Media Networks

Architectures, Applications, and Standards

Edited by

Hassnaa Moustafa and Sherali Zeadally

CRC Press
Taylor & Francis Group

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
Version Date: 20120322

International Standard Book Number: 978-1-4398-7728-9 (Hardback)

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

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Preface

Recent advances in networking technologies, personal, entertainment and home equipment, and multimedia services have dramatically changed users' consumption models for multimedia and audiovisual services creating a new category of users known as prosumers (producers–consumers). Consequently, media networks is an emerging subject that currently attracts the attention of research and industrial communities due to the expected large number of services and applications in the short-term accompanied by a strong change in users' consumption model and style.

Media Networks: Architectures, Applications, and Standards studies media networks with special attention devoted to video and audiovisual services and aims to be a comprehensive and essential reference on media networks and audiovisual domain, to fill a gap in the market on media networks, and to serve as a useful reference for researchers, engineers, students, and educators. Industrial audiences are also expected to be up-to-date with the current standardization activities in this domain, the deployment architectures, network technologies, technical challenges, users' experience, and killer applications.

This book helps in learning the media network, which is an emerging type of network, and in acquiring a deep knowledge of this network and its technical and deployment challenges through covering media networks basics and principles, a broad range of architectures, protocols, standards, advanced audiovisual and multimedia services, and future directions.

The book is divided into three parts: Part I focuses on digital TV in Chapters 1 through 6; Part II covers media content delivery and quality of experience (QoE) in Chapters 7 through 14; and Part III gives special attention to user-centricity and immersive technologies that take into account advanced services personalization, immersive technologies architectures and applications, e-health, and societal challenges in Chapters 15 through 23.

This book has the following salient features:

- Provides a comprehensive wide-scale reference on media networks and audiovisual domain

- Covers basics, techniques, advanced topics, standard specifications, and future directions
- Contains illustrative figures enabling easy reading

We owe our deepest gratitude to all the chapter authors for their valuable contribution to this book and their great efforts. All of them were extremely professional and cooperative. We express our thanks to Auerbach Publications (Taylor & Francis Group) and especially Richard O'Hanley for soliciting the ideas in this book and working with us for its publication, and Jennifer Ahringer for her huge efforts in the production process. Last but not least, a special thank you to our families and friends for their constant encouragement, patience, and understanding throughout this project.

The book serves as a comprehensive and essential reference on media networks and is intended as a textbook to teach this emerging type of network, or to help readers acquire a deep knowledge of these networks and the technical and deployment challenges that must be overcome to enable us to carry out and continue research in this area.

We welcome and appreciate your feedback and hope you enjoy reading the book.

Hassnaa Moustafa
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Editors

Hassnaa Moustafa has been a senior research engineer at France Telecom R&D (Orange Labs), Issy Les Moulineaux (France) since January 2005. She obtained her tenure in computer science (HDR) in June 2010 from the University of Paris XI, her PhD in computer and networks from Telecom ParisTech in December 2004 and her master's in distributed systems in September 2001 from the University of Paris XI. Her research interests include mobile networks, basically *ad hoc* networks and vehicular networks. Routing, security, authentication and access control are the main areas of her research interests in these types of networks. Moreover, she is interested in NGN, IPTV, services' convergence and personalization.

Dr. Moustafa is a regular member of the IETF and a member of the IEEE and IEEE ComSoc. She manages a number of research projects at France Telecom and has many publications in a number of international conferences including *ICC*, *Globecom*, *PIMRC*, *VTC*, *Mobicom*, among others, and in a wide number of international journals. Dr. Moustafa edited books and coauthored a wide range of book chapters with CRC Press. She has also served as chairperson and co-chairperson at several international conferences and workshops and has coedited several journal special issues. In addition, she served as a TPC member for a wide number of international conferences and workshops including *IEEE ICC*, *IEEE Globecom*, and several *ACM* conferences, and served as a peer reviewer for several international journals including *IEEE Transactions on Wireless Communications*, *IEEE Transactions on Parallel and Distributed Systems*, *IEEE Transactions on Mobile Computing*, *IEEE Transactions on Broadcasting*, *Wiley Wireless Communications and Mobile Computing Journal*, *Springer Telecommunication Systems Journal*, *Springer Annals of Telecommunications*, *Elsevier Computer Networks*, and *IEEE ComSoc*.

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Introduction

Recent advances in networking technologies, personal, entertainment, home equipments, and multimedia services have dramatically changed users' consumption models for multimedia and audiovisual services creating a new category of users known as prosumers (producers–consumers). Users are now empowered with low-cost technologies that enable them to create and contribute a whole range of different media types and applications and making them available through various ways such as UGC (User Generated Contents) on YouTube or Dailymotion. On the other hand, the users' consumption model for video and audiovisual services has changed; consumption of video services during mobility and through different kinds of portable devices (such as tablet devices) is a drastic increase. 3D content is also of great interest, and users' content sharing is becoming increasingly popular. Entertainment and social services are experiencing an unprecedented growth while interactivity and personalization of services are also achieving a great success. All these dramatic changes in technologies, user behaviors, and expectations are making network operators, equipment manufacturers and service and content providers work hard to cope with this evolutional trend in the media domain and to change their traditional business models to adapt to this evolution and handle the emergence of multiple actors. In addition, over-the-top (OTT) players are continuously introducing new actors who provide new multimedia and audiovisual services through numerous innovative applications that are accessible through the Internet (including peer-to-peer applications).

Consequently, media networks are an emerging area that is currently attracting the attention of research and industrial communities because of the expected rapid growth of a large number of services and applications accompanied by strong changes in users' consumption model, habits, and lifestyle.

This book, *Media Networks: Architectures, Applications, and Standards*, explores media networks focusing on video and audiovisual services. Our goal is to present a comprehensive and essential reference on media networks and the audiovisual domain, to fill a gap in the market on media networks, and to serve as a useful reference for researchers, engineers, students, and educators. Industrial audiences are also expected to be up-to-date with the current standardization activities on this domain, the deployment architectures, network technologies, technical challenges, users' experience, and killer applications.

The book will help newcomers to the area of media networks, which are an emerging type of network, to acquire a deep knowledge of these networks and their technical and deployment challenges. The book covers a range of topics related to media networks including fundamental definitions, basics and principles, a broad range of architectures, protocols, standards, advanced audiovisual and multimedia services, and future directions.

The book is broadly divided into three parts: Part I focuses on Digital TV in Chapters 1 through 6. Then, Part II covers media content delivery and Quality of Experience (QoE) in Chapters 7 through 14. Finally, Part III gives special attention to User-Centricity and Immersive Technologies that take into account Advanced Services Personalization, Immersive Technologies Architectures and Applications, E-Health, and societal challenges in Chapters 15 through 23.

In Part I of the book, Chapter 1 presents Digital TV technologies along with their deployment architectures as well as the role of the major contributors (such as network operators, service providers, content providers, and manufacturers) and the future trends. Chapter 2 gives an overview on Open IPTV general concept, services, architectures, content delivery, market aspects, and business models. Chapter 3 presents an overview of Mobile TV along with recent Mobile TV standards that have been recently deployed, identifying some of the technological and deployment challenges that need to be addressed to achieve cost-effective service distribution together with business models for Mobile TV. Chapter 4 is about connected TV. It presents an overview of connected TV technology, various past efforts made in the past in the connected devices area and gives an overview on some of the related standardization efforts. Chapter 5 presents an overview on 3D video. This chapter identifies some of the requirements that must be met to enable 3DTV services over an end-to-end delivery chain. It describes related standardization efforts and identifies subsequent challenges to introduce new 3D video services with enhanced 3D quality of experience. Chapter 6 describes standardization activities on digital TV including IPTV, Mobile TV, and Content Delivery Networks (CDNs).

In Part II of the book, Chapter 7 introduces the Future Internet discussing Future Internet Media applications, demonstrating the new vision of collaboration between Internet services and underlying networks. Chapters 8 and 9 cover Information-Centric Networks (ICN) focusing on ICN solution approaches highlighting the major challenges that need to be considered to enable ICN-related applications (such as Web, VoIP), technical aspects (such as Naming and Addressing, Routing, Security, Resources Management, and Content Caching) and related standardization efforts. Chapters 10 and 11 focus on CDN introducing the recent changes in the Internet eco-systems that have led to an increased interest in CDNs. They present CDNs architectures that are being deployed while considering the different technical challenges and standardization efforts related to CDN issues, and also present an overview on CDN actors and market trends in this area. User satisfaction and experience are becoming increasingly important factors for many consumer-related businesses and media networks and services are no exception. To evaluate customer satisfaction and user experience, QoE is being used as a metric. Chapters 12 through 14 focus on QoE in Future Media Networks. These chapters describe QoE-related topics which include different transport protocols, compression technologies, users' consumption trends, QoE evaluation methods, QoE introduction in CDN architectures, and QoE considerations in 3D media delivery systems.

In Part III of the book, Chapter 15 focuses on perceived QoE in user-centric multimedia applications. Chapter 16 identifies the deficiencies in current delivery mechanisms for immersive 3D media and presents solutions based on content-aware processing, coding, and adaptation techniques. Chapters 17 and 18 focus on services personalization presenting an overview on IPTV services personalization and the context-awareness principle used in services personalization. Chapters 19 and 20 consider metadata exploitation and semantically linked media for user-centric services in Future Media networks, respectively. Chapter 21 gives an overview on Telepresence systems. This chapter presents features differentiating them from conventional videoconferencing systems and describes technical constraints and requirements of Telepresence systems in addition to providing a review of ongoing standardization efforts. Chapter 22 discusses the current trends in Media Networks aimed at improving the effectiveness of healthcare particularly the technological aspects that aim to encourage and engage users in their own rehabilitation in community and home settings. Finally, Chapter 23 concludes the book by describing some of the societal challenges for Networked Media.

I

DIGITAL TV

Chapter 1

Digital TV

Hassnaa Moustafa, Farhan Siddiqui,
and Sherali Zeadally

Contents

1.1 Introduction

Digital TV market evolution is presenting new entertainment services and business opportunities for network operators, service providers, and contents providers. *Consumers* are increasingly demanding instant access to digital content through various terminals. Another emerging trend is that *communication devices* are becoming entertainment devices, while the continuous proliferation of fixed and mobile broadband is providing faster and more reliable access to digital contents. Furthermore, *Content providers* are looking for new channels of distribution and revenue streams. The advances in digital TV technology enable a new model for service provisioning, moving from traditional broadcaster-centric TV services to a new interactive and user-centric model.

This chapter provides a detailed review of digital TV technologies along with the evolution of analogue TV to digital TV. We describe the history of Internet Protocol Television (IPTV) together with the real motivations for this technology. We also review the various architectural components of IPTV and present related IPTV standardization activities. An additional important contribution of this chapter is the focus on the different digital TV competitors along with deployment challenges that need to be overcome to fully enable digital TV technology anywhere, anytime, from any device.

1.2 History and Current Status

Today's industry is migrating from conventional analog TV to a new era of digital TV technology through upgrading of the current wired/wireless networks and the deployment of advanced digital platforms. In this context, IPTV has emerged as a technology delivering a stream of video content over a network that uses the Internet Protocol (IP). IPTV is mainly seen as traditional TV delivered over the IP using a broadband network, which is most commonly high-speed Digital Subscriber Line (xDSL). The delivery chain of IPTV is similar to that of cable, satellite or terrestrial transmission, and under the control of an operator. The history of IPTV dates back to the 1990s when several works and trials were carried out for the digital television over Asymmetric Digital Subscriber Line (ADSL). The deployment of IPTV technology began in the late 1990s with the implementation of the broadband ADSL. During this period many industrial companies started to develop IPTV solutions such as Set-Top-Box (STB) terminals, service platforms, and Video on Demand (VoD) servers. IPTV is currently seen as a part of the triple-play and quadruple-play bundles that are typically offered from network operators worldwide.

IPTV provides the traditional linear TV programs in the form of Broadcast (BC) services together with VoD, and Personal Video Recording (PVR) services. Moreover, some value-added services include Electronic Program Guide (EPG), widgets, traffic, and weather services. IPTV can be generally defined as a system that enables the delivery of real-time television programs, movies, and other types of interactive video content and multimedia services (audio, text graphics, data) over a managed IP-based network to provide the required level of Quality of Service (QoS), Quality of Experience (QoE), and interactivity [1]. The type of service providers involved in deploying IPTV services range from large telephone companies and private network operators in different parts of the world to cable and satellite TV carriers.

An emerging parallel approach for digital TV is Internet TV (sometimes called Internet Video or unmanaged IPTV). Unlike IPTV, Internet TV is any video delivered over the public Internet to PCs and some dedicated boxes while relying on the same core base of IP technologies. The debate on which is the winner among IPTV and Internet TV is long and no predictions could be done so far. The Internet TV approach is mainly different from the classical IPTV approach in that it leverages the public Internet to deliver video for end-users without using secure dedicated managed private networks as those used by IPTV. Consequently, Internet TV could not assure a guarantee for the TV QoE because some of the IP packets may be delayed or lost and the video streams are hence transmitted to the user in a best effort fashion with a resolution that might be low. In contrast, the Internet TV has no geographical limitations where TV service can be accessed from any part of the world as long as one has Internet access. Internet TV also consists of some real-time offerings (such as sports and political events) as well as a large proportion of User Generated Content (UGC), like YouTube (UGC is almost called Internet Video). Delivery of this content is mostly under the control of content producers, aggregators, and Over The Top (OTT) operators.

Advances in digital TV technologies enable a new model for service provisioning, moving from traditional broadcaster-centric TV services to a new user-centric TV model. The change in the users' behaviors from active to passive, the content digitization allowing easier distribution, and the support of broadband-enabled technologies have changed our TV experience. Digital TV allows TV services to evolve into true converged services, blending aspects of communications, social media, interactivity, and search and discovery in new ways. These efforts address the growing consumer desire for greater personalization and customization of TV experiences and are promising in allowing low-cost services for end users and a revenue system for broadcasters based on personalized advertising methods, as well as new business opportunities for network operators, service providers, and many more actors. Indeed, the digital TV market evolution is enabling new entertainment services: (i) consumers are increasingly demanding instant access to digital content through various terminals; (ii) communication devices are becoming entertainment devices; (iii) the increasing proliferation of fixed and mobile broadband networks are providing faster and more reliable access to digital content, (iv) content providers are looking for new channels of distribution and revenue streams. The participation of several actors along the digital TV value chain has an important potential in its market evolution, allowing content/service providers and network operators to create new business opportunities and to promote smart services, while enhancing users' interactions with the digital TV system and the QoE which in turn increases users' satisfaction and the acceptability of services.

1.3 Digital TV Market

1.3.1 Digital TV Deployment and Investment Trends Worldwide

The Internet has fundamentally changed our habitual ways of interacting with content and each other. The user is changing his/her media consumption from passive to interactive mode and gets used to personalized, sociably usable, and interactive content. In this context, the digital media industry is considered as a basic element in the entertainment sector. Digital TV is being used to deliver entertainment services where Set-Top-Boxes (STBs) are seen as the key to digital TV service distribution around the world. Indeed, the digital TV market has been a great success throughout the world. In the next few years, digital sales of STBs are expected to reach almost 150 million worldwide. In the United States, IPTV subscribers in Q1/2009 reached 583,000 combined for U.S. Verizon and AT&T compared with 114,000 subscribers for the two largest cable operators, Comcast and Time Warner during the same period. The United States, together with Japan, Canada, China, South Korea, and Germany are considered the leaders in terms of High-Definition Television (HDTV). However, the penetration of HDTV in the Digital TV market is lower than 10% for TV homes worldwide and the majority of these HDTV subscribers are located in the United States. This is slowly changing with the prices coming down somewhat and an increasing focus from broadcasters on developing High Definition (HD) content. In Europe, France presents one of the Europe's key markets for telecom convergence and has Europe's largest IPTV sector, adopting triple play bundles. The United Kingdom has established itself as a leader in the European digital media marketplace, where digital TV is expected to grow on average 12% every year [2]. During 2007, the triple play model in Europe expanded dramatically with the increasing number of incumbents and second-tier operators who developed services to attract new customers and reduce loss of customers. In addition, the quad-play offers have also emerged in 2007, mainly in the United Kingdom [2]. The entrance of the telecommunication companies into the television business has created new and significant competition for the traditional pay television platforms. The installed base of homes with network entertainment centers worldwide (2009–2011) is illustrated in Table 1.1.

According to estimates from Bernstein Research, video platforms from AT&T and Verizon are set for steady growth. Fiber Optic Service (FiOS) TV from Verizon is projected to hit the 2 million mark by the end of 2011 and reach as many as 4.7 million customers in 2012, according to the Wall Street Bernstein firm. U-verse TV from AT&T is predicted to hit the 801,000 customer mark by the end of the

Table 1.1 Homes with Network Entertainment Worldwide

Year	*Homes (million)*
2009	115
2010	140
2011	180

Source: Data from BuddeComm Estimates, 2008.

year, and U-verse TV could hit an estimated 5.5 million subscribers in 2012, according to Bernstein's predictions (Figure 1.1).

1.3.2 IPTV Market

With the advent of the digital TV industry and the wide deployment of broadband networks, interactive TV (iTV) is attracting a lot of interest. Many TV programs now have an interactive element to them. The Multimedia Home Platform allows the progress of Television-commerce (T-commerce–electronic commerce using digital television) around the world. iTV and interactive content are also being incorporated into mobility, with further progress expected throughout the next two years [2]. In this context, IPTV is considered as a revolutionary delivery system that can incorporate interactivity and other value-added applications running over an existing broadband IP platform. Telecommunication companies view IPTV as a tremendous opportunity for future revenue growth in terms of telco investment. In fact, many IPTV market forecasters predict that in the coming years global IPTV subscribers will generate substantial increases in revenues. IPTV is projected to be a

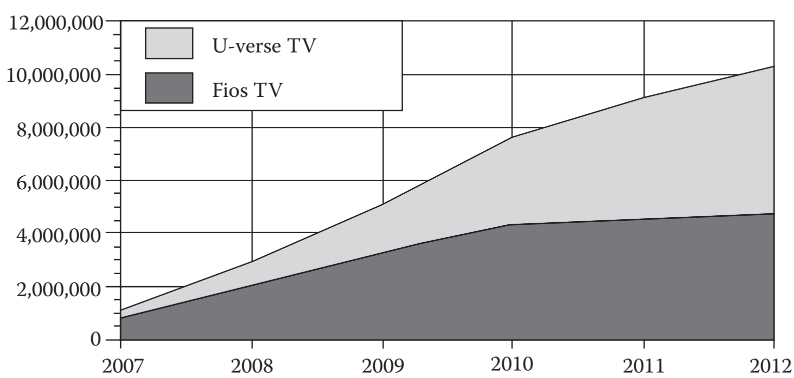

Figure 1.1 Telecos platform growth projections. (Data from Bernstein Research (4/2008) The Bridge 2008.)

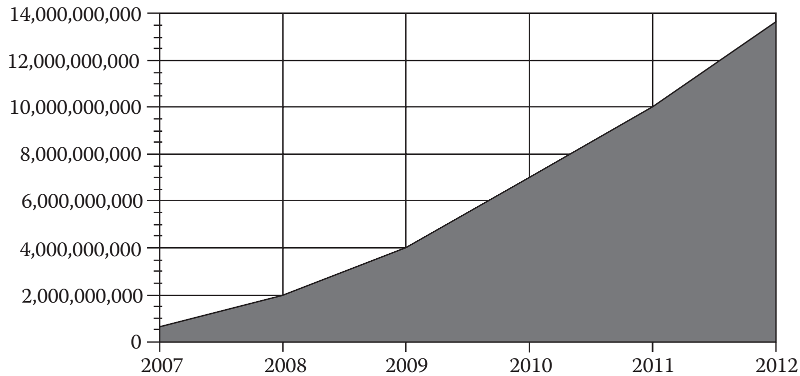

Figure 1.2 US IPTV revenues. (Data from Strategy Analytics (3/2008) The Bridge 2008.)

fast-growing sector over the next 4 years. The US IPTV market is expected to grow to about 15.5 million by 2013 (Figure 1.2). While IPTV holds less than 5% share of the total television households in 2009, the percentage is expected to approach 13% in 2013. The Multimedia Research Group (MRG) [3], a market research firm that publishes market analyses of new technologies, is forecasting that the number of global IPTV subscribers will grow from 26.7 million in 2009 to 81 million in 2013, a compound annual growth rate of 32% (as illustrated in Figure 1.3) [4].

According to forecasts from the Telecommunication Management Group (TMG), IPTV has succeeded in countries with relatively low pay-TV penetration but with a high broadband usage, which is the case among some countries in Europe, home to the largest number of IPTV subscribers worldwide. In terms of service

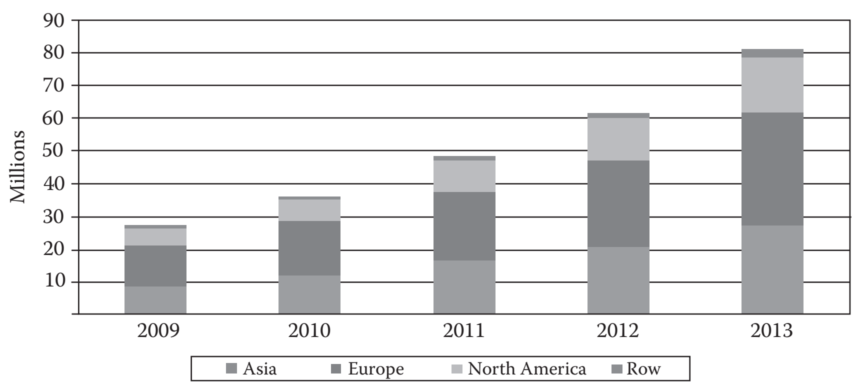

Figure 1.3 Global IPTV subscriber forecast. (Data from Global IPTV subscribers, Copyright ÓMRG, Inc. 2009.)

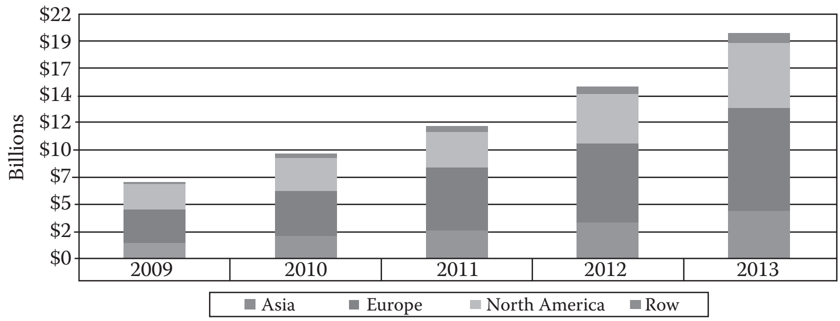

Figure 1.4 Global IPTV service revenue forecast. (Data from Global IPTV service revenue. Copyright Ó MRG, Inc. 2009.)

revenue, the global IPTV market was $6.7 billion in 2009 and is expected to grow to $19.9 billion in 2013, a compound annual growth rate of 31% (as illustrated in Figure 1.4). By 2013, Europe and North America will generate a larger share of global revenue due to very low Average Revenue Per User (ARPUs) in China and India, the fastest growing (and ultimately, the biggest markets) in Asia [5].

Service providers are also expected to increase their expenditures on IPTV equipment over the next 5 years, with spending reaching as high as $8.9 billion in 2013 (Figure 1.5). The IPTV world forum has highlighted the operators' need to focus on content and on making this content more accessible to consumers.

Indeed, operators have been increasing the amount of content they offer to their subscribers; most IPTV services now have portfolios of dozens of TV channels, supplemented by, on average, 5000 VoD assets. However, in many cases, this investment in content has failed to result in a corresponding increase in revenue because consumers are unable to find the programs they want due to poor user interfaces. To address this issue, Belgacom (which runs one of the most successful IPTV services in Western

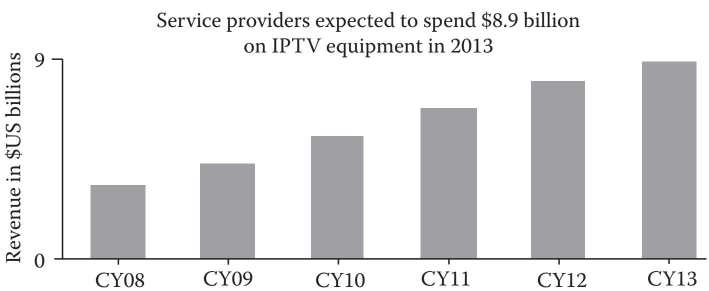

Figure 1.5 Service providers investments in IPTV. (© Infonetics Research, IPTV and Switched Digital Video Equipment, Services and Subscribers. Quarterly Market Size, Share and Forecasts, March 2009.)

Europe, in terms of penetration of its broadband subscriber base) created its own dedicated TV channels for its football content, as well as three themed zones (Adrenaline, Family, and Premiere) for its movie VoD content: each zone offers easy access to four recommended titles, which are refreshed regularly. The growing importance of making content more accessible to consumers was also underlined by the emerging content recommendation engine market [6], using algorithms that analyze data collected from a range of sources, including user profiles and ratings, patterns of content consumption, and recommendations from social networks. These engines can be used not only to suggest relevant viewing choices to the subscriber, but also to target advertising dynamically. Consequently, this will enable IPTV operators to increase their revenues for valuable content both through increased subscription of VoD services and through advertising revenue. Content monetization and customization are still in the early stages of development and, in order for them to mature, various issues still need to be addressed—such as the fact that the TV continues to be a communal, rather than an individual device, and the various concerns about privacy and targeted advertising.

1.4 IPTV

IPTV has been driven several drivers and has become a practical reality that is both commercially and technologically successful. These drivers include advances in digital technologies and consumer electronic devices, broadband evolution, Web services enrichment, social networking popularity, increased entertainment demands, and various business and commercial needs.

The digitization of television allowed for starting a new TV era where IPTV will play a crucial role. Indeed, most satellite, terrestrial, and cable TV providers have started to switch their delivery platforms from analog to digital and most video production studios are now using digital technologies to record and store content with improvements in compression techniques for digital video content. As a result, there is no longer a need to support legacy analog technologies and the adoption of IP-based video content is gaining popularity. In addition, the pervasiveness of the Internet has brought the need for high speed, always on Internet, access to the home. This need is being satisfied through broadband access technologies such as DSL, cable, fiber, and fixed wireless networks. The adoption of broadband Internet access by many households in turn has become a very powerful motivation for consumers to start subscribing to IPTV services. It is worth noting that people's homes and lifestyles are evolving, adopting a range of new technologies that help making life easier and keeping consumers entertained. Digital entertainment devices such as gaming consoles, multiroom audio systems, digital STBs, and flat screen televisions are now quite common, and the migration of Standard Definition (SD) Television to HDTV has increased consumers demand on entertainment and multimedia services, all allowing for continuous evolution of home networks and creating the notion of the *Home Cinema*. Inside the home, technologies enable the "whole home" ecosystem to communicate, and emerging Over The Top (OTT) networking technologies expand the reach of the "home" everywhere in the community and the world, with or without reliance on traditional core network infrastructure [7]. Besides, the dramatic reduction in costs of PCs, the number of households that own multiple PCs and smart devices is rapidly increasing creating a rich environment for home multimedia network services. Moreover, the mobile user experience and the vast offers of services for smart phones (including unlimited Internet access) increases the demand of mobile users for TV and video streaming services on mobile.

Web services are also observing an explosive growth with low-cost application developments and low cost of disk space both local and "in cloud." This triggers the IPTV evolution with advanced services as Personal Video Recording (PVR) capabilities on one hand, and on the other, the Internet TV is in continuous evolution allowing not only video delivery over Internet but also User Generated Content (UGC).

Finally, some business and commercial drivers also play an important role in the evolution of IPTV technology. The increased competition is forcing many telecommunication companies to start the process of offering IPTV services to their subscribers and to extend its limit to include broadband Internet connections and digital telephony forming what is known as the *triple-play* bundle (that currently observes an increasing penetration rate through billions of subscribers worldwide) as well as the *quadruple-play* bundle through adding wireless Internet connectivity. Besides, satellite and terrestrial companies are allowed to provide their customer bases with IP-based pay TV services as a means of opening new market opportunities and contributing to this new business challenge.

1.5 IPTV Architecture Components and Different Standards

The IPTV chain is mainly composed of four domains: (i) the *Consumer Domain* interfacing with the end user, (ii) the *Network Provider Domain* allowing the connection between the consumer domain and the service provider domain, (iii) the *Service Provider Domain* which is responsible for providing consumers with the services, and (iv) the *Content Provider Domain* which owns the content or is licensed to sell contents. In practice, the service provider could act as a content provider.

1.5.1 High-Level Functional Architecture of IPTV

The IPTV functional architecture (Figure 1.6) identifies five different functions in an IPTV system. These functions include Content Provisioning, IPTV control, Content Delivery, End system, and IPTV System Management/Security [8].

- *Content provision:* This function prepares IPTV contents. After the contents are ingested from content sources into the Content Provision, they are converted

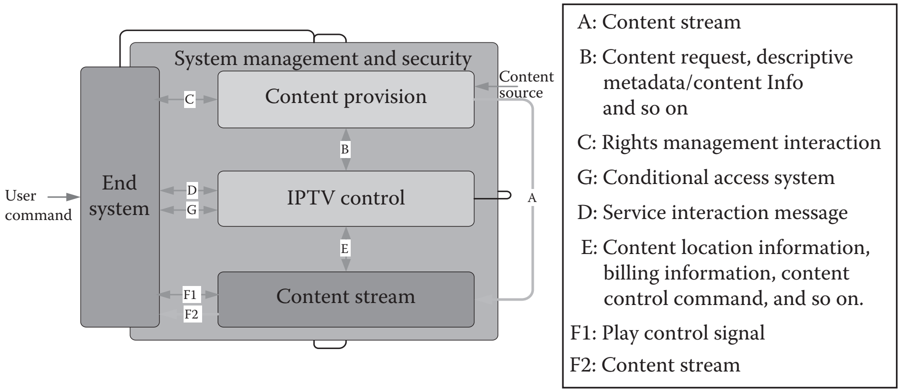

Figure 1.6 IPTV functional architecture. (Adapted from ITU Telecommunications Standardization Sector: Focus Group on IPTV Draft, *Classifications of IPTV Service and its Meaning*, FG IPTV-ID-0026, 2006.)

into the designated format and encrypted for right management by the Content Provision Functions. After this process, the contents are transferred to the Content Delivery functions.

- *IPTV control:* This function is responsible for IPTV service preparation control and other functions such as packing contents into services, generating content distribution policy, and publishing these deliverable services. IPTV Control is also responsible for issuing the content license to users according to their subscriptions.
- *Content delivery:* This function delivers contents which are packed in IPTV services to the end system. To support services such as VoD and Personal Video Recoding (PVR), and to achieve transport efficiency, the contents are stored/cached within the Content Delivery. When the end user requests a portion of the content, the IPTV Control functions request the Content Delivery functions to provide the content data.
- *End system:* The end system is responsible for collecting control commands from users, and interacting with IPTV Control functions to get service information, content license and keys for decryption. The end system also provides the capability for content acquisition, content decrypting, and decoding.
- *IPTV system management and security:* System Management and Security functions are responsible for the overall system status monitoring, configuration, and security aspects.

1.5.2 Initiatives to Standardize IPTV

With the advancements in IPTV technologies, the delivery of interactive and personalized multimedia services including IPTV services over Next Generation

Networks (NGNs) becomes the objective of several standardization bodies such as ITU-T (International Telecommunication Union-Telecommunication) [9], ETSI/TISPAN (Telecoms & Internet converged Services & Protocols for Advanced Networks) [10], Open IPTV Forum [11], Alliance for Telecommunications Industry Standard (ATIS) [12], and 3GPP [13].

Two main architectures have been approved for IPTV delivery, namely by the ITU-T and the ETSI/TISPAN. The *ITU-T* formed a Focus Group on IPTV (FG IPTV) with the mission of coordinating and developing the global IPTV standard architecture based on a client–server architecture with the addition of a service delivery platform while considering the following key areas: Digital Rights Management (DRM), QoS/QoE metrics, Metadata, and interoperability and test. The *ETSI/TISPAN* emerged with the mission to develop specifications for next generation wireless and fixed networking infrastructures, defining IPTV as a Next Generation Network (NGN) service and utilizes the IP Multimedia Subsystem (IMS). This architecture can connect to legacy networks via gateways that form part of the IMS or any other Session Initiation Protocol (SIP)-based infrastructure. On the other hand, the *ATIS* has launched a subgroup called IPTV Interoperability Forum (IIF) to mainly produce an overall reference architecture for deploying IPTV services while focusing on four major areas, infrastructure equipment, content security, interoperability testing, and QoS.

Besides, the *Open IPTV Forum* has the objective to work with other standardization bodies to define end-to-end specifications for delivering IPTV services across a variety of different networking architectures. Mobility service entirely based on the IP Multimedia Subsystem (IMS) is considered within the Open IPTV Forum and is a set of specifications from the 3GPP for delivering IP multimedia to mobile users.

As for the digital TV services transmission, the Digital Video Broadcast (DVB) [14] is specifying technologies allowing interoperable STBs within the DVB-IP Group [15] to provide a sort of Plug and Play STBs receiving IPTV service over IP. The DVB has also defined the Multimedia Home Platform (MHP) [16] which is a Java-based middleware for IPTV which is interoperable with some propriety IPTV middleware. With the publication of the first set of DVB standards for IPTV, services can be launched that benefit from the advantages that come with open standards. The industry has particularly welcomed the standardization of the Broadband Content Guide, similar to the Electronic Programming Guide (EPG) used in "traditional" digital TV, and the Service Discovery and Selection mechanism. Due to the standardized information availability, the Service Discovery and Selection (SD&S) mechanisms allow a STB to efficiently recognize the multicast and unicast offerings of IPTV service operators on a broadband network. Many DVB member companies have participated in the working groups and are now integrating DVB-IPTV into their product lines. DVB's interactive middleware specifications, Multimedia Home Platform (MHP) and Globally Executable MHP (GEM) also include IPTV profiles. GEM-IPTV has been deployed in more than 900,000 Set-Top Boxes in South Korea.

In improving the (de)compression and coding of content, the Moving Pictures Experts Group (MPEG) [17] is developing several specifications that are relevant to IPTV, such as the MPEG-E standard [18] comprising of various Application Programming Interfaces (APIs). In parallel, the MPEG-7 [18] is representing specific low-level features of the content, such as visual (e.g., texture, camera motion) or audio (e.g., melody) features and also metadata structures for describing and annotating content. MPEG-21 [18], also called Multimedia Framework, defines an open framework to enhance the management of digital media resources exchange and consumption, aiming to achieve functions such as digital content creation, distribution, user privacy protection, terminals, and network resource extraction.

1.5.3 IPTV Operation

An IPTV service requires a video head-end. This is the point in the network at which linear (e.g., broadcast TV) and on-demand content is captured and formatted for distribution over the IP network. Typically, the head-end ingests national feeds of linear programming via satellite either directly from the broadcaster or programmer or via an aggregator. Some programming may also be ingested via a terrestrial fiber-based network. *Video encoders* and *VoD servers* are the major sources of video content for IPTV services. The video head-end is composed of the following components [19]:

- *Video encoder:* A video encoder can encode real-time video analog signals from a content provider or a live event location to a digital format based with given video compression technology such as MPEG2/4. The encoder also deals with on-demand content stored or re-distributed at different video on-demand servers after the encoding and other processing, such as digital rights and encryption.
- *Live video broadcast server:* A live video broadcast server is in charge of reformatting and encapsulating video streams in case video streams with different formats from a video encoder or pre-encoded video file are received. The server also interfaces the core network and transmits the video signal over the core network toward the access network.
- *Video on demand server:* A VoD server hosts on-demand content with streaming engines and is equipped with a large storage capacity.

After encoding, each channel is encapsulated into IP packets and is transmitted over the network. There are two major parts of the transport network in general—*core* and *access* networks.

- *Core networks:* These connect the access networks to customer premises and can be simply a single national distribution network running Gigabit Ethernet or IP/Multi Protocol Label Switching (MPLS) plus various regional distribution networks running carrier grade Ethernet. Managed content is usually centralized and processed within the national distribution network before being delivered to different access networks. However, a wider range of choices for the unmanaged content by other content providers can be made, and the unmanaged content is fed into the national distribution network to the customers through the Internet.

- *Access networks:* These serve as a critical part of the transport network and are used to reach each individual customer at his or her home through the STB. Sometimes referred to as "the last mile," the broadband connection between the service provider and the household can be accomplished using a variety of technologies. The technologies available today are mainly xDSL and Coaxial Hybrid Fiber Cable (HFC) or fiber techniques such as Fiber-To-The-Node (FTTN), to extend the reach to customer communities before xDSL or cable wiring. Telecom service providers often make use of the DSL technology to serve individual households. Fiber technology such as Passive Optical Networking (PON) is also sometimes used to connect homes. IPTV networks will use variants of Asymmetrical DSL (ADSL) and Very-High-Speed DSL (VDSL) to provide the required bandwidth to run an IPTV service to the household. The service provider puts a device (such as a DSL modem) at the customer premises to deliver an Ethernet connection to the home network [20].

Given that the bandwidth of the access networks usually is very limited, to cater to all of the customers for simultaneous access of the TV channels, multicasting has been widely adopted to enable a scalable delivery of video data for IPTV. Instead of unicasting multiple flows of live content across the whole transport network, a goal of multicasting is to conserve bandwidth and minimize unnecessary packet duplication. A single transmission of each unique video data is shared among a group of customers who demand the same live content (e.g., thousands of viewers tuning in to a sporting event). Data are replicated only at appropriate branching locations, such as a regional edge router when it is necessary to fork another sub-stream to reach another group of customers or an individual customer. The grouping of encoded video streams, representing the channel line, is transported over the service provider's IP network. Each of these networks is unique to the service provider and usually includes equipment from multiple vendors. These networks can be a mix of well-engineered existing IP networks and purposefully built IP networks for video transport. At the network edge, the IP network connects to the access network.

- The home network distributes the IPTV service throughout the home. The end point in the home network, to which user devices are connected, is the Set-Top Box (STB). A STB is usually installed with middleware client software to obtain the program guide data, decode MPEG2, MPEG4 video data, and display on the screen. Alternatively, a Web browser can obtain the program guide data from a central server. A STB can also be integrated with a DSL or cable modem or even with an IEEE 802.11 switch for home Internet access networking [20].

1.6 IPTV Services

IPTV services, as described in ITU's IPTV document [21], can be classified into three categories such as basic channel service, enhanced selective service, and interactive data service [21]. The basic channel services are composed of Audio and Video (A/V) channels, Audio channels, and A/V with data channels. These services are broadcasted similar to traditional TV channel services. The enhanced selective services encompass the Near VoD broadcasting, Real VoD, Electronic Program Guide (EPG), Personal Video Recorder (PVR), Business to Business (B2B), Customer to Customer (C2C), Multiangle service, and so on. Enhanced selective services are transmitted through the basic channel service for the customer's convenience and provide a wide choice of multimedia content. Finally, interactive data service is made up of T-information, T-commerce, T-communication, T-entertainment, and T-learning. More specific service types are described in Table 1.2 [21].

1.6.1 Basic Channel Service

- *Audio and video:* the audio and video channel service provides a picture quality similar to Digital Versatile Disk (DVD) or higher quality display in many resolutions. AV signals are transmitted without uplink feedback.
- *Audio only:* the Audio-only channel delivers only audio signals from one point to another. An audio waveform submitted to the channel input results in a similar (not necessarily identical) waveform at the channel output. Audio signals are transmitted without uplink feedback.
- *Audio, video, and data:* the audio, video, and data channel services are A/V channel services combined with interactive data for the related or supplementary information of program using a bi-directional link. Users can enjoy the downlink A/V channel streaming and accesses more detailed information via the uplink channel simultaneously.

1.6.2 Enhanced Selective Services

- *Near VoD broadcasting:* Near VoD service is the consumer video service used by multichannel broadcasters using high-bandwidth distribution mechanisms. Multiple copies of a program are broadcasted at short time intervals (typically 10–20 min) providing convenience for viewers, who can watch the program without tuning in at a scheduled point in time.
- *Real VoD:* Real VoD services allow users to select and watch video content over a network as part of an interactive and enhanced selective service. Real

Table 1.2 IPTV Service Classifications

Classifications	*Services*
Basic Channel Service	Audio and video Audio only Audio, video, and data
Enhanced Selective Service	Near VoD (Video on Demand) broadcasting Real VoD MoD (Music on Demand) including Audio book. EPG (Electronic Program Guide) PVR (Personal Video Recorder) B2B hosting (Business-to-business hosting) C2C hosting (Customer-to-customer hosting) Multiangle service
Interactive Data Service	T-information (news, weather, traffic, advertisement, etc.) T-commerce (security, banking, shopping, auction, and ordered delivery) T-communication (mail, messaging, SMS, channel chatting, VoIP, Web, video conference, and video phone) T-entertainment (photo album, game, karaoke, and blog) T-learning (education for children, elementary, middle and high school student, languages, and estate)

VoD services are either “stream” content, allowing viewing while the video is being downloaded, or “download” it in which the program is brought in its entirety to a set-top box or similar device before viewing starts.

- *Music on demand (MoD):* MoD including audio book services that allow users to select and appreciate music or audio contents over an IP network as an interactive enhanced selective service much like VoD.
- *EPG:* An Electronic Program Guide is an on-screen guide to scheduled service programs, contents and additional descriptive information, allowing a viewer to navigate, select and discover content by time, title, channel, and so on, by using a remote control, a keyboard, a touchpad, or even a phone keypad. Sometimes, EPG is also known as an Internet Media Guide (IMG), Interactive Program Guide (IPG), or Broadband Contents Guide (BCG) in an equivalent meaning. Generally, EPG can be displayed in several types such as Mosaic EPG, Box EPG, Text EPG, Mini EPG, Tree EPG, and so forth in accordance with the service provider’s business model.

- *PVR:* The PVR is a consumer electronics device service that records television programs to the hard drive-based digital storage in standalone set-top boxes or networks. This can provide the "time shifting," "trick modes," and complementary convenience functions such as recording onto DVDs, commercial skip, sharing of recordings over the Internet, programming and remote control by Personal Digital Assistants (PDAs), networked PCs, or Web browsers.
- *Business-to-business (B2B) hosting:* The B2B hosting service is an IPTV hosting service for the special group or business unit subscriber. It connects the channel, VoD, and portal service made by customer business unit to the IPTV platform to supply particular groups with real-time broadcasting channels, value-added interactive services, and T-community activity. Generally, it includes a regional community, religion unit, and small business company broadcasting and interactive data services.
- *Customer-to-customer (C2C) hosting:* The C2C hosting service is an IPTV hosting service for the customer as an individual channel type. This service allows subscribers to make their own channel by uploading A/V, application, and data that they produce and providing other subscribers what they create.
- *Multiangle service:* This service provides various different camera angles that one can view. The viewer can select angles which he/she likes to watch. For example, when the customer watches the baseball game in TV, he can see the first base, third base, or backfield according to viewer's wish not by the channel director's attention.

1.6.3 Interactive Data Services

- *T-information (news, weather, traffic and advertisement, etc.):* T-information is a television information service that supports a considerable amount of useful information such as news, weather, traffic, and advertisements. The viewer can choose contents on the overlapped linked program screen or an independent menu.
- *T-commerce (security, banking, stock, shopping, auction, and ordered delivery):* T-commerce is a television commercial service that allows viewers to purchase goods and use financial services such as banking, stock, auction, and so on. For example, personal banking services support the user to view account balances, review past account activity, pay bills, and transfer money between accounts.
- *T-communication (mail, messenger, SMS, channel chatting, VoIP, Web, multiple video conference, and video phone):* T-communication is a television communication service that enables people to exchange information such as voice, video, and data. Users can send (or receive) the mail and message while watching TV. In addition, viewers can simultaneously interact with other people via two-way video and audio transmissions using video conference.

T-communication is a key convergence service of telecommunication and broadcasting in the IPTV world.

- *T-entertainment (photo album, game, karaoke, and blog):* T-entertainment is a television entertainment service that contributes to viewer's amusement by providing exciting items such as powerful games, vivid karaoke, and friendly photo albums. Games can be subdivided into single player and multiplayer games according to the number of players. Moreover, games can be classified into network linked and stand alone, according to the network interaction type.
- *T-learning (education for children, elementary, middle and high school student, languages, and estate):* T-learning is a television learning service that educates viewers through lectures, tutorials, performance support systems, simulations, job aids, game, and more.

1.7 IPTV Deployment Challenges and Success Factors

Although IPTV technology is observing a great evolution, there are still many challenges that need to be overcome for IPTV technology to achieve a truly ubiquitous IPTV deployment. From the network point of view, one major challenge is the huge bandwidth required to carry IPTV services, which is generally far higher than the bandwidth required to support Voice over IP (VoIP) and Internet access services. In addition, VoD uses unicast transport to provide communications between the IPTV consumer devices and VoD servers, and in turn generates huge amounts of traffic in the network. Indeed, efficient networking solutions should allow the IPTV distribution networks to support high bandwidth carrying capacities and multicast transport mechanisms. Efficient caching mechanisms through caching video content nearest to the user (considering the location of video servers in the operator network) can reduce network bandwidth consumption.

Quality is also an important prerequisite and challenge in IPTV deployment. It is worth pointing out that the current quality of IPTV does not currently match that of cable TV services and still the triple-play offers fail to assure similar quality level during the simultaneous use of Internet and TV. There also exists a mobile version of IPTV called Mobile IPTV. Mobile IPTV extends IPTV services over IP-based networks to mobile networks. Mobile IPTV allows users to enjoy IPTV services anywhere and even while on the move. Quality is an obstacle for Mobile IPTV, where the two main drawbacks affecting the quality of mobile IPTV are the bandwidth and terminal capabilities [22]. This gap is expected to shrink as the bandwidth increases, especially with Fiber To The Home (FTTH) and Long-Term Evolution (LTE) technologies and the continuous improvements in video codecs. Platforms standardization is another challenge for the wide interoperable deployment of IPTV. Indeed, the great evolution in IPTV technologies led to the development of many different platforms, devices, and codecs. However, the lack of standards limits the interoperability and hence applications' innovations. Moreover, careful business models present a nonnegligible challenge in IPTV deployment. First, the coexistence of IPTV and the Internet TV should be carefully considered through a smart business model that would be beneficial for all parties involved in the deployment of Digital TV (whether Internet TV or IPTV). In addition, the existence of several actors in the IPTV value chain creates a tough competition among the different offers of IPTV services by pushing network operators and service providers to propose value-added services not only to attract new clients but also to reduce the churn. By developing well-thought out business models that work with the different actors, new business opportunities will be made available to all of them.

The main technical challenges faced by current IPTV systems are outlined below:

- *Architectural scalability and reliability:* With the growing number of IPTV subscribers, maintaining the stability of the IPTV architecture and providing efficient and reliable service delivery up to the last mile becomes a challenge. Poor scalability of the IPTV architecture can manifest itself in the form of excessive network demands (necessitating very expensive bandwidth upgrades), compromised QoS, and so on.
- *High-quality video:* IPTV has stringent QoS requirements, and meeting these requirements is a key success factor for service providers as they strive to build customer loyalty. Indeed, customers' QoE is the key value upon which service providers must differentiate themselves. The delivery of IPTV is a nascent and highly competitive area, and for customers to truly embrace IPTV, and the broader Multi-play offering, it must meet or exceed their QoE expectations.
- *Capacity of access networks:* The capability of access networks is a crucial issue for the successful deployment of IPTV services. Since most homes are currently equipped with multiple end-user devices (TVs, computers, etc.), there is a greater demand for high-speed access networks. Technologies offering higher bandwidth support (e.g., ADSL2+) help in supporting IPTV services. Furthermore, encryption technologies can help reduce bandwidth requirements and therefore counteract increasing bandwidth capacity demands.
- *Interoperability and standardization:* Standardization is imperative for the development of a worldwide mass market in low-cost IPTV services. Many entities are working on different aspects of IPTV. However, there is no well-defined coordination among them. To gain acceptance and reach technical and commercial success, it is essential to coordinate the efforts of all entities working in various parts of IPTV.
- *Robust and secure content protection:* Content Security is also one of the most critical issues for IPTV success. Without proper content security, subscribers will stay with their current TV service providers. The choice of appropriate content protection solution is imperative to complete negotiations success-

fully throughout the content acquisition process. Without IPTV security, service providers cannot live up to the expectations of both customers and content creators in terms of availability, level of quality, and exclusivity when a premium is requested.

- *Compatibility and accessibility:* Compatibility which will facilitate multiple services is also expected to be one of the significant factors influencing IPTV adoption. Compatibility at the individual level means that consumers can enjoy various services on the IPTV format. This implies that IPTV will become a common platform for voice, video, and data resulting in triple and even quadruple services. IPTV will not just be another medium for telecasting; it will change the entire value–chain relationship. Instead of one-to-many, there will be new opportunities for one-to-one interaction on an unprecedented scale. Customers' focus on compatibility present some technical challenges to the providers as to integration, making sure the mixture of software, hardware and related gear that make up an IPTV network functions properly.
- *Personalization of content and services:* IPTV providers will have to differentiate their service bundles from the video services that are already available on the market in various forms such as Web TV and mobile TV. The IPTV providers may develop interactive and proactive applications. Interactive functionality is the most promising feature for new IPTV services. The user wants more control over the contents especially for the rewind and pausing options. Users want the function to enable or disable on-screen advertising, the selection of languages, instant messaging boards, and so on. The new IPTV services should provide more interactive interfaces to attract and facilitate the end-users. Indeed, IPTV can satisfy the consumers' new demands if IPTV effectively brings TV media to the public who can serve as a producer as well as a consumer.
- *Managing heterogeneity of access networks:* Clients may request IPTV services using varied local access networks including ADSL, Cable Modem, Universal Mobile Telecommunication System (UMTS), Wireless LAN (WLAN), Worldwide Interoperability for Microwave Access (WiMAX), and so on. All these network connections support distinct characteristics and vary for their uplink and downlink capacities. This variation in the bandwidth capacities can influence the offered video quality.
- *Multiaccess devices:* End users may access IPTV services using a wide variety of devices such as TV, Laptop, PDAs, cellular phone, other handheld devices, and so on. These devices possess heterogeneous characteristics in terms of screen resolution, data rate, and so on. To be able to ensure smooth contents delivery and acceptable QoS levels, it is essential to consider the capabilities of all devices at the receiving end. Furthermore, it is also possible that a single home accesses different TV channels using different terminals at the same time. In this context, the service provider has the challenge of dealing with

the available bandwidth and efficient content adaptation to meet the needs of all users.

- *Dynamic subscriber behaviors:* In a realistic multiplay user environment, subscribers behave in a dynamic fashion. Household receiving Multi-play services from a single provider may be simultaneously initiating channel-change and new Internet-connection requests while having multiple VoIP telephone conversations. When scaled across the subscriber base, this dynamic behavior can be very demanding on the control plane of IPTV network elements, and can potentially jeopardize the QoE IPTV viewers receive.
- *Dynamic network characteristics:* The condition of the access network can change dramatically during the process of video streaming. Therefore, it is important for IPTV providers to efficiently perform dynamicity management in order to monitor the current network conditions regularly and maximize the utilization of available resources while minimizing packet drop ratios. Congestion control mechanism may also be employed to ensure the smooth delivery of media content. This becomes even more essential when there are many customers.
- *Efficient video coding:* Video encoding is considered as the most important aspect in the multimedia contents streaming applications and other IPTV services. Efficient video coding techniques lead to improved content portability and management. Highly efficient coding schemes can also help in improving access network throughput resulting in better QoS/QoE for IPTV users.
- *Efficient routing schemes and bandwidth utilization:* Efficient routing plays a major role for the efficient deployment of the VoD and IPTV services. VoD unicast transmissions increase the traffic load on the networks compared to IPTV (multicast). The situation becomes worse while delivering the service to the millions of clients. Service providers must implement efficient routing to serve clients with efficient utilization of the available bandwidth and putting lower loads onto the networks.
- *Overall QoS/QoE:* Successful deployment of IPTV services requires excellent QoS for video, voice, and data. QoS metrics for video include jitter, number of out-of-sequence packets, packet-loss probability, network fault probability, multicast join time, delay, and so on. QoS metrics for voice includes Mean Opinion Score (MOS), jitter, delay, voice packet loss rate, and so on. QoS metrics for IPTV services include channel availability, channel start time, channel change time, channel change failure rate, and so on. In order to gain wide acceptance, it is crucial for IPTV providers to be able to provide high-quality TV service, video, voice, as well as interactive services [23]. To efficiently provide clients with a satisfying IPTV service and to maintain a high QoE level, user data should be prioritized depending on their service category. However, it is hard to determine how much bandwidth should be

reserved for a QoS-guaranteed flow especially when the video quality that the user perceives is actually dependent on individual human perception [24].

- *User interface and multichannels view:* With the growing IPTV industry and the availability of hundreds of TV channels, users want to watch more than one channel at the same time. For example, someone might wish to have a look at some game score and at the stock market while watching a movie. We need to design special multichannel interfaces along with the picture-in-picture features that can allow the user to open different channels with their preferred settings.
- *Billing issues:* To become competitive, profitable, and meet growing consumer expectations, IPTV service providers will need an end-to-end, flexible billing solution that can provide rapid roll-out and trials of new Broadcast, VoD Pay-Per-View, and other services. The solution will need to provide both customer-centric and partner-centric features and automatically flow and expand to support all IPTV components while communicating with other IPTV enabling systems.

1.8 Future of Digital TV

The future of Digital TV concerns mainly the huge increase in mobile TV and video streaming services, personalized services, and social evolution through opening the Digital TV model (including IPTV, Mobile TV, and Web TV) to social networking applications. TV services personalization is one of the essential pillars for new and rich service offers based on content individual adaptation: the domain of targeted advertisements is an important example enriching service offers. TV services personalization promises to open up new market opportunities and enable the creation of new services through advanced services personalization, and consequently, more digital content consumption and investments. In this context, new business models are expected involving different actors along the Digital TV chain, which has a socio-economic dimension. Users will become an active part in the content creation; the advertiser will be ready to pay more for the targeted ad space. The revenues can come from two sides—the users and the advertisers. A dynamic customer profile database will also allow taking a step beyond advertising—becoming a multi-sided marketplace where other kind of sellers and buyers can meet. Digital TV is expected to change the user experience via quality, personalization, new services (such as content personalization, recommendation, and personalized channels), mobility, user interactions, targeted services (advertisements), and multidevices usage. We note that TV services personalization requires the identification of watchers in a distinguished and individual manner. Several studies are being done on adequate and user-friendly identification techniques for TV services personalization (currently focusing on IPTV). These include, using a special PIN code for each user through remote controls that could be even personal remote controls (using for instance the users' cell phones). Near Field Communication (NFC), Radio Frequency Identifiers (RFID), and finger prints scanners are also being studied as advanced identification technologies. A decision on which identification technology can be a success depends on many factors, as the users' acceptability, market feasibility for introducing a new identification technology upon the Digital TV architecture (including IPTV, Web TV, and Mobile TV), the expected investments cost of deploying such identification technologies compared to the expected revenues from the Digital TV services personalization in general.

The IMS (IP Multimedia Subsystem) offers a standard unified infrastructure for management and control of services (through decoupling the control from the service layer). IMS appears to be a promising underlying architecture for Digital TV deployment allowing for interoperability and facilitating the deployment of new services fitting the services' convergence and personalization—which meets the social networking current trends and paves the way to an open TV converged model including (IPTV, Web TV, Mobile TV, and Social Network Services).

Several standardization bodies are studying IMS to develop solutions for the fixed and mobile TV services (examples are ETSI/TISPAN, Open IPTV Forum, 3GPP, and ITU), and several industrials (France Telecom, Ericsson, Huawei, Thomson, and ZTE) nowadays show interest to the IMS deployment for Digital TV.

IPTV via satellite is a market that has attracted a lot of attention over recent years. Compared to satellite TV, IPTV appears to be a compelling and highly competitive platform. However, true demand and opportunity for satellite-delivered IPTV is not entirely clear at this early stage, where many questions remain regarding the precise demand for satellite broadcasting in a fiber and copper-centric telco environment, particularly in the United States. In this early stage of the market cycle, extensive analysis on the potential of IPTV via satellite in terms of market and technology trends and the role that the satellite industry can play in the emerging IPTV industry has to be undertaken. In the future, a converged model is expected in which satellite technology's ability to provide cost-effective broadcast services can be positioned as a natural broadcast enabler and would seem a perfect fit to distribute and deliver TV programming to IPTV providers. In this context, satellite capacity providers can act as "head-ends-in-the-sky" and become infrastructure core components in enabling IPTV services, and could generate retail revenues through revenue-sharing arrangements with content providers and IPTV service providers.

1.9 Conclusion

This chapter presents a detailed review on Digital TV technologies showing the challenging transition in the TV world from analogue to digital TV as well as the history and current status of Digital TV and emerging trends for the digital TV market. IPTV evolution compared to Web TV is also presented with a particular emphasis on IPTV's different architectural components, its standardization activities and market status. Another important contribution of this chapter is the focus on the different competitors for IPTV technology and the current challenges associated with IPTV deployment. The chapter concludes by discussing some technical issues related to the future for Digital TV while considering different existing technologies (such as IPTV, Web TV, Mobile TV, Social Networking Services, and Satellite TV).

Acronyms

ADSL	Asymmetric Digital Subscriber Line
API	Application Programming Interfaces
ARPU	Average Revenue Per User
ATIS	Alliance for Telecommunications Industry Standard
B2B	Business to Business
BC	Broadcast
BCG	Broadband Contents Guide
C2C	Customer to Customer
DRM	Digital Rights Management
DVB	Digital Video Broadcast
EPG	Electronic Program Guide
FG	Focus Group
FiOS	Fiber Optic Service
FTTN	Fiber-To-The-Node
GEM	Globally Executable MHP
HD	High Definition
HDTV	High Definition Television
IIF	Interoperability Forum
IMG	Internet Media Guide
IMS	IP Multimedia Subsystem
IP	Internet Protocol
IPG	Interactive Program Guide
IPTV	Internet Protocol Television
iTV	Interactive TV
LTE	Long-Term Evolution
MHP	Multimedia Home Platform
MoD	Music on Demand
MOS	Mean Opinion Score
MPEG	Moving Pictures Experts Group
MPLS	Multi Protocol Label Switching
MRG	Multimedia Research Group
NFC	Near Field Communication
NGN	Next Generation Network
OTT	Over The Top

PDA	Personal Digital Assistants
PON	Passive Optical Networking
PVR	Personal Video Recording
QoE	Quality of Experience
QoS	Quality of Service
RFID	Radio Frequency Identifiers
SD	Standard Definition
SD&S	Service Discovery and Selection
SIP	Session Initiation Protocol
STB	Set Top Box
TMG	Telecommunication Management Group
UGC	User Generated Content
UMTS	Universal Mobile Telecommunication System
VDSL	Very-High-Speed DSL
VoD	Video on Demand
VoIP	Voice over IP
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless LAN

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Chapter 2

Open-IPTV Services and Architectures

Emad Abd-Elrahman and Hossam Afifi

Contents

2.1 Introduction

This chapter provides a brief description and new visions regarding the convergence network architecture for an Open-IPTV model. Also, it counts the benefits of this architecture to mobility and security issues. With the new Open-IPTV model, the migration toward converged networks between different Content Providers (CP) infrastructures becomes natural. The general management methodology will add value to the overall control between those providers. This optimization includes two cost factors that are important for a provider: Capital Expenditure (CAPEX) and Operational Expenditure (OPEX).

Recently, the aspect of cloud network has proliferated within the Internet Service Providers (ISPs). It enhances the multimedia business efficiency. Cloud infrastructure solutions have matured and provided reasonable interoperability under the current Internet regulations and standards [1]. While the cost of deploying delivery network solutions for IPTV has increased over the last several years, the operational expense of maintaining and managing the network also continues to rise. That is why we are searching for collaboration between IPTV service providers.

The rest of this chapter is organized as: Section 2.2 highlights some definitions and terminologies about IPTV. Section 2.3 introduces the components of the open IPTV architecture and its analysis in flow control way. Section 2.4 compares between different ways of content transmissions. Section 2.5 differentiates between the current model for business IPTV delivery and the proposed one for collaborative delivery based on cloud network for domestic region. Section 2.6 handles some issues relevant to access IPTV in Nomadic situations. The model analysis, motivations from cloud design, collaborations, and cost analysis are discussed in Section

2.7. Section 2.8 analyzes some use cases access in different nomadic situations. Section 2.9 concludes the study of this chapter.

2.2 Definitions and Terminologies

The current status of IPTV model can be summarized in Figure 2.1. We have three models: IMS-based standard model based on the IP Multimedia Subsystem (IMS) [2] core as a controller, NGN-based [3] standard model based on Next Generation Network architecture, and finally, the Internet model, Google TV [4]. We have combinations of these infrastructures like Digital Video Broadcasting DVB. The DVB project could use either IMS or NGN so we can call it a hybrid model. In DVB-IPI-based architecture, the DVB-IPTV service is the video service provided over IP like TV over IP or the Video-on-demand (VOD) over IP as specified in refs. [5–7].

We expect the future to have collaborative model (Cloud-Based) for IPTV delivery. It will have advantages over the other models in terms of low investments cost, better delivery performance, and converged system in design.

2.2.1 Definitions

The term Internet Protocol TeleVision (IPTV) has many definitions. But, the ITU-T definition [8:4] is the more general one: "IPTV is defined as multimedia services such as television/video/audio/text/graphics/data delivered over IP-based networks managed to provide the required level of QoS/QoE, security, interactivity and reliability."

Actually, there are two models for general IPTV management:

- *The managed model:* It concerns access and delivery of content services over an end-to-end managed network by the operator (like Orange or Free Triple-play operators in France).
- *The unmanaged model:* It concerns access and delivery of content services over an unmanaged network (e.g., the Internet) without any quality of service (QoS) guarantees. YouTube represents one such type of this model.

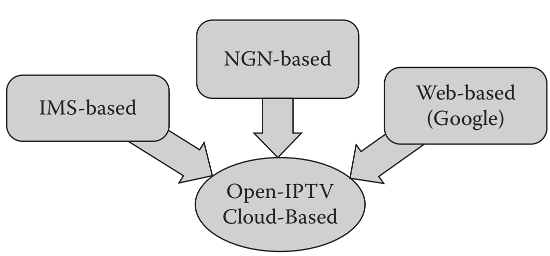

Figure 2.1 IPTV models collaboration.

2.2.2 Open-IPTV Services

The Open IPTV means offering TV over both managed and unmanaged networks. The terminal (TV) is also modified to accommodate built-in IP services.

To obtain an open IPTV service, we may need to reform the Set-Top-Box (STB). In order to propose a new aspect of STB that matches the new era of different access types and forms of videos, we need to highlight the characteristics of STBs. Moreover, we will define the advantages and disadvantages of adopting each type either for the operator or client. In Figure 2.2, we differentiate the current proposed services under the managed and unmanaged networks.

2.2.2.1 Physical Set-Top-Box (P-STB)

This system represents the actual implemented scenario. It mainly depends on physical Hardware of STB and leased connection between the consumer and content provider.

Advantages: The service security assurance and bandwidth guarantee are advantages of this model. Also, the good management of STB provided by the CP is naturally guaranteed.

Drawbacks: With the present model of IPTV, the delivery is based on physical STB restricted to specific location. But, as the consumers are increasingly becoming mobile, they demand bandwidth regardless of their locations to satisfy their entertainment. So, the lack in this model is the inability to support Nomadism (Mobility and Nomadic Access aspects).

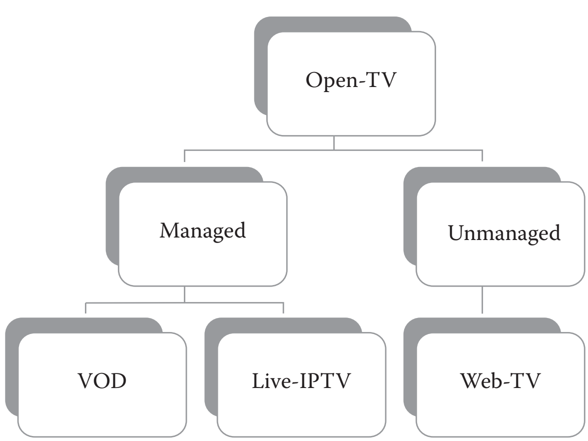

Figure 2.2 Open TV components.

2.2.2.2 Software Set-Top-Box (S-STB)

STB in this case depends on Software instead of Hardware for controlling the received channels and videos. It could be a USB disk carrying all necessary information.

Advantages: It will satisfy the consumer desires for enjoying all their subscription videos anywhere. So, this type is highly recommended for nomadic access services.

Drawbacks: The operators cannot be in control of everything. Management of user policies and authorization while changing the location is challenging.

As the future will probably adopt the new model of Set-Top-Box (STB) in a software form, we will no more need to restrict the physical location of IPTV services.

2.2.2.3 Virtual Set-Top-Box (V-STB)

It is a kind of S-STB but resides in the operator premises instead of user side. So, it is like an HTTP application accessed remotely by the client.

Advantages: The operator could control everything easily. For the client, no prerequisites are needed for one's system to start accessing the service except for a simple IP connectivity.

Drawbacks: Delay between the client application and the STB server is the big issue. Also, some security problems for user identification are produced in this type.

2.2.2.4 Open Set-Top-Box (O-STB)

It is a kind of hybrid STB that groups features from P-STB and S-STB. The O-STB can be accepted to run for any operator. Also, it can accept many kinds of video services like managed IPTV, Web TV, Social Networks (like YouTube), and VOD service.

Advantages: It will have an easy deployment manner and end of compatibility issues. Also, it is modern and suitable for new style of life.

Drawbacks: It may suffer from some complexity in design.

2.2.3 Some IPTV Terminologies

The common IPTV categories used could be classified as:

- *Pay-TV:* This service refers to the subscription-based TV service delivered in either traditional analog forms, digital or satellite. In different countries, we have similar terms referring to "Packs" and channels like Canal-Satellite, Showtime, ART, and so on.
- *TV-OTT:* TV Over-The-Top; it is one of the American TV services that provides a seamless consumer experience for accessing linear content through the

broadcast network on a TV set, as well as nonlinear services such as Catch-up TV and Video on Demand (VOD) through a broadband IP network. It is also designed to allow the provider to extend content and the consumer experience to additional platforms including PCs, mobile, gaming consoles, and connected TVs.

- *IPTV "Follow-me:"* allows the user to continue to access one's IPTV service while moving and changing one's screen. (Content adaptation while Mobility is an issue.)
- *Personal IPTV "My Personal Content Moves with Me:"* It allows the user to access one's personalized IPTV content in any place in one's domestic region with the reception of the bill on one's own home subscription (like Nomadic Access).
- *TVA:* TV-Anytime is developed by a specific IPTV group [9] which is interesting in the interoperability and security for future TV.
- *Open IPTV:* is a model of TV service that will be based on borderless technology. A hybrid model that merges the traditional Broadcasting TV with the Web-TV in one thing. OIPF (Open IPTV Forum) [10] is a well-known group in this field.

2.3 Open-IPTV Architectural Components

Open IPTV term could be defined as an integral solution for both managed and unmanaged IPTV services. It could be considered as a kind of TV anywhere/anytime but it goes beyond the subscriber domestic home region to include all possible access.

We have mainly two models of IPTV service delivery:

Managed service: This is the service provided by IPTV service providers based on standard STB and reserved link BW. The contents are mainly generated by the operators but in some situations the clients could generate and diffuse their contents like "Personalized TV."

UnManaged service: This may be called Internet IPTV which has no guarantee for QoS. YouTube is one of the famous representations of this model. The majority of contents in these methods could be generated by the customers themselves.

So, Open IPTV architecture means providing an integral solution for both managed and unmanaged IPTV services in one model. As a result, this will require searching new attaching point with the access network based on software Set-Top-Box (S-STB). Moreover, this kind of S-STB will add more scalability in the access. Video services can either be based on Managed or Unmanaged scenarios.

We can follow the state diagram in Figure 2.3 which explains the steps of accessing video service based on an open IPTV architecture as:

1. The client application regardless of the accessing device (PC, Mobile, or TV) initiates a request for the Web manager index. This manager is just a repository for indexing different videos, channels, or multimedia services. This manager also integrates the functionality of the "recommendation system" that recommends information items like movies, TV program/show/episode, VOD, music, books, news, images, Web pages, and so on, that are likely to be of interest to the user. Finally, the recommender system gives its decisions based on comparing the user profile with some social reference characteristics.
2. By clicking on a specific choice from the previous manager, a request will pass to the back office manager asking about the client privacy.
3. The answer will either be positive or negative for accessing the client choice based on AAA decision and will forward a notification to index system.
4. The Web manager notifies the client application to start accessing the video but after accepting the DRM agreement.
5. The client application starts activating the client DRM engine.

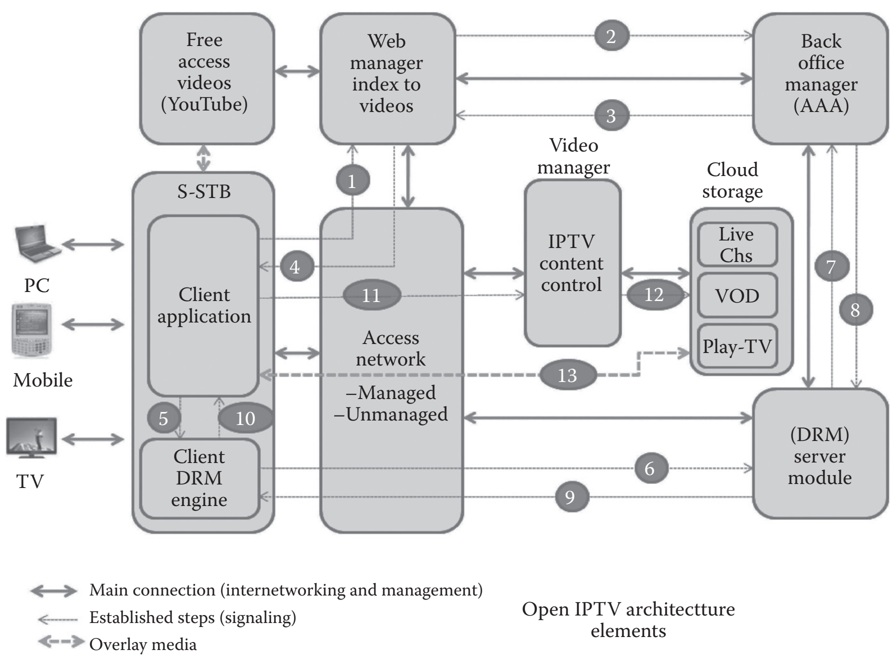

Figure 2.3 Flow control for open IPTV architecture.