bandwidth to the consumer to violate the policy being enforced by the TRC, then the join *shall not* be successful. The IGMP (or MLD) protocol used to request a channel change is not reliable, nor does it provide a means to indicate a channel change failure. However, if the ITF can determine that the join was not successful by observing that the requested virtual channel service stream did not arrive after a time limit, the ITF *may* log this event as a fault.

If the TRC rejects the channel change request, it may be desirable for the ITF to: 1) know the reason for it, or 2) give the Linear TV Application the opportunity to make suggestions or give instructions to other ITFs in the consumer's domain to release network resources. In these cases, the RACF, IPTV Service Control Function, and Linear TV Application may be used. This procedure or alternative procedures are for further study.

9 Channel Changes Requiring Modification of Linear TV Service Resources

This section describes the process of changing from one Virtual Channel Services Stream to another that requires a different amount of network resources and with the ITF configured to conserve Linear TV Application bandwidth (ConserveLTVABandwidth=True). The ITF knows how much bandwidth it is currently using and how much bandwidth is required for the intended Virtual Channel Service Stream, so it is able to determine when network resources need to be modified. A modification of

network resources is requested prior to changing Virtual Channel Service Streams. A non-IMS coupled case is described in section 9.1. An IMS case is described in section 9.2.

The flow diagrams show the flows and transactions involved with network resource modification for Linear TV service. The diagrams continue with representative flows for the selection of the virtual channel service stream. Other sequences for joining a Virtual Channel Service Stream are possible such as those described in section 8.

9.1 Non-IMS Coupled

Figure 13 shows the flow for a channel change with a bandwidth update in a non-IMS coupled implementation. As a precondition of this flow, the multicast Virtual Channel Service Stream for Linear TV Virtual Channel Service Stream A and B are being delivered to the Access Node. Channel A is being multicast to the ITF.

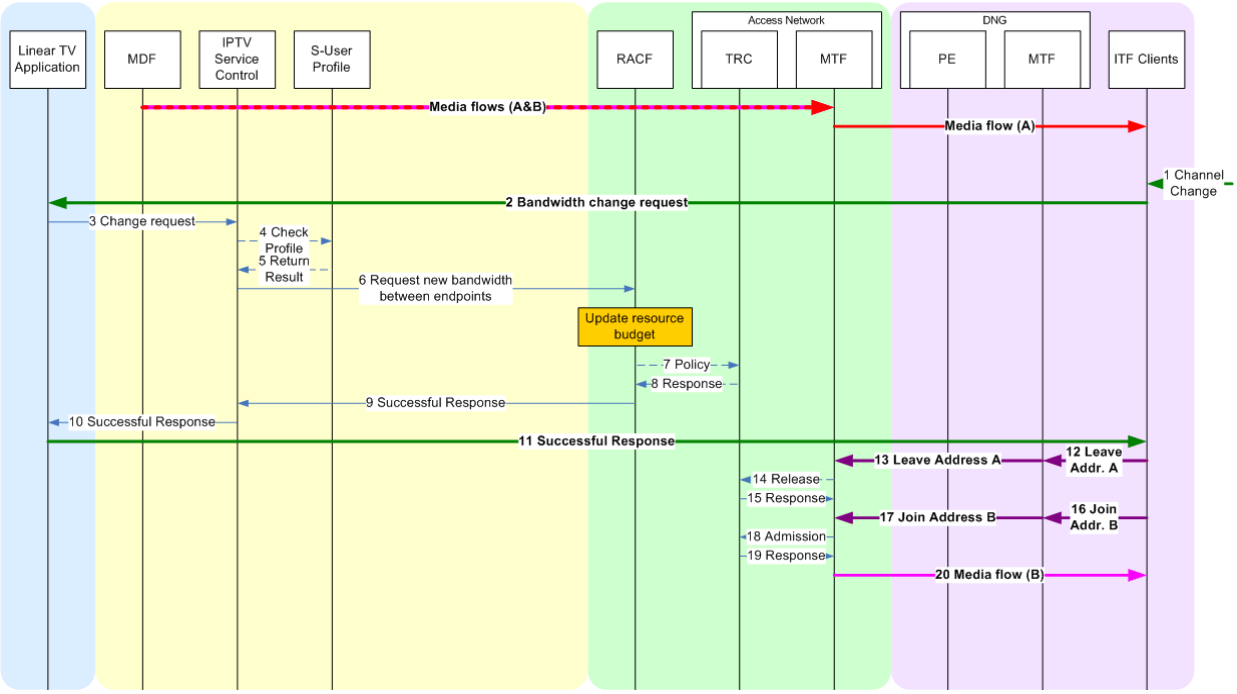

Figure 13: Non-IMS Channel Change - Coupled

1. A channel change is signaled to the ITF through user interaction or other means. In this flow, the ITF is selecting channel B.
2. The ITF requests a bandwidth change from the Linear TV Application (E1).
3. The Linear TV Application signals the IPTV Service Control Function to request the updated network resources for the reception of the selected Virtual Channel Service Stream (A1).
4. The IPTV Service Control Function *may* optionally validate the ITF's bandwidth request against the S-User Profile.
5. The S-User Profile returns the profile data which the IPTV Service Control Function uses to validate the bandwidth request.

6. The IPTV Service Control Function requests the RACF to allocate the access network resources needed to support the selected Virtual Channel Service Stream. The RACF allocates the bandwidth needed by the multicast delivery function in the access network (S3).
7. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
8. The TRC signals its acceptance of the policy update (Rp).
9. The RACF signals that the bandwidth allocation is complete to the IPTV Service Control Function (S3).
10. The IPTV Service Control Function informs the Linear TV Application that the allocation is complete and the application is now available to the user (A1).
11. The IPTV Application informs the ITF that the allocation is complete (E1).
12. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active Virtual Channel Service Stream. In this figure, the first MTF is in the DNG (E6-Cm).
13. If the Virtual Channel Service Stream is not being locally replicated, then the Multicast Group "Leave" is forwarded to the preceding Multicast Transport Function. In this figure, the "Leave" is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream A to the ITF is stopped (E5-Cm).
14. When the MTF replicating the Virtual Channel Service Stream receives the Leave request, if the ITF was the last entity receiving the replication, the MTF can request that the TRC deallocate the access network resources for the replication since they are no longer needed.
15. The TRC signals its completion of the replication deallocation back to the MTF.
16. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the selected Virtual Channel Service Stream. In this figure, the first MTF is in the DNG and the selected channel is Virtual Channel Service Stream B (E6-Cm).
17. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
18. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast Virtual Channel Service Stream with the TRC. The TRC readjusts the bandwidth to support the multicast Virtual Channel Service Stream.
19. The TRC signals its approval of the admission request back to the MTF.
20. The MTF configures the multicast forwarding table(s) to deliver the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream B is delivered to the ITF (Md).

9.1.1 Resources Unavailable

If the network architecture allows for the oversubscription of network resources, such as an overabundance mixture of SD and HD-capable ITFs within the household, then it is conceivable that the RACF may deny the resource request and will send an "INSUFFICIENT_RESOURCES (4041)" Error Code (per ITU-T Q.3301.1) message back to the IPTV Service Control Function over interface S3 during step 9 in the message sequence above. In this event, the following actions *shall* be taken:

1) The IPTV SCF *shall* inform the IPTV Application over the A1 interface that insufficient resources are available. The protocol for this interface is for further study.
2) The IPTV Application *shall* interact with the ITF Linear TV client over the E1 interface to:
   a) Inform the Linear TV client that there are insufficient resources for the channel change. This message is for further study.
   b) If the Linear TV Application has visibility of all ITFs in the consumer's domain, then it may be able to make suggestions or give instructions to the other Linear TV clients to release network resources and make them available for the Linear IPTV channel acquisition. This interaction is for further study.
3) If the ITF is unable to acquire the desired channel, it *may* request another channel requiring fewer network resources. For instance, if the ITF is unable to acquire an HD channel, it may attempt to acquire an SD channel. This is for further study.
4) Operational error codes (alarms or logging events) *may* be issued into the OSS/BSS system to notify the service and network operators that a full service denial has occurred due to lack of network resources.

9.2 IMS-based Resource Management during Channel Change

In IMS-based IPTV systems, two methods, re-INVITE and UPDATE, *shall* be supported to update the allocated resources in the network when a channel change requires such an update, according to the SIP specification identified in ATIS-0800013, *Media Formats and Protocols Specification* [4].

9.2.1 ITF-initiated SIP Session Modification

When the ITF determines there is a need for Linear TV SIP session modification, the ITF *shall* generate a re-INVITE request or an UPDATE request, depending on the dialogue state.

The ITF *shall* include an SDP offer in a session modification request. The format of the SDP *shall* be the same as for a SIP session initiation.

Upon receipt of a re-INVITE request or an UPDATE request, including an SDP offer, the IPTV control function *may* modify the SDP answer in accordance with the user subscription. If the IPTV control function finds a media line not compatible with the user's subscription, it *shall* set the port of this media line to 0. If none of the media lines are acceptable, it *shall* reply with a 403 error response.

This case is illustrated in Figure 14 and Figure 15.

9.2.1.1 SIP Session Modification for Resource Update Using Re-INVITE

Figure 14 covers the use of a SIP Re-INVITE to achieve the resource update. As a precondition of this flow, the multicast streams for Linear TV Virtual Channel Service Stream A and B are being delivered to the Access Node.

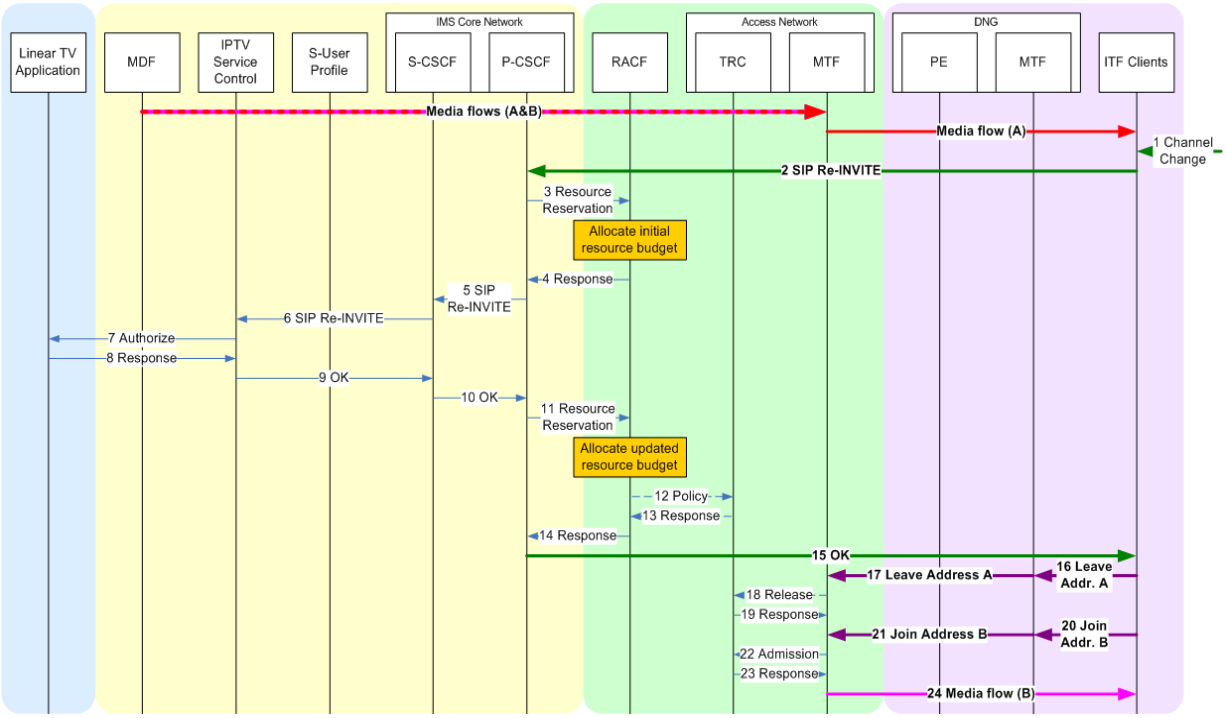

Figure 14: IMS-based Resource Management during Channel Change – Re-INVITE Case

1. A channel change is signaled to the ITF through user interaction or other means. In this flow, the ITF is selecting Virtual Channel Service Stream B.
2. The ITF requests an update to the allocated resources by sending a SIP INVITE to the P-CSCF. This INVITE is a Re-INVITE sent within the existing dialog (E3).
3. The P-CSCF initiates a resource reservation request (reservation phase) to the RACF based on the bandwidth requested in the incoming INVITE. The RACF allocates the requested bandwidth (S3).
4. The RACF signals that the bandwidth allocation is complete to the P-CSCF (S3).
5. The P-CSCF forwards the INVITE to the S-CSCF.
6. The S-CSCF forwards the INVITE to the IPTV Service Control Function.
7. The IPTV Service Control Function requests authorization from the IPTV Application for the resource allocation change (A1).
8. The IPTV Application signals approval of the allocation change. The IPTV Application *may* also return the bandwidth requirement for the selected Virtual Channel Service Stream (A1).
9. The IPTV Service Control Function returns 200 OK to the S-CSCF.
10. The S-CSCF returns 200 OK to the P-CSCF.
11. The P-CSCF initiates a resource reservation request (commitment phase) to the RACF based on the Bandwidth for the selected Virtual Channel Service Stream. The RACF allocates the required bandwidth for the Virtual Channel Service Stream (S3).
12. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
13. The TRC signals its acceptance of the policy update (Rp).
14. The RACF signals that the bandwidth allocation is complete to the P-CSCF (S3).
15. The P-CSCF returns 200 OK to the ITF (E3).

16. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active Virtual Channel Service Stream. In this figure, the first MTF is in the DNG (E6-Cm).
17. If the Virtual Channel Service Stream is not being replicated at that MTF, then the Multicast Group "Leave" is forwarded to the preceding Multicast Transport Function. In this figure, the "Leave" is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream A to the ITF is stopped (E5-Cm).
18. When the MTF replicating the Virtual Channel Service Stream receives the Leave request, if the ITF was the last entity receiving the replication, the MTF can request that the TRC deallocate the resources for the replication since it is no longer needed.
19. The TRC signals its completion of the replication deallocation back to the MTF.
20. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the selected Virtual Channel Service Stream. In this figure, the first MTF is in the DNG and the selected Virtual Channel Service Stream is channel B (E6-Cm).
21. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network.
22. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast stream with the TRC. The TRC readjusts the bandwidth to support the multicast Virtual Channel Service Stream (E5-Cm).
23. The TRC signals its approval of the admission request back to the MTF.
24. The MTF configures the multicast forwarding table(s) to deliver the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream B is delivered to the ITF (Md).

9.2.1.2 SIP Session Modification for Resource Update Using UPDATE

Figure 15 covers the use of a SIP UPDATE to achieve the resource update. As a precondition of this flow, the multicast streams for Linear TV Virtual Channel Service Streams A and B are being delivered to the Access Node.

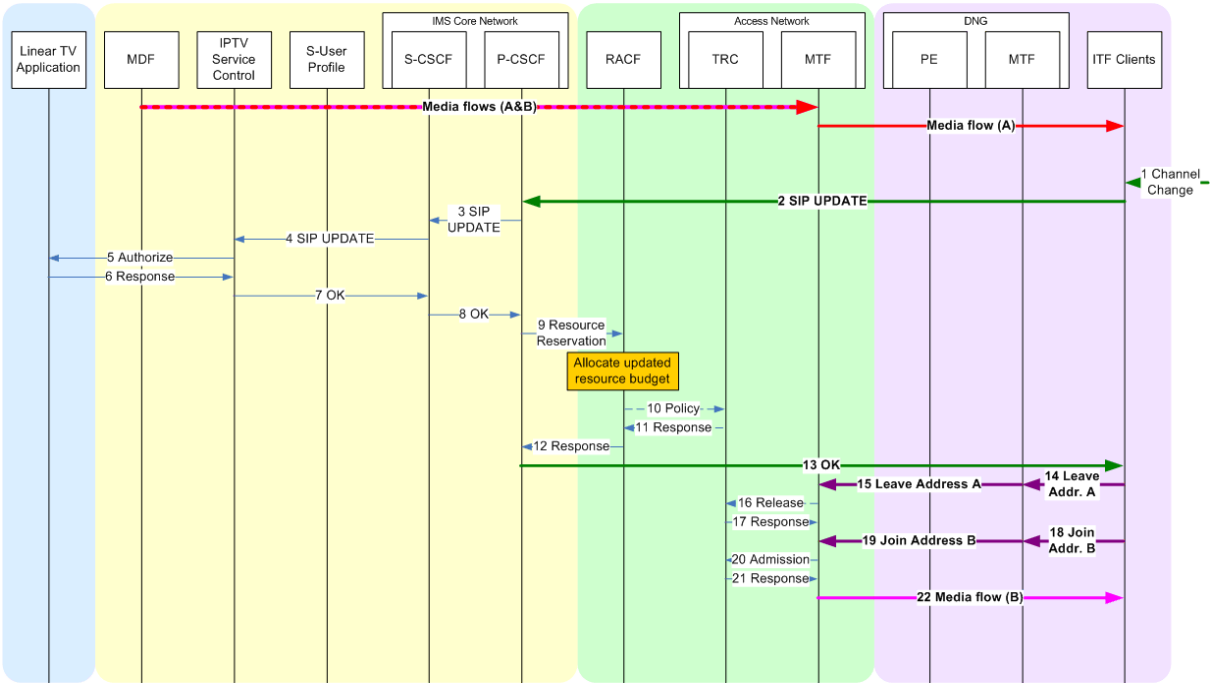

Figure 15: IMS-based Resource Management during Channel Change – UPDATE Case

1. A channel change is signaled to the ITF through user interaction or other means. In this flow, the ITF is selecting channel B.
2. The ITF requests an update to the allocated resources by sending a SIP UPDATE to the P-CSCF (E3).
3. The P-CSCF forwards the UPDATE to the S-CSCF.
4. The S-CSCF forwards the UPDATE to the IPTV Service Control Function.
5. The IPTV Service Control Function requests authorization from the IPTV Application for the resource allocation change (A1).
6. The IPTV Application signals approval of the allocation change. The IPTV Application *may* also return the bandwidth requirement for the selected channel (A1).
7. The IPTV Service Control Function returns 200 OK to the S-CSCF.
8. The S-CSCF returns 200 OK to the P-CSCF.
9. The P-CSCF initiates a resource reservation request to the RACF based on the bandwidth requested in the 200 OK. The RACF allocates the requested bandwidth (S3).
10. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
11. The TRC signals its acceptance of the policy update (Rp).
12. The RACF signals that the bandwidth allocation is complete to the P-CSCF (S3).
13. The P-CSCF returns 200 OK to the ITF (E3).
14. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active Virtual Channel Service Stream. In this figure, the first MTF is in the DNG (E6-Cm).

15. If the Virtual Channel Service Stream is not being locally replicated, then the Multicast Group "Leave" is forwarded to the preceding Multicast Transport Function. In this figure, the "Leave" is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected channel through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream A to the ITF is stopped (E5-Cm).
16. When the MTF replicating the Virtual Channel Service Stream receives the Leave request, if the ITF was the last entity receiving the replication, the MTF can request that the TRC deallocate the resources for the replication since it is no longer needed.
17. The TRC signals its completion of the replication deallocation back to the MTF.
18. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the selected Virtual Channel Service Stream. In this figure, the first MTF is in the DNG and the selected Virtual Channel Service Stream is channel B (E6-Cm).
19. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
20. When the MTF receives the Join request, it *may* optionally check the admission policy for the multicast Virtual Channel Service Stream with the TRC. The TRC readjusts the bandwidth to support the multicast Virtual Channel Service Stream.
21. The TRC signals its approval of the admission request back to the MTF.
22. The MTF configures the multicast forwarding table(s) to deliver the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream B is delivered to the ITF (Md).

9.2.2 IPTV Control Function Initiated SIP Session Modification

When the IPTV control function determines there is a need for a Linear TV SIP session modification, it *shall* send a re-INVITE or an UPDATE request, depending on the dialogue state. The IPTV control function acts as an originating UA in that regard.

Upon receipt of a re-INVITE request or an UPDATE request, the ITF's SDP answer *shall* reflect the media capabilities and required bandwidth as available for the Linear TV SIP session.

10 IPTV SERVICE TERMINATION

10.1 Non-IMS Coupled

Figure 16 shows the flow for Linear TV Application Session termination in the case of a non-IMS coupled implementation. This flow assumes that Linear TV Application Session is established to the ITF.

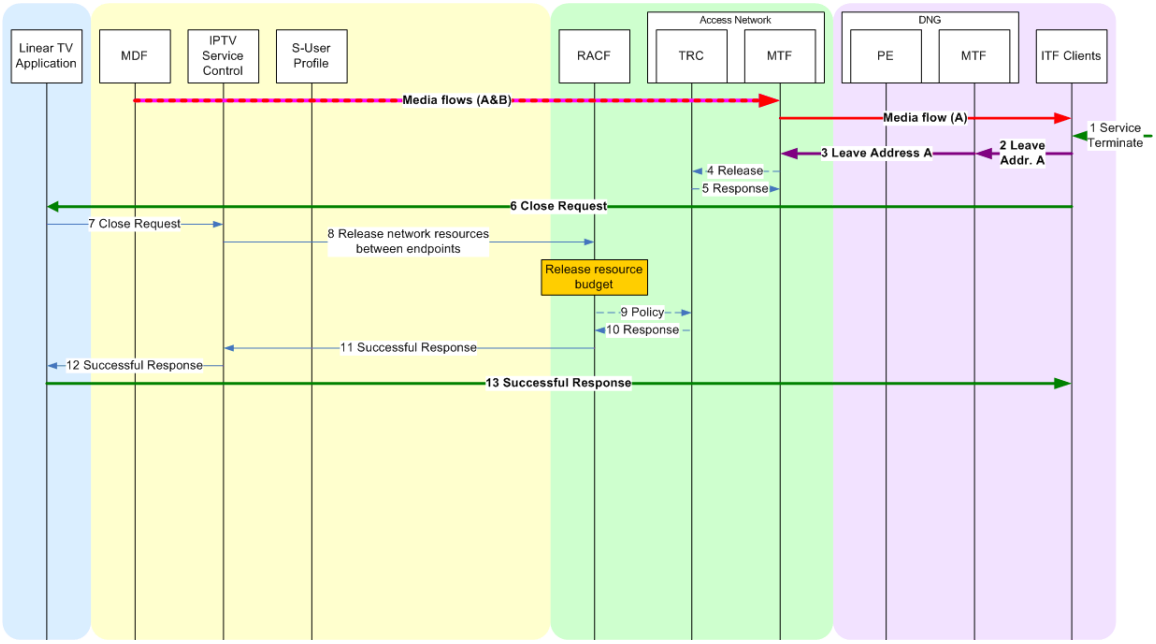

Figure 16 : Non-IMS IPTV Service Termination – Coupled

1. The Linear TV Service termination is triggered through user interaction or other means.
2. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active channel. In this figure, the first MTF is in the DNG (E6-Cm).
3. If the channel is not being locally replicated, then the Multicast Group "Leave" is forwarded to the preceding MTF. In this figure, the "Leave" is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected channel through the multicast replication function(s) to the ITF. The multicast flow for channel A to the ITF is stopped (E5-Cm).
4. When the MTF replicating the channel receives the Leave request, if the ITF was the last entity receiving the replication, the MTF *may* request that the TRC deallocate the access network resources for the replication since they are no longer needed.
5. The TRC signals its completion of the replication deallocation back to the MTF.
6. The ITF requests that the Linear TV Application session be closed by the Linear TV Application (E1).
7. The Linear TV Application signals the IPTV Service Control Function to release the network resources for the Linear TV service (A1).
8. The IPTV Service Control Function requests the RACF to deallocate the network resources for the Linear TV service in the access network. The RACF deallocates the bandwidth needed by the multicast delivery function in the access network (S3).
9. The RACF signals that the bandwidth deallocation is complete to the IPTV Service Control Function (S3).
10. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
11. The TRC signals its acceptance of the policy update (Rp).

12. The IPTV Service Control Function informs the Linear TV Application that the deallocation is complete and the application is now unavailable to the user (A1).
13. The Linear TV Application informs the ITF that the Linear TV service is terminated (E1).

10.2 IMS

Figure 17 shows the flow for Linear TV Service termination in the case of an IMS-based implementation. This flow assumes that Linear TV Service is established to the ITF.

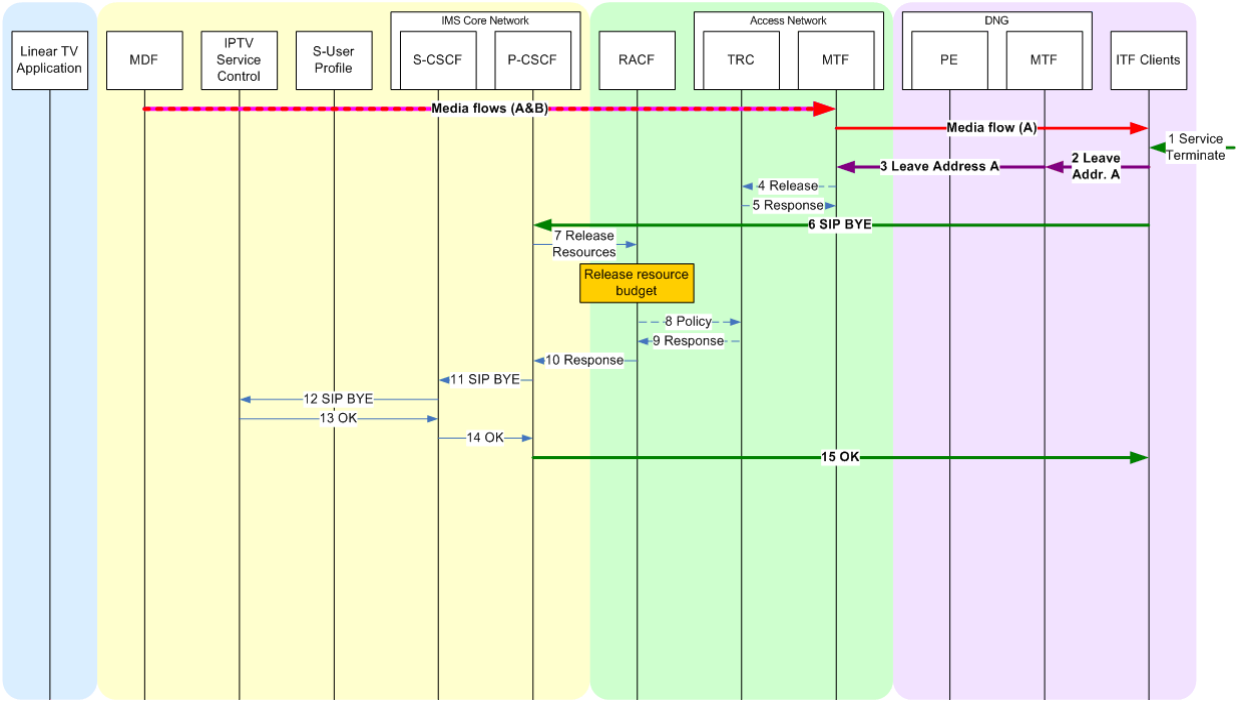

Figure 17: IMS Linear TV Service Termination

1. The Linear TV service termination is triggered through user interaction or other means.
2. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active channel. In this figure, the first MTF is in the DNG (E6-Cm).
3. If the channel is not being locally replicated, then the Multicast Group "Leave" is forwarded to the preceding Multicast Transport Function. In this figure, the "Leave" is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected channel through the multicast replication function(s) to the ITF. The multicast flow for channel A to the ITF is stopped (E5-Cm).
4. When the MTF replicating the channel receives the Leave request, if the ITF was the last entity receiving the replication, the MTF can request that the TRC deallocate the resources for the replication since it is no longer needed.
5. The TRC signals its completion of the replication deallocation back to the MTF.
6. The ITF sends a SIP BYE to the P-CSCF (E3).

7. The P-CSCF requests the RACF to deallocate the network resources for the Linear TV service in the access network. The RACF deallocates the bandwidth needed by the multicast delivery function in the access network (S3).
8. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
9. The TRC signals its acceptance of the policy update (Rp).
10. The RACF signals that the bandwidth deallocation is complete to the P-CSCF (S3).
11. The P-CSCF forwards the SIP BYE to the S-CSCF.
12. The S-CSCF forwards the SIP BYE to the IPTV Service Control Function.
13. The IPTV Service Control Function sends 200 OK to the S-CSCF.
14. The S-CSCF sends 200 OK to the P-CSCF.
15. The P-CSCF sends 200 OK to the ITF. The dialog is now closed and the SIP session is terminated (E3).

11 CONTENT STREAM MEDIA FORMATS AND PROTOCOLS

This section specifies the media profiles formats and protocols, media metadata, and media encapsulations used on the Md reference point for the Virtual Channel Service Stream.

11.1 Video and Audio Encoded Media

An ITF *shall* support the following encoded media profiles: AVC, HE-AAC, and AC-3 as defined in ATIS-0800013, *Media Formats and Protocols Specification*. An ITF *may* support additional encoded media formats and algorithms.

Note -- AC-3 is supported in order to provide compatibility with existing consumer home theater systems which expect native AC-3 digital encoding out of the ITF over common digital interfaces such as SPDIF and HDMI.

11.1.1 Standard Definition Profile

Video:

Required: AVC Main Profile @ Level 3.0

Optional: AVC High Profile @ Level 3.0

Audio:

Required: HE-AAC Profile @ Level 2 (up to 2 channels, restricted to 48 kHz sampling rate)

AC-3 & E-AC-3 Profile - 48 kHz sampling, up to 448 kbps bitrate, up to 5.1 channels

Optional: HE-AACv2 Profile @ Level 2 (restricted to 48kHz sampling rate)

HE-AAC Profile @ Level 4 (up to 5.1 channels, restricted to 48 kHz sampling rate)

HE-AAC Surround Sound Baseline Profile, Level 3, with Level 2 downmix restrictions

11.1.2 High Definition Profile

Video:

Required: AVC High Profile @ Level 4.0

Audio:

Required: HE-AAC Profile @ Level 4 (restricted to 48kHz sampling rate)
AC-3 & E-AC-3 Profile - 48 kHz sampling, up to 448 kbps bitrate, up to 5.1 channels

Optional: HE-AACv2 Profile @ Level 2 (restricted to 48kHz sampling rate)
HE-AAC Surround Sound Baseline Profile, Level 3, with Level 2 downmix restrictions

11.1.3 Picture in Picture Profile

Video:

Required: AVC Main Profile @ Level 1.3

Audio:

Required: None

Optional: HE-AACv2 Profile @ Level 2 (constrained to stereo up to 48 kbps, restricted to 48kHz sampling rate)

11.1.4 Video Formats

The ITF *shall* support either all the video formats for the 30Hz systems, or all the video formats for the 25Hz systems as specified in the tables below.

Table 2: HD Video Formats – 30 Hz Systems

Horizontal Resolution (pixels)	Vertical Resolution (lines)	Scan Type	Frame Rate	Aspect Ratio
1920	1080	P	23.976	16:9
1440	1080	P	23.976	16:9
1280	1080	P	23.976	16:9
960	1080	P	23.976	16:9
1920	1080	I	29.97	16:9
1440	1080	I	29.97	16:9
1280	1080	I	29.97	16:9
960	1080	I	29.97	16:9
1280	720	P	59.94	16:9
960	720	P	59.94	16:9
640	720	P	59.94	16:9

Scan type: I = interlaced, P = progressive

Table 3: SD Video Formats – 30 Hz Systems

Horizontal Resolution (pixels)	Vertical Resolution (lines)	Scan Type	Frame Rate	Aspect Ratio
720	480	I	29.97	16:9, 4:3
704	480	I	29.97	16:9, 4:3
640	480	I	29.97	4:3
544	480	I	29.97	16:9, 4:3
528	480	I	29.97	16:9, 4:3
480	480	I	29.97	16:9, 4:3
352	480	I	29.97	16:9, 4:3
352	240	P	29.97	16:9, 4:3
320	240	P	29.97	4:3

Scan type: I = interlaced, P = progressive

Table 4: PiP HD Video Formats – 30 Hz Systems

Horizontal Resolution (pixels)	Vertical Resolution (lines)	Scan Type	Frame Rate (Note 1)	Aspect Ratio (Note 1)
192	192	P	23.976, 29.97, 59.94	16:9
192	144	P	23.976, 29.97, 59.94	16:9
128	96	P	23.976, 29.97, 59.94	16:9
96	96	P	23.976, 29.97, 59.94	16:9

Scan type: I = interlaced, P = progressive

Note 1 -- Aspect ratio and frame rate of the PiP matches the aspect ratio of the main picture.

Table 5: PiP SD Video Formats – 30 Hz Systems

Horizontal Resolution (pixels)	Vertical Resolution (lines)	Scan Type	Frame Rate (Note 1)	Aspect Ratio (Note 1)
192	192	P	29.97	16:9, 4:3
192	144	P	29.97	16:9, 4:3
128	96	P	29.97	16:9, 4:3
96	96	P	29.97	16:9, 4:3

Scan type: I = interlaced, P = progressive

Note -- Aspect ratio and frame rate of the PiP matches the aspect ratio of the main picture.

Table 6: HD Video Formats – 25 Hz Systems

Horizontal Resolution (pixels)	Vertical Resolution (lines)	Scan Type	Frame Rate	Aspect Ratio
1920	1080	P	25	16:9
1440	1080	P	25	16:9
1280	1080	P	25	16:9
960	1080	P	25	16:9
1920	1080	P	24	16:9
1440	1080	P	24	16:9
1280	1080	P	24	16:9
960	1080	P	24	16:9
1920	1080	I	25	16:9
1440	1080	I	25	16:9
1280	1080	I	25	16:9
960	1080	I	25	16:9
1280	720	P	50	16:9
960	720	P	50	16:9
640	720	P	50	16:9

Scan type: I = interlaced, P = progressive

Table 7: SD Video Formats – 25 Hz Systems

Horizontal Resolution (pixels)	Vertical Resolution (lines)	Scan Type	Frame Rate	Aspect Ratio
720	576	I	25	16:9, 4:3
704	576	I	25	16:9, 4:3
544	576	I	25	16:9, 4:3
528	576	I	25	16:9, 4:3
480	576	I	25	16:9, 4:3
352	576	I	25	16:9, 4:3
352	288	P	25	16:9, 4:3

Scan type: I = interlaced, P = progressive

Table 8: PiP HD Video Formats – 25 Hz Systems

Horizontal Resolution (pixels)	Vertical Resolution (lines)	Scan Type	Frame Rate (Note 1)	Aspect Ratio (Note 1)
192	192	P	24, 25, 50	16:9
192	144	P	24, 25, 50	16:9
128	96	P	24, 25, 50	16:9
96	96	P	24, 25, 50	16:9

Scan type: I = interlaced, P = progressive

Note -- Aspect ratio and frame rate of the PiP matches the aspect ratio of the main picture.

Table 9: PiP SD Video Formats – 25 Hz Systems

Horizontal Resolution (pixels)	Vertical Resolution (lines)	Scan Type	Frame Rate	Aspect Ratio (Note 1)
192	192	P	25	16:9, 4:3
192	144	P	25	16:9, 4:3
128	96	P	25	16:9, 4:3
96	96	P	25	16:9, 4:3

Scan type: I = interlaced, P = progressive

Note 1: Aspect ratio and frame rate of the PiP matches the aspect ratio of the main picture.

11.1.5 General AVC and Transport Stream Bitstream Constraints

The general AVC bitstreams (all Profiles) *shall* be constrained as shown in Table 10.

Table 10: AVC and Transport Stream Coding Constraints

Total Mux TS Bitrate	CBR only (Null TS packets inserted)
Video ES	CBR or Capped VBR
GOP Size	Fixed and/ or adaptive 2 seconds maximum
PES Packet Header	PES packet per video frame is mandatory
Number of PIDs	Maximum of 32 per TS

11.1.6 Bitrate Restrictions

Although AVC constrains the maximum bitrate for each Level (e.g., L1.1=0.192Mbps, L3.0=10Mbps, L4.0=20Mbps), the maximums *shall* be further constrained as indicated in Table 11.

Table 11: AVC Bitrates

Media Profile	Codec Profile/level	Maximum Video Bit rate (Mbps)
SD AVC	MP@L3.0	5
HD AVC	MP@L4.0	10

11.2 Media Metadata and Data

Closed captioning, content advisories (ratings and V-chip technology), active format description and bar data, and legacy vertical blanking interval formats *shall* be carried as described in ATIS-080013, *Media Formats and Protocols Specification* [4].

11.3 Media Encapsulations

For the Linear TV service, the ITF receives media as one or more Virtual Channel Service Streams.

11.3.1 MPEG-2 Transport Streams

An ITF *shall* support the encapsulation of encoded media in an MPEG-2 Transport Streams as described in ATIS-0800013, *Media Formats and Protocols Specification* [[4]], section 6.1, for a Single Program Transport Stream (SPTS). The Program within the SPTS *shall* contain either zero or one video Elementary Stream (ES) *shall* contain zero or more audio ESs, and *may* contain one or more data Program Elements. The Program *shall* contain at least one Program Element.

11.3.2 RTP

MPEG-2 Transport Streams *shall* be encapsulated in RTP according to ATIS-0800013, *Media Formats and Protocols Specification* [[4]].

12 REFERENCE POINTS

The section describes several of the important interfaces between functions involved with Linear TV service. These interfaces are identified by a reference point designation. The reference points are shown in Figure 3 and Figure 4. The flow diagrams in sections 7 through 10 show the flow of information across these reference points for several stages of Linear TV service.

12.1 A1

The interface between the Linear TV Application and IPTV Service Control Function is used for:

- Forwarding service signaling information between the Linear TV Application and the IPTV Service Control Function to request network information and the resources required to deliver multicast Virtual Channel Service Stream.
- Forward signaling information between the Linear TV Application and other functions.

The A1 reference point defined by the ATIS IIF corresponds to the A1 reference point in ITU-T Y.1910 [10].

Message exchanges across this interface are for further study.

12.2 E1

The E1 reference point identifies the interface between the ITF Linear TV client function and the Linear TV Application function. It is used by the ITF to support service and application configuration. The E1 reference point defined by the ATIS IIF corresponds to the E1 reference point in ITU-T Y.1910 [10]. For non-IMS static Linear TV service with static network resource allocation, E1 *may* be used to convey to the ITF the Linear TV Application session bandwidth allocated to the home. For non-IMS Linear TV service with dynamic network resource allocation, E1 *shall* be used to request and release network resources for Linear TV service to an ITF. The Linear TV Application *may* manage resources to individual ITFs or aggregate resources to all ITFs sharing a Linear TV Application session.

Messages across the E1 reference point *shall* comply with HTTP according to ATIS-0800013, *Media Formats and Protocols Specification* [[4]]. The messages across the E1 interface *shall* be authenticated and *may* be encrypted.

The ITF device *shall* send an HTTP Request message using the GET method to the LinearTVApplicationServer identified in the metadata [8].

The format of the message *shall* be:

```
GET /ltvaSession/<action>?subscriberId=<subscriberId>&deviceMac=<deviceMac>
&ltvaBandwidth=<bandwidth requested>  HTTP/1.1
```

Where <action> is

ResourceRequest:	to request or modify Linear TV Application resources.
	A subsequent ResourceRequest supersedes the previous request.
ResourceRelease:	to release Linear TV Application session resources.

Where subscriberId is a character string defined by the Service Provider to represent the subscriber under whom the device is operating.

Where deviceMac is the MAC address of the device.

Where ltvaBandwidth is the bandwidth requested by the ITF for the Linear TV service. Other parameters related to the Linear TV Application session can *may* also be provided. These parameters are for further study.

In response to the HTTP request, the Linear TV Application server *shall* send a response with a status code. For a successful resource request or resource release, HTTP 200 OK *shall* be sent to the ITF. For an unsuccessful resource request or resource release, HTTP 4xx *shall* be sent to the ITF. If the Linear TV Application session request fails from lack of network resources, then HTTP 409 Conflict *may* be sent. Optionally, this response *may* provide information that can be used by the ITF to resolve the conflict and make a subsequent request successful, such the amount of resources that are available.

12.3 E3 (IMS Usage)

The E3 reference point identifies an interface between the ITF Service Control Client and the core IMS functions. It is used by the ITF Service Control Client to initiate a Linear TV SIP session upon attachment to the Linear TV service, change network resources used by the Linear TV SIP session, and to tear down the Linear TV SIP session when terminating the service. It can optionally be used for exchanging service and application discovery information. This reference point corresponds to the IMS-based IPTV E3 interface in ITU-T Y.1910 [10] which corresponds to the Gm reference point defined in ITU-T Y.2021 [11], clause 11.4.3.

12.4 E3 (Non-IMS Decoupled Usage)

This non-IMS reference point is not required for basic Linear TV service. Appendix A describes how IPTV session control *may* be used for non-IMS based Linear TV with trick play modes and for network resource allocation decoupled from the application layer. This reference point corresponds to the non-IMS based IPTV E3 reference point in ITU-T Y.1910 [10], clause 11.3.2.

12.5 E4

The E4 reference point between the CDER function and the ITF's Error Recovery Client provides a means to control the recovery of packets lost as they traversed the network between Multicast Delivery Functions and the ITF. Two alternatives for error recovery *may* be used. One alternative is an application layer FEC (which does not use E4), and the other alternative is RTP retransmissions.

If application layer retransmission is used for packet loss recovery, E4 *shall* be used to request the retransmission of identified packets. The application layer retransmission protocol *shall* be as specified in ATIS-0800013, *Media Formats and Protocols Specification*, section 9.1.2.

12.6 E5-Cm and E6-Cm

Linear TV utilizes IP multicast to efficiently deliver IP-encapsulated video content between video processing sites and ultimately to the ITF. The network-level efficiencies are achieved through the creation of a multicast distribution tree for each multicast group (or aggregate trees where applicable). Each multicast group equates to a Virtual Channel Service Stream. Instead of tuning to a specific stream with all channels being received, the ITF selectively "joins" a multicast group and becomes a leaf node for that group's distribution tree so that only the requested Virtual Channel Service Streams are sent into the consumer domain.

The consumer behavior of "channel surfing" or "channel zapping" corresponds to the frequent addition and removal of leaf nodes for multicast groups delivered to the ITF. The desired consumer experience for this "channel change" operation is to be rapid. The E5-Cm and E6-Cm reference points are used to signal channel changes. The ATIS IIF E5-Cm interface corresponds to the E5-Cm reference point in ITU-T Y.1910 [10].

A more comprehensive treatment of multicast networks will be provided in ATIS-0800019, *Multicast Network Service Specification* [[6]].

12.6.1 Multicast requirements for IPv4

IPv4 multicast *shall* be as defined in ATIS-0800013, *Media Formats and Protocols Specification* [[4]].

The E5-Cm and C6-Cm reference points *should* use IGMPv3 for Linear TV channel change signaling when using IPv4.

The E5-Cm and C6-Cm reference points *may* use IGMPv2 for Linear TV channel change signaling when using IPv4 with the following accommodations:

- For Consumer Domain ITFs that use the optional IGMPv2 for join/leave signaling in legacy platforms, the Network Provider must be willing to provide the IGMPv2-to-IGMP v3 mapping function within the DNG or edge network element to map any (*,G) groups to the proper (S,G) to be used by Source Specific Multicast (SSM).
- If the IGMPv2-to-IGMPv3 SSM mapping function is required, each set of IGMPv2 receivers downstream from the mapping function *shall* have each (*, G_N) all be mapped to a single (S, G_N) as configured within the mapping definition.
- Any network elements allowed to support IGMPv2 *should* provide "fast leave" capabilities to prevent unnecessary forwarding of multicast groups over bandwidth constrained portions of the network such as a DSL loop.

The multicast transport and consumer multicast services *may* require the scoping of multicast groups within a pre-defined regional boundary.

12.6.2 Multicast requirements for IPv6

IPv6 multicast *shall* be as defined in ATIS-0800013, *Media Formats and Protocols Specification* [[4]].

The E5-Cm and C6-Cm reference points *should* use MLDv2 for Linear TV channel change signaling when using IPv6.

The E5-Cm and C6-Cm reference points *may* use MLDv1 for Linear TV channel change signaling when using IPv6 with the following accommodations:

- For Consumer Domain ITFs that use MLDv1 for join/leave signaling, the Network Provider must be willing to provide the MLDv1 to MLDv2 SSM mapping function within the DNG or edge network element to map any (*,G) groups to the proper (S,G) to be used by SSM.
- If the MLDv1-to-MLDv2 SSM mapping function is required, each set of MLDv1 receivers downstream from the mapping function *shall* have each (*, G_N) all be mapped to a single (S,G_N) as configured within the mapping definition.
- Any network elements allowed to support MLDv1 *should* provide "fast leave" capabilities to prevent unnecessary forwarding of multicast groups over bandwidth constrained portions of the network such as a DSL loop.

12.7 Md

The multicast media stream from the Multicast Delivery Function to the Multicast Client is delivered across the Md reference point.

Virtual Channel Service Stream *shall* be encoded, encapsulated in MPEG2 transport streams, and encapsulated in RTP as specified in section 11.

Md *may* optionally support packet loss recovery. Two alternatives *may* be used; one based on an application layer FEC, and the other on RTP retransmissions.

12.7.1 Application Layer FEC

When using application layer FEC, the Md reference point *shall* carry the repair packets associated with a Virtual Channel Service Stream from the MDF to the Multicast Client. The generation of the repair packets and their transport *shall* be as specified in ATIS-0800013, *Media Formats and Protocols Specification* [4], section 9.1.1.

12.7.2 Application Layer Retransmission

When using application layer retransmission, the Md reference point *shall* carry the retransmitted packets. The format and transport of the retransmitted packets *shall* be as specified in ATIS-0800013, *Media Formats and Protocols Specification,* section 9.1.2.

12.8 Multicast Transport Resource Control: Rp

The Rp reference point is used in some resource management scenarios between the RACF and a TRC function in an Access Node or other transport node for resource admission control of multicast and/or unicast flows.

The Rp reference point *may* use the information components and information exchanges specified in ITU-T Y.2111 (RACF R1) [12].

The Rp reference point *may* use DIAMETER for the information exchanges.

Note – The ITU-T has not specified the protocol(s) used for the information exchanges.

12.9 DNG Policy Enforcement Control: Rh' (Informative)

The Rh' reference point allows the RACF to push the policy decisions to the DNG, and also allows the DNG to request admission decisions. The RACF specifies:

- Resources to be reserved and/or committed for Virtual Channel Service Streams;
- QoS handling, such as packet marking and policing to use;
- Gate control (opening/closing) for a media flow; and
- Resource usage information request and report for a subscriber.

ITU-T Y.2111 (RACF R1) [12] specifies the functional and information exchange requirements for the Rh' reference point. The information elements and flows are for further study.

12.10 S3 (Rs)

For non-IMS-based IPTV, the S3 reference point defined by the ATIS IIF identifies an interface between the IPTV service control functional block and RACF for requesting control of transport resources. This reference point corresponds to the S3 interface in ITU-T Y.1910 [10], clause 11.3.7, which corresponds to the Rs reference point in ITU-T Y.2111 [12].

For IMS-based IPTV the ATIS IIF S3 reference point is a reference point between core IMS functions and RACF. It is used by core IMS functions to request RACF to control transport resources. This reference point corresponds to the S3 interface in ITU-T Y.1910 [10], clause 11.4.8, which corresponds to the Rs reference point as defined in ITU-T Y.2111 [12].

APPENDIX A: NON-IMS DECOUPLED SERVICE CONTROL [INFORMATIVE]

Linear TV service involves the allocation or confirmation of the availability of network resources. There are two approaches to resource allocation for non-IMS Linear TV service: *coupled* and *decoupled*. Resources can be allocated when the Linear TV Application session is established (coupled case) or when a media control session is established (decoupled case). Coupled service control is described in Sections 7, 9, and 10. Decoupled service control is described in this section.

A.1 Reference Architecture

Figure 17 shows a functional architecture for non-IMS based Linear TV Service. Figure 17 is the same as Figure 4 with the addition of a Service Control Client in the ITF and the E3 interface for IPTV control protocol between the Service Control Client and the IPTV SCF.

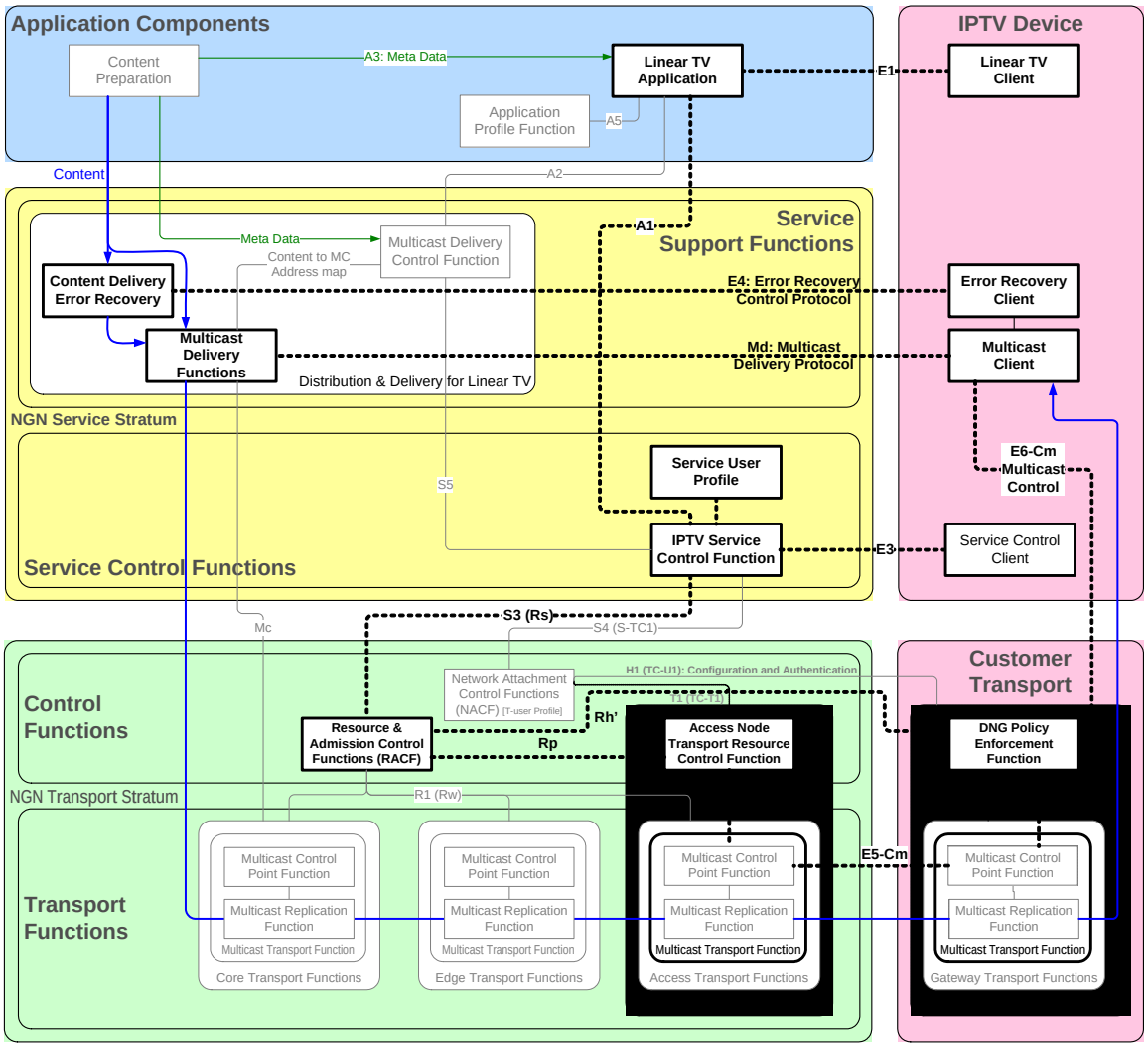

Figure 18: Functional Architecture for non-IMS Linear TV with Decoupled Service Control

The Service Control Client in the ITF device allows the ITF to request network resources when a media control session is established and releases network resources when the media control session is

terminated. Note that the network resources allocation of the Linear TV Application Session is kept synchronized through bi-directional communications between the Service Control Client and the IPTV Application Client. The E3 interface can be used to control a Linear TV Service with trick play modes to Setup, Play, Pause, and Teardown a streaming session.

A.2 Service Attachment and Initial Channel Acquisition

Figure 19 shows the signal flow for Linear TV service attachment and initial resource acquisition in the case of a non-IMS decoupled implementation. As a precondition of this flow, the multicast streams for Linear TV Virtual Channel Service Streams A and B are being delivered to the Access Node. The flow diagram shows representative flows for the selection of the initial Virtual Channel Service Stream. Other sequences for joining a Virtual Channel Service Stream are possible, such as those described in section 8.

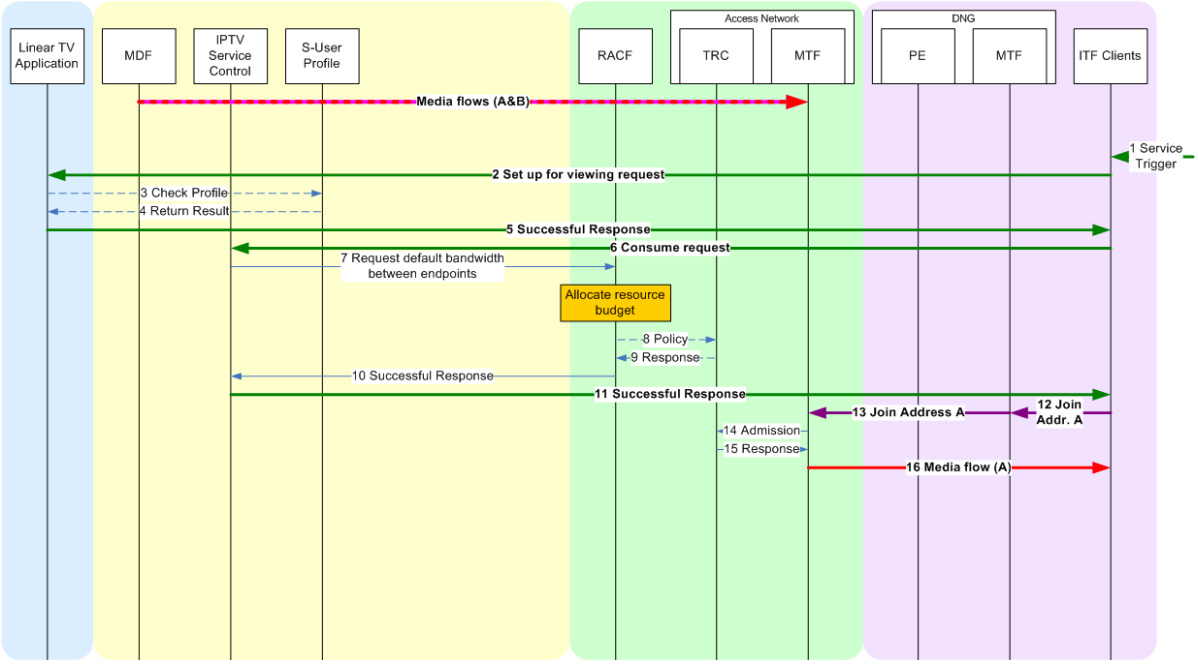

Figure 19: Non-IMS Service Attachment and Initial Channel Acquisition – Decoupled

1. The Linear TV service is triggered through user interaction, preset recording instructions, or other means.
2. The ITF requests the Linear TV Application to establish a Linear TV Application session.
3. The Linear TV Application *may* optionally validate the ITF's connection against the S-User Profile.
4. The S-User Profile returns the profile data which the IPTV Application uses to validate the service connection.
5. The IPTV Application signals the ITF that the Linear TV service setup is complete and is now available to the user.
6. The ITF contacts the IPTV Service Control Function to request the network resources for the reception of the Linear TV service.

7. The IPTV Service Control Function requests the RACF to allocate the access network resources needed to support the path from the MDF to the ITF. The RACF allocates the bandwidth needed by the multicast delivery function in the access network (S3).
8. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
9. The TRC signals its acceptance of the policy update (Rp).
10. The RACF signals that the bandwidth allocation is complete to the IPTV Service Control Function (S3).
11. The ITF receives confirmation of the availability of network resources.
12. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the initial Virtual Channel Service Stream. The initial Virtual Channel Service Stream *may* be a home Virtual Channel Service Stream, the last Virtual Channel Service Stream watched, or some other "default" Virtual Channel Service Stream. In this figure, the first MTF is in the DNG and the initial Virtual Channel Service Stream is Virtual Channel Service Stream A (E6-Cm).
13. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
14. When the MTF receives the "Join" request, it *may* optionally check the admission policy for the multicast stream with the TRC.
15. The TRC signals its approval of the admission request back to the MTF.
16. The MTF configures the multicast forwarding table(s) to deliver the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream A is delivered to the ITF (Md).

A.2.1 Resources Unavailable

If the network architecture allows for the oversubscription of network resources, such as an overabundance of ITFs within the household, then it is conceivable that the RACF may deny the resource request and will send an "INSUFFICIENT_RESOURCES (4041)" Error Code (per ITU-T Q.3301.1) message back to the IPTV Service Control Function over interface S3 during step 10 in the message sequence above. In this event, the following actions *shall* be taken:

1) The IPTV SCF *shall* inform the IPTV Application over the A1 interface that insufficient resources are available. The protocol for this interface is for further study.
2) The IPTV Application *shall* interact with the ITF Linear TV client over the E1 interface to:
    a. Inform the Linear TV client that there are insufficient resources for initial channel acquisition. This message is for further study.
    b. If the Linear TV Application has visibility of all ITFs in the consumer's domain, then it may be able to make suggestions or give instructions to the other Linear TV clients to release network resources and make them available for the Linear IPTV channel acquisition. This interaction is for further study.
3) If the ITF is unable to acquire the desired channel, it *may* request another channel requiring fewer network resources. For instance, if the ITF is unable to acquire an HD channel, it may attempt to acquire an SD channel. This is for further study.
4) Operational error codes (alarms or logging events) *may* be issued into the OSS/BSS system to notify the service and network operators that a full service denial has occurred due to lack of network resources.

A.3 Channel Change

Figure 20 shows the signal flow for a channel change with a bandwidth update in a non-IMS decoupled implementation. As a precondition of this flow, the multicast Virtual Channel Service Stream for Linear TV Virtual Channel Service Streams A and B are being delivered to the Access Node. Virtual Channel Service Stream A is being multicast to the ITF. The flow diagram shows representative flows for the selection of the initial Virtual Channel Service Stream. Other sequences for joining a Virtual Channel Service Stream are possible, such as those described in section 8.

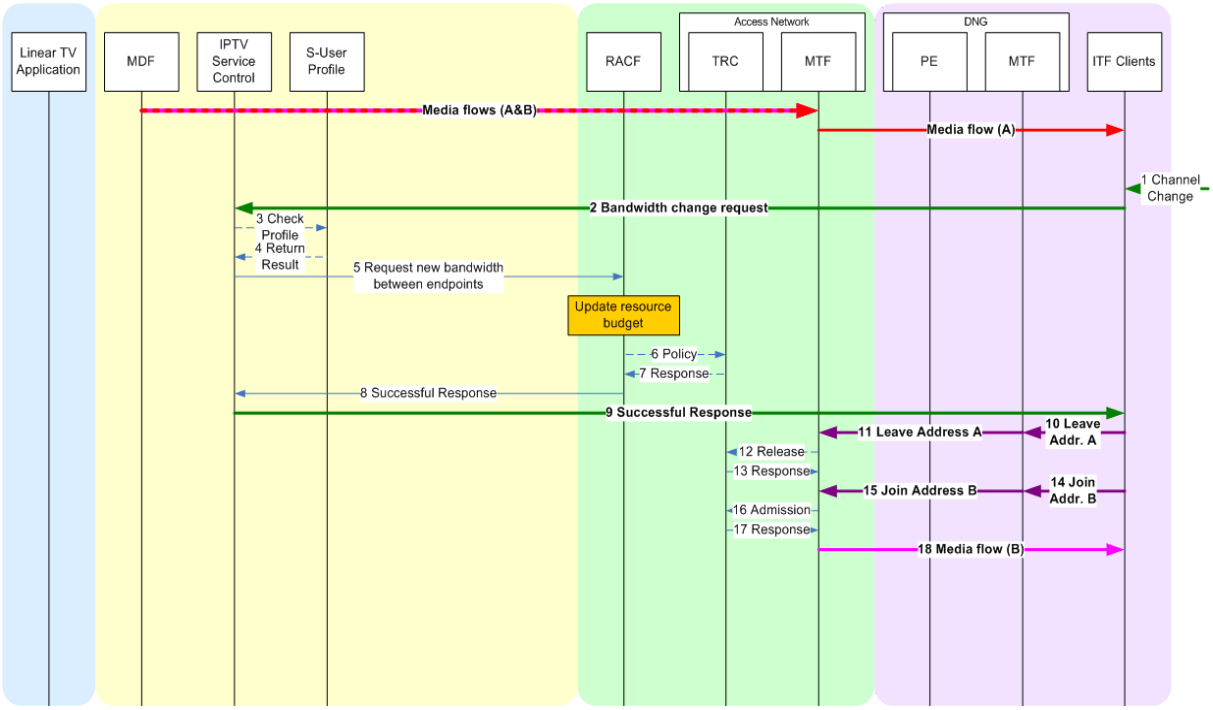

Figure 20: Non-IMS Channel Change – Decoupled

1. A channel change is signaled to the ITF through user interaction or other means. In this flow, the ITF is selecting channel B.
2. The ITF contacts the IPTV Service Control Function to request additional network resources for the selected channel (E3).
3. The IPTV Service Control Function *may* optionally validate the ITF's bandwidth request against the S-User Profile.
4. The S-User Profile returns the profile data which the IPTV Service Control Function uses to validate the bandwidth request.
5. The IPTV Service Control Function requests the RACF to allocate the resources needed to support the path from the MDF to the ITF (S3). The RACF allocates the bandwidth needed by the multicast delivery function in the access network.
6. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC (Rp).
7. The TRC signals its acceptance of the policy update (Rp).

8. The RACF signals that the bandwidth allocation is complete to the IPTV Service Control Function (S3).
9. The IPTV Service Control Function informs the ITF that the allocation is complete (E3).
10. The ITF issues a Multicast Group "Leave" request via IGMP/MLD to the first Multicast Transport Function for the active channel. In this figure, the first MTF is in the DNG (E6-Cm).
11. If the channel is not being locally replicated, then the Multicast Group "Leave" is forwarded to the preceding Multicast Transport Function. In this figure, the "Leave" is forwarded to the MTF in the Access Network. The MTF updates the multicast forwarding table(s) to halt delivery of the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream A to the ITF is stopped (E5-Cm).
12. When the MTF replicating the Virtual Channel Service Stream receives the "Leave" request, if the ITF was the last entity receiving the replication, the MTF can request that the TRC release the resources for the replication since it is no longer needed.
13. The TRC signals its completion of the resource release back to the MTF.
14. The ITF issues a Multicast Group "Join" request via IGMP/MLD to the first Multicast Transport Function for the selected Virtual Channel Service Stream. In this figure, the first MTF is in the DNG and the selected Virtual Channel Service Stream is "channel B" (E6-Cm).
15. If the Virtual Channel Service Stream is not available, then the Multicast Group "Join" is forwarded to the preceding Multicast Transport Function. In this figure, the "Join" is forwarded to the MTF in the Access Network (E5-Cm).
16. When the MTF receives the "Join" request, it *may* optionally check the admission policy for the multicast stream with the TRC. The TRC readjusts the bandwidth to support the multicast Virtual Channel Service Stream.
17. The TRC signals its approval of the admission request back to the MTF.
18. The MTF configures the multicast forwarding table(s) to deliver the selected Virtual Channel Service Stream through the multicast replication function(s) to the ITF. The multicast flow for Virtual Channel Service Stream B is delivered to the ITF (Md).

A.3.1 Resources Unavailable

If the network architecture allows for the oversubscription of network resources, such as an overabundance mixture of SD and HD-capable ITFs within the household, then it is conceivable that the RACF may deny the resource request and will send an "INSUFFICIENT_RESOURCES (4041)" Error Code (per ITU-T Q.3301.1) message back to the IPTV Service Control Function over interface S3 during step 8 in the message sequence above. In this event, the following actions *shall* be taken:

1) The IPTV SCF *shall* inform the IPTV Application over the A1 interface that insufficient resources are available. The protocol for this interface is for further study.
2) The IPTV Application *shall* interact with the ITF Linear TV client over the E1 interface to:
   a. Inform the Linear TV client that there are insufficient resources for the channel change. This message is for further study.
   b. If the Linear TV Application has visibility of all ITFs in the consumer's domain, then it may be able to make suggestions or give instructions to the other Linear TV clients to release network resources and make them available for the channel change. This interaction is for further study.

3) If the ITF is unable to acquire the desired channel, it *may* request another channel requiring fewer network resources. For instance, if the ITF is unable to acquire an HD channel, it may attempt to acquire an SD channel. This is for further study.
4) Operational error codes (alarms or logging events) *may* be issued into the OSS/BSS system to notify the service and network operators that a full service denial has occurred due to lack of network resources.

A.4 Termination

Figure 21 shows the signal flow for Linear TV service termination in the case of a non-IMS decoupled implementation. As a precondition, this flow assumes that Linear TV Service is established to the ITF.

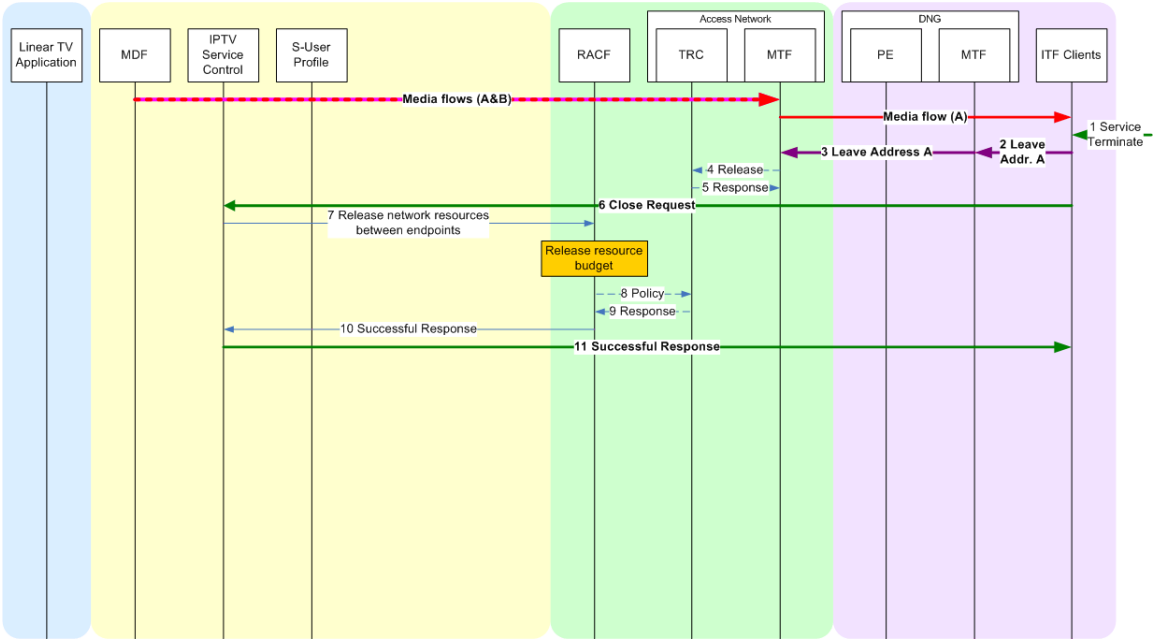

Figure 21: Non-IMS Linear TV Service Termination – Decoupled

1. The Linear TV service termination is triggered through user interaction or other means.
2. The ITF requests that the Linear TV session be closed by the Linear TV Service Control Function (E3).
3. The IPTV Service Control Function requests the RACF to release the network resources for the Linear TV service in the access network (S3). The RACF releases the network resources.
4. If needed, the RACF modifies the policy for the resources managed by the Access Node TRC.
5. The TRC signals its acceptance of the policy update.
6. The RACF signals that the bandwidth release is complete to the IPTV Service Control Function (S3).
7. The Linear TV Service Control Function informs the ITF that the Linear TV Application session is terminated (E3).