IP MULTICAST WITH APPLICATIONS TO IPTV AND MOBILE DVB-H

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For Anna and the kids.
And for my parents Gino and Angela

Also thanking
Mike Neen

PREFACE

This book updates early-release published work undertaken by the author in the early-to-mid-1990s on the topic of video-for-telcos ("telco TV"), video-over-packet, video-over-DLS, and video-over-ATM contained in the book *Video Dialtone Technology: Digital Video over ADSL, HFC, FTTC, and ATM*, McGraw-Hill, 1995, and based on extensive hands-on work on broadband communications and digital video/digital imaging. At this juncture, the focus of this book (and for this industry) is completely on commercial-quality video over IP, IPTV.

Of late there has been renewed interest in IP multicast protocols and technologies because of the desire by traditional telephone companies to deliver entertainment-level video services over their network using next-generation infrastructures based on IP networking, by the cell phone companies for video streams to hand held telephone sets and personal digital assistants (PDAs), and by the traditional TV broadcast companies seeking to enter the same mobile video market. Critical factors in multicasting include bandwidth efficiency and delivery tree topology optimization.

IP multicast technology is stable and relatively easy to implement, particularly for architecturally simple (yet large) networks. A lot of the basic IP multicast mechanisms were developed in the mid-to-late 1980s, with other basic work undertaken in the 1980s. A number of recent functional enhancements have been added. From a commercial deployment perspective, IP multicast is now where IP was in the mid-1990s: poised to take off and experience widespread deployment. Examples of applications requiring one-to-many or many-to-many communications include but are not limited to digital entertainment video and audio distribution, multisite corporate videoconferencing, broad distribution financial data, stock quotes and news bulletins, database replication, software distribution, and content caching (for example, Web site caching).

The text literature on IP multicast is limited and somewhat dated, particularly in reference to IPTV applications. This compact text is intended for practitioners that seek a quick practical review of the topic with emphasis on the major and most-often used aspects of the technology. Given its focus on IPTV and DVB-H it can also be used by technology integrators and service providers that wish to enter this field.

Following an introductory discussion in Chapter 1, Chapter 2 covers multicast addressing for payload distribution. Chapter 3 focuses on multicast payload forwarding. Chapter 4 covers the important topic of dynamic host registration using the Internet Group Management Protocol. Chapter 5 looks at multicast routing in sparse-mode environments and the broadly used PIM-SM. Chapter 6 discusses CBT. Chapter 7 looks at multicast routing for dense-mode protocols and PIM-DM in particular. Chapter 8 examines DVMRP and MOSPF. The next chapter, Chapter 9, covers IP multicasting in IPv6 environments. Chapter 10 looks at Multicast Listener Discovery (MLD) snooping switches. Finally, Chapters 11 and 12 give examples in the IPTV and (mobile) DVB-H environments, respectively. Portions of the presentation are pivoted off and summarized from fundamental RFCs; other key sections are developed here for the first time, based on the author's multidecade experience in digital video. The reference RFCs and protocols are placed in the proper context of a commercial-grade infrastructure for the delivery of robust, entertainment-quality linear and nonlinear video programming.

Telephone carriers (telcos), cell phone companies, traditional TV broadcasters, cable TV companies, equipment manufacturers, content providers, content aggregators, satellite companies, venture capitalists, and colleges and technical schools can make use of this text. The text can be used for a college course on IP multicast and/or IPTV. There is now a global interest by all the telcos in Europe, Asia, and North America to enter the IPTV and DVB-H market in order to replace revenues that have eroded to cable TV companies and wireless providers. Nearly all the traditional telcos worldwide are looking into these technologies at this juncture. Telcos need to compete with cable companies and IPTV and DVB-H is the way to do it. In fact, even the cable TV companies themselves are looking into upgrading their ATM technology to IP. This book is a brand-new look at the IP multicast space.

ABOUT THE AUTHOR

Daniel Minoli has many years of technical hands-on and managerial experience (including budget and/or PL responsibility) in networking, telecom, video, enterprise architecture, and security for global best-in-class carriers and financial companies. He has worked at AIG, ARPA think tanks, Bell Telephone Laboratories, ITT, Prudential Securities, Bell Communications Research (now Telcordia), AT&T, Capital One Financial, and SES AMERICOM, where he is director of terrestrial systems engineering. Previously, he also played a founding role in the launching of two companies through the high-tech incubator Leading Edge Networks Inc., which he ran in the early 2000s; Global Wireless Services, a provider of secure broadband hotspot mobile Internet and hotspot VoIP services; and InfoPort Communications Group, an optical and Gigabit Ethernet metropolitan carrier supporting Data Center/SAN/channel extension and Grid Computing network access services.

For several years he has been Session-, Tutorial-, or overall Technical Program Chair for the IEEE ENTNET (Enterprise Networking) conference. ENTNET focuses on enterprise networking requirements for large financial firms and other corporate institutions.

At SES AMERICOM, Mr. Minoli has been responsible for engineering satellite-based IPTV and DVB-H systems. This included overall engineering design, deployment, and operation of SD/HD encoding, inner/outer AES encryption, Conditional Access Systems, video middleware, Set Top boxes, Headends, and related terrestrial connectivity. At Bellcore/Telcordia, he did extensive work on broadband; on video-on-demand for the RBOCs (then known as Video Dialtone); on multimedia over ISDN/ATM; and on distance learning (satellite) networks. At DVI he deployed (satellite-based) distance-learning system for William Patterson College. At Stevens Institute of Technology (Adjunct), he taught about a dozen graduate courses on digital video. At AT&T, he deployed large broadband networks also to support video applications, for example, video over ATM. At Capital One, he was involved with the deployment of corporate Video-on-demand over the IP-based intranet. As a consultant he handled the technology-assessment function of several high-tech companies seeking funding, developing multimedia, digital video, physical layer switching, VSATs, telemedicine, Java-based CTI, VoFR & VPNs, HDTV, optical chips, H.323 gateways, nanofabrication/(Quantum Cascade Lasers), wireless, and TMN mediation.

Mr. Minoli has also written columns for *ComputerWorld, NetworkWorld*, and *Network Computing* (1985–2006). He has taught at New York University (Information Technology Institute), Rutgers University, Stevens Institute of Technology, and

Monmouth University (1984–2006). Also, he was a Technology Analyst At-Large, for Gartner/DataPro (1985–2001); based on extensive hand-on work at financial firms and carriers, he tracked technologies and wrote around 50 CTO/CIO-level technical/architectural scans in the area of telephony and data systems, including topics on security, disaster recovery, IT outsourcing, network management, LANs, WANs (ATM and MPLS), wireless (LAN and public hotspot), VoIP, network design/economics, carrier networks (such as metro Ethernet and CWDM/DWDM), and e-commerce. Over the years, he has advised Venture Capitals for investments of $150M in a dozen high-tech companies. He has acted as Expert Witness in a (won) $11B lawsuit regarding a VoIP-based wireless Air-to-Ground communication system, and has been involved as a technical expert in a number of patent infringement proceedings.

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INTRODUCTION TO IP MULTICAST

1.1 INTRODUCTION

Although "not much" new has occurred in the "science" of the Internet Protocol (IP) multicast space in the past few years, there is now keen interest in this technology because of the desire by traditional telephone companies to deliver entertainment-level video services over their networks using next-generation infrastructures based on IP networking and by the cell phone companies to deliver video streams to handheld telephone sets and Personal Digital Assistants (PDAs). A critical factor in multicasting is bandwidth efficiency in the transport network. IP multicast, defined originally in RFC 988 (Request for Comments) (1986) and then further refined in RFC 1054 (1988), RFC 1112 (1989), RFC 2236 (1977), RFC 3376 (2002), and RFC 4604 (2006), among others, is the basic mechanism for these now-emerging applications. The technology is stable and relatively well understood, particularly for architecturally simple (yet large) networks.

Even in spite of the opening statement above, enhancements to IP multicast have actually occurred in the recent past, including the issuing of Internet Group Management Protocol (IGMP), Version 3 (October 2002); the issuing of Multicast Listener Discovery

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(MLD), Version 2 for IP, Version 6 (IPv6) (June 2004); the issuing of Source-Specific Multicast (SSM) for IP (August 2006); and the publication of new considerations for IGMP and MLD snooping switches (May 2006). Work is also underway to develop new protocols and architectures to enable better deployment of IP over Moving Pictures Expert Group 2 (MPEG-2) transport and provide easier interworking with IP networks.

From a commercial deployment perspective, IP multicast is now where IP was in the mid-1990s: poised to take off and experience widespread deployment. Examples of applications requiring one-to-many or many-to-many communications include, but are not limited to, digital entertainment video and audio distribution, multisite corporate videoconferencing, broad-distribution financial data, grid computing, stock quotes and news bulletins distribution, database replication, software distribution, and content caching (e.g., Web site caching).

This book provides a concise guide to the IP multicast technology and its applications. It is an updated survey of the field with the underlying focus on IP-based Television (IPTV)[1] (also known in some quarters as telco TV) and Digital Video Broadcast—Handheld (DVB-H) applications.

IPTV deals with approaches, technologies, and protocols to deliver commercial-grade Standard-Definition (SD) and High-Definition (HD) entertainment-quality real-time linear and on-demand video content over IP-based networks, while meeting all prerequisite Quality of Service (QoS), Quality of Experience (QoE), Conditional Access (CA) (security), blackout management (for sporting events), Emergency Alert System (EAS), closed captions, parental controls, Nielsen rating collection, secondary audio channel, picture-in-picture, and guide data requirements of the content providers and/or regulatory entities. Typically, IPTV makes use of Moving Pictures Expert Group 4 (MPEG-4) encoding to deliver 200–300 SD channels and 20–40 HD channels; viewers need to be able to switch channels within 2 s or less; also, the need exists to support multi-set-top boxes/multiprogramming (say 2–4) within a single domicile. IPTV is not to be confused with simple delivery of video over an IP network (including video streaming), which has been possible for over two decades; IPTV supports all business, billing, provisioning, and content protection requirements that are associated with commercial video distribution. IP-based service needs to be comparable to that received over cable TV or direct broadcast satellite. In addition to TV sets, the content may also be delivered to a personal computer. MPEG-4, which operates at 2.5 Mbps for SD video and 8–11 Mbps for HD video, is critical to telco-based video delivery over a copper-based plant because of the bandwidth limitations of that plant, particularly when multiple simultaneous streams need to be delivered to a domicile; MPEG-2 would typically require a higher bit rate for the same perceived video quality. IP multicast is typically employed to support IPTV.[2]

[1] Some also use the expansion "IPTV (Internet TV)," e.g., CHA 200701. We retain the more general perspective of IPTV as TV (video, video on demand, etc.) distributed over any kind of IP-based network (including possibly the Internet).

[2] While some have advanced Peer-to-Peer (P2P) models for IPTV (e.g., see CHA 200701), nearly all the commercial deployment to date is based on the classical client–server model; this is the model discussed in this book.

Properly, DVB-H is a protocol. More broadly, DVB-H deals with approaches and technologies to deliver commercial-grade, medium-quality, real-time linear and on-demand video content to handheld, battery-powered devices such as mobile telephones and PDAs. IP multicast is also typically employed to support DVB-H.

1.2 WHY MULTICAST PROTOCOLS ARE WANTED/NEEDED

There are three types of communication between systems in an IP network:

- Unicast—here one system communicates directly to another system
- Broadcast—here one system communicates to all systems
- Multicast—here one system communicates to a select group of other systems

In traditional IP networks, a packet is typically sent by a source to a single destination (unicast); alternatively, the packet can be sent to all devices on the network (broadcast). There are business- and multimedia-entertainment applications that require a multicast transmission mechanism to enable bandwidth-efficient communication between groups of devices where information is transmitted to a single multicast address and received by any device that wishes to obtain such information. In traditional IP networks, it is not possible to generate a *single transmission* of data when this data is destined for a (large) group of remote devices. There are classes of applications that require distribution of information to a defined (but possibly dynamic) set of users. IP multicast, an extension to IP, is required to properly address these communication needs. As the term implies, IP multicast has been developed to support efficient communication between a source and multiple remote destinations.

Multicast applications include, among others, datacasting, distribution of real-time financial data, entertainment digital television over an IP network (commercial-grade IPTV), Internet radio, multipoint video conferencing, distance learning, streaming media applications, and corporate communications. Other applications include distributed interactive simulation, grid computing [MIN200401], and distributed video gaming (where most receivers are also senders). IP multicast protocols and underlying technologies enable efficient distribution of data, voice, and video streams to a large population of users, ranging from hundreds to thousands to millions of users. IP multicast technology enjoys intrinsic scalability, which is critical for these types of applications.

As an example in the IPTV arena, with the current trend toward the delivery of High-Definition TV (HDTV) signals, each requiring in the 12-Mbps range, and the consumers' desire for a large number of channels (200–300 being typical), there has to be an efficient mechanism of delivering a signal of 1–2 Gbps[3] in aggregate to a large number of remote

[3] Currently a typical digital TV package may consist of 200–250 SD signals each operating at 3 Mbps and 30–40 HD signals each operating at 12 Mbps; this equates to about 1 Gbps; as more HDTV signals are added, the bandwidth will reach in the range of 2 Gbps.