IPTV Systems: Benefits, Challenges, and Future Trends

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Abstract – **Starting from the point of view that Internet Protocol Television (IPTV) will be an application for next-generation Internet and will provide new revenue opportunities for service providers, this article seeks to provide an overview of benefits, challenges and feature trends in this fields. In the first part, we survey IPTV system architecture, together with video headend, transport network and home network. Service assurance aspects specific to IPTV are discussed. We emphasize that the future peer-to-peer (P2P) IPTV systems should be design to meet the expectations of users for quality of experience. The key success factors, benefits and associated challenges of launching IPTV over WiMAX are evaluated, too.**

Keywords – **IPTV system, P2P IPTV, Service level surveillance, WiMAX.**

I. Introduction

Network access bandwidth of widely available consumer services is increasing. The convergence of the trends has fueled increasing interest in delivery of IP services via IP networks known as Internet Protocol Television (IPTV). A number of operators and vendors are working on IPTV standardization to support wider availability and interoperability of IPTV as a secure reliable managed service. While the technologies for packet video have been explored for some time, a number of issues remain in the design, development and deployment of commercially viable IPTV services. These include standardization of architectural elements, content protection, and service aspects including portability, scalability, interoperability, performance and accounting. Telecommunication companies are under increased pressure due to competition from multiple system operators and the changing communications and entertainment needs of residential consumers. These pressures are driving the telecommunications companies to design and deploy metro networks capable of delivering broadcast video and Video on Demand (VoD) services through IP broadband connectivity, known as IPTV [1]. IPTV services are becoming one of the most promising applications over next generation networks. To ensure that IPTV services meet the high expectations of end users, factors affecting Quality of Service (QoS) or a user Quality of Experience (QoE) must be properly considered. A variety of factors can affect the quality of IPTV audio and video, such as the content preparation process, network reliability and terminal performance. Industry must have access to tools designed to assess the QoE of IPTV services [2]. IPTV, an emerging Internet application would revolutionize the entertainment and media industries. However, IPTV also has the potential to over whelm the Internet backbone and access networks with traffic. To date, IPTV over peer-to-peer (P2P) streaming networks has advanced significantly using two different approaches: tree-push versus mesh-pull [3]. In particular, the mesh-pull streaming approach has achieved a number of successful commercial deployments.

With two-way communication capability and point-to-point distribution, each viewer can chose individual programs flexibly and of lover cost. According to a study by the Multimedia Research Group, the number of IPTV subscribers will grow from 4.3 million in 2005 to an estimate 36.8 million by 2009, with a compound annual growth rate of 72 percent, and the IPTV service revenue will increase from $ 740 million to $ 4.6 billion in 2009, with a compound annual growth rate of 56 percent [4]. Telecommunications service providers are racing to provide IPTV/ VoD, voice, and data – the so called triple-play services.

This work is organized as follows. An overview of the IPTV system and the generic architecture are outlined. Then, the future trend of IPTV is discussed. Then, the P2P IPTV will be presented. Following this, the key success factors for IPTV, the benefits and the challenges over WiMAX are identified. The concluding remarks close the presentation.

II. IPTV System

IPTV is an integration of voice, video, and data services using high bandwidth and high speed Internet access. IPTV system includes several components as shown in Fig. 1. The main components are: video headend, transport network (which includes core network and access network), as well as home network.

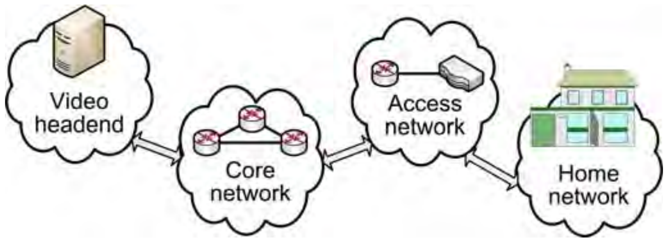

Fig. 1. IPTV system

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A. Video Headend

The video headend (VH) is composed of the following components: video encoder, live video broadcast server, VoD server, content and subscriber management. Video encoder can encode real-time video analogue signals from a content provider or a live event location to a digital format based on a given video compression technology MPEG 2/4. The encoder also deals with on demand content stored or redistributed at different VoD servers after the encoding and other processing, such as digital rights and encryption. Remember that video consists of a sequence of frames taken at regular time intervals (typically every 33.3 ms or 40 ms). Because in its raw form video requires a bit rate much too high for economical transports, it is compressed using video codec technology. As shown in Fig. 2, this technique relies on organizing the frames into a set of anchor frames (also referred to as I-frames), often regularly spaced in time, and a set of predicted frames (also referred to as P or B-frames) between these anchor frames. The anchor frames are encoded (with image compression techniques similar to still image, compression) without making reference of other frames. The predicted frames are first predicted based on one or more surrounding frames, using the estimated motion of the objects in the frames it refers to. To reconstruct a predicted frame, the decoder requires only the decoded versions of the frames it refers to, the motion of the objects, and some information pertaining to the unpredictable parts of that frame. All predicted frames between two anchor frames, together with the starting anchor frame, often are referred to as a group of pictures (GoP) and distance between anchor frames as the GoP size. A typical choice for the GoP size ranges between 0.5 s and 2 s. Most standardized codecs use a motion compensated predictive technique [5, 6].

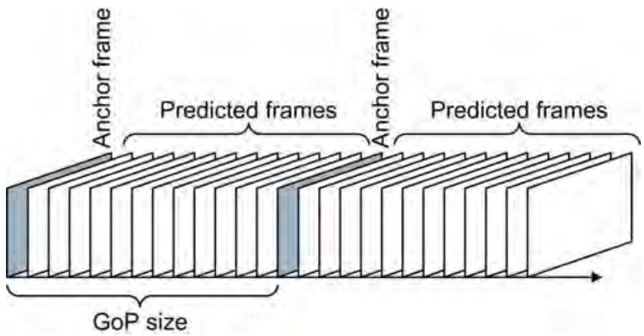

Fig. 2. Predictive image coding

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 preencoded video file are received. The server also interfaces the core network and transmits the video signal over the core network toward the access network.

VoD server houses on demand content with streaming engines and a large storage capacity.

Content and subscriber management systems are essential to facilitate the operation of IPTV services in terms of subscription account setup or client central, billing and authentication for back-office control, as well as digital right and security issues for content and delivery control.

To conclude, VH captures all programming content, including linear programs and VoD content. The VH receives the contents through satellite or terrestrial fiber networks. This part of IPTV system also is responsible for encoding the video streams into MPEG-2 or MPEG-4 formats. Then, the content is encapsulated into IP packets that are sent to the core network (CN), using IP multicast, or IP unicast.

B. Transport Network

In general there are two major parts of the transport network: core and access networks.

Core networks connect the access networks to customer premises and can be simply a single national distribution network running Gigabit Ethernet or IP/Multiple Protocol Label Switching (MPLS) plus various regional distribution networks running carrier-grade Ethernet [7]. The CN groups the encoded video streams into their respective channels. The CN is unique to the service provider and often includes equipment from multiple vendors. At this stage, IPTV traffic can be protected from other Internet data traffic to guarantee a high level of QoS. Managed content is usually centralized and processed within the national distribution network before being delivered to different access networks.

Access network serves as a critical part of the transport network and are used to reach each individual customer at home. The technologies available today are mainly xDSL and coaxial hybrid fibre cable (HFC) or fiber technologies such as fiber-to-the-node (FTTN). As 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 pocket duplication. A single transmission of each unique video date is shared among a group of customers who demand same live content. Data is replicated only at appropriate branching locations such as a regional edge router when it is necessary to force another subsystem to reach another group of customers or an individual customer. The last-mile access network contains the broadband remote access server (BRAS) which is responsible for maintaining user policy management, such as authentication and subscription details. It also enforces QoS policies for the IPTV traffic. In the reverse direction, traffic from multiple end users is aggregated and routed to the CN by digital subscriber line access multiplexers (DSLAMs).

C. Home Network

The last-mile home network distributes the data, voice, and IPTV/video traffic in subscribing homes. Suppose that each home has two to three TV sets on average. If each set shows one channel and another picture-in-picture channel, then the home network should support at least two high definition TV (HDTV) channels and two to three standard definition TV

(SDTV) channels simultaneously. The average data rate for SDTV is approximately 2-5 Mb/s and for an HDTV channel, approximately 5-10 Mb/s, depending on the video encoding used. For high quality video streaming services, a packet loss rate of 10-6 or less, end-to-end latency on the order of a few tens of milliseconds should be guaranteed. If a home has approximately 4 television sets, 2-3 SDTV and 1-2 HDTV, the sets simultaneously consume up to 20 Mb/s. At this point, bandwidth management among different traffic classes to homes becomes a critical issue. In case a wireless access technology such as WiMAX is adopted, it will be of ultimate importance to by fully exploring the fading channel diversity of all the receiving subscriber stations.

III. Peer-to-Peer IPTV

Peer-to-peer (P2P) IPTV is a new kind of IPTV, different from the infrastructure based scheme introduced previously in which each IPTV user is potentially a server with multicasting received content to other IPTV users [8]. In a P2P system, users serve as peers and participate in video data sharing.

P2P streaming networks do not rely on a dedicated delivery infrastructure and hence offer the possibility of peers can be utilized for video transmission so as to reduce the server load dramatically. Therefore, P2P streaming appears to be the most promising mechanism for the IPTV deployment. Content owners often are not equipped with a strong content delivery infrastructure. The low cost incurred in the P2P streaming paradigm is particularly appealing to these content owners. Nevertheless, the large volume of video traffic generated by P2P application has been raising the traffic load on the network infrastructures of telecommunications operators.

There exist two major design issues for constructing a P2P streaming network. The first one deals with the problem how to form an overlay topology between peers, while the second is how to deliver video content efficiently. The content approaches can be classified into two categories:

- Peers form tree-shaped overlay and video content is pushed from the origin server to peers, namely it is co-called tree-push approach.
- Peers form a mesh-shaped overlay, and they pull video from each other for content delivery, namely it is the mesh-pull approach.

Over the years, many tree-push systems have been proposed and were evaluated in academic and thy achieved some success. Unfortunately, they never took off commercially. On the other hand, mesh-pull IPTV systems have enjoyed a number of successful deployments, such as Cole streaming, PP Live and others. The major advantages of mesh-pull systems are the simple design principle and inherent robustness, particularly desirable for the highly dynamic P2P environment.

IV. IPTV Services

Generally, IPTV services can be classified by their type of content and services. By the type of content, we have: on demand content and live content, while when taking into account services, there exist managed and unmanaged services.

In the case of on demand content, with pre-encoded and compressed content, a customer is allowed to browse an online movie catalogue, to watch trailers and to select a movie of interest. Unlike the case of live video, a customer can request or stop the video content at anytime and is not bound by a particular TV schedule. The playout of the selected movie starts nearly instantaneously on the costumer's devices.

For live content, a customer is required to access a particular channel for the content at a specific time, similar to accessing a conventional TV channel. A customer cannot request to watch the content from the beginning if he joins the channel late. Similar to a live satellite broadcast, live content over IPTV can be a showing or a live event, or a show encoded in real-time from a remote location (for example a soccer game).

In managed services, video content can be offered by the phone companies who operate the IPTV business, or obtained from comment providers in which the content is usually well-managed in terms of the coding and playout quality as well as in the selection of video titles. Bandwidth or delivery and costumer equipment are arranged carefully for serving the best playout performance and quality to the customers.

As for unmanaged services, the technology of IPTV itself enables playout of any live or on-demand video content from any third parity over the Internet. Therefore, nothing stops a customer from accessing video content directly. With a wide range of choice for content selection, obviously the unmanaged services have an advantage at the expense of non-guaranteed playout quality and performance.

A. Quality of Service and Traffic Management

Quality of Service (QoS) guarantee and traffic management are challenging for core and access networks in particular for IPTV services. For down-stream traffic, differentiated services are used for different users with different schedules. Each user class requires a separate scheduler to prevent the starvation of lower classes. Admission control is required for a QoS guarantee. In IPTV services a user requests changing by sending a request for a video channel. After the request is accepted by admission control, a multicast tree is built to send video and voice of the requested channel with QoS guarantees. The procedure causes a channel changing delay. In the IPTV sets in a household are off, the available bandwidth can be used for Internet access and other uses.

The goal of traffic management is to efficiently support QoS requirements for diverse services, including policing, scheduling, flow control, multicasting, traffic differentiations, admission control, and so on. It is implemented via either a centralized manner or a distributed manner. The later approach is more scalable and flexible. Policing ensures that traffic conforms to a service level aggregation (SLA). Scheduling ensures the handling on voice, video and data traffic to meet QoS requirements such as delay, its variation, and so on, as well as efficient utilization of bandwidth. Flow control is to control traffic flow to avoid or reduce temporary congestion. Multicasting is used both in downstream and upstream to efficiently utilize bandwidth. Traffic differentiation gives higher priority traffic such as voice, audio and video a higher priority to the transmitted and gives data a lower priority. This should bi done in both the core networks and the access networks. Admission control decides to accept or reject upstream and downstream bandwidth requests, ensuring an accepted flow of bandwidth that satisfies the QoS requirement. Service providers must indicate the level of the QoS that is guaranteed in an SLA, which may cause communication costs for the service providers. QoS guarantee mechanisms and traffic management for IPTV services require further research.

B. Service Level Surveillance

The service level management process for video services is a challenging technical task. The quality management process applies to the end-to-end service traffic path and so requires that all network elements on this path should support Simple Network Management Protocol (SNMP), management information bases (MIBs) or similar accessible data for accumulating management information. In the case of triple play services, especially video delivery, special attention should bi given to newly introduced devices such as Ethernet as well as customer getaways and set-top boxes. Performance metric violations and hard faults trigger alarms that must be analyzed in order to report, identify and troubleshoot existing on upcoming problems. The main functions of service level surveillance include integrated IPTV performance and fault event correlation, root cause analysis and service impact analysis. To implement such functionality, service models are used that keep information of dependencies among IPTV network components and events in different layers. As a first step of automation, service models allow the network administrators to navigate on scene from end-effects to potentially root-causes. More advances tools automatically correlate large event streams and determine a minimum number of potential root-causes. Another use of service models is the combination of multilayer metrics to evaluate key quality indicators and key performance indicators. These summarizing indicators allow IPTV network administrators to have an integrated view of the overall service health and inspect specific metrics.

There are possible attacks and network outage failures for IPTV services. Rapid recovery after attacks/failures is important to minimize negative impact. IPTV services should provide user security and privacy with confidential delivery of data such as program channels and content, prevention of attacks from malicious users/software and Denial of Service (DoS). In future research the following issues must be solved: distributed digital rights management (DRM) to protect the copyright of video contents, the authentication of clients to verify their access privileges, and the prevention of traffic flooding over-consumption attacks.

V. IPTV OVER WIMAX

The question often arises is what will occur in future IPTV services in order to choose the correct technologies for corresponding extensions. WiMAX should always be included to facilitate the success factors for the IPTV services.

The success of the IPTV services is determined by the time and volume of profitable operations. Getting the maximum number of subscribers as soon as possible for IPTV services program is clear goal for any service provider. It has been reported that from time to time xDSL and cable broadband access is not available in some areas due to geographical distance and user-density. Meanwhile, the deployment of xDSL and cable wiring overhead is not as easy and scalable as that of WMAN technologies. As an alternative to the conventional wired access network technologies, WiMAX offers the ease of deployment similar to other wireless technologies, but with larger service coverage and more bandwidth. Delivering IPTV services over WiMAX to complement the current IPTV deployment can capture the maximum number of subscribers under the same infrastructure and provide even better accessibility to the same pool of video content for mobile users in the future [9].

Today Telecoms are actively seeking ways to offer triple or quadruple play services. WiMAX is considered a very good candidate to provide new services such as wireless broadband access and mobile Voice over Internet Protocol (VoIP) telephony. IPTV over WiMAX can further achieve economy of scale in terms of more services and better service availability under a common infrastructure.

We can enumerate the emerging trends of IPTV for the aspects of mobility, accessing unmanaged content, and supporting high-quality video, such as HDTV. WiMAX others benefits for such promotion with its reservation-based bandwidth allocation, cost-effective and infrastructure-free deployment and stringent QoS support for the four types of service: unsolicited granted service (UGS), real-time polling service (rtPS), non real-time polling service (nrtPS), and best effort (BE) traffic [10]. Enabling rtPS in the wireless broadband access can support perfectly the bandwidth requirements of managed content of the IPTV service providers, especially for HDTV and SDTV. When the more and more portals available in the Internet core that offer a great deal of rich and free of demand video content, it is very attractive approach to allow non only home IPTV users, but also mobile users to access this unmanaged content without affecting the quality and performance of other paid live content. The incorporating of rtPS and BE service can be manipulated to support these demands, such that the best flexibility and economy can be achieved without losing much quality in content delivery. The extendibility for supporting the future trends of IPTV services over common WiMAX access infrastructure creates long-term and growing economics of scale to the state-of-the-art IPTV operation.

VI. CONCLUSION

IPTV is an emerging technology that allows consumers to watch high-quality digital TV over the Internet via an IPTV set-top box or a PC. While IPTV is technically a data service, it is important from a revenue perspective that it deserves special attention. IPTV consists of VoD and SDV. With VoD, each IP stream is viewed by one TV. With SDV multiple TVs can view a simple IP stream. Thus, VoD relies on IP unicast, while SDV relies on IP multicast. Both require high QoS to minimize frames loss, high bandwidth to minimize "blue screens" and fast system response to minimize channel change times.

Also, IPTV is well suited for time-shifted TV, and network personal video recorder. For all the services, the buffer in the network must be larger than what is required for fast channel change. A key challenge issue in the IPTV application is in-home distribution with affordable deployment cost and sufficient flexibility, scalability and reliability. Consumers will subscribe to IPTV services that provide satisfactory QoS, value, service differentiation and convenience.

The current practice of mesh-pull P2P streaming systems demonstrate the feasibility of large-scale application layer multicast on top of the best-effort Internet. Despite its early successes, P2P IPTV is still in an early stage. Many often and interesting research problems remain to be addressed to design and deploy the next generation P2P IPTV services with superior user QoE. P2P IPTV systems should be enhanced with appropriate server infrastructure support to achieve a high level of QoS. On the other hand, the popularity of P2P IPTV applications on the Internet has posed a great challenge for network infrastructures to support tremendous P2P IPTV traffic.

IPTV service assurance assumes all of the challenges in assuring broadband access networks while adding layers of complexity for monitoring and managing video content origination, authorization and distribution through QoS-enabled IP networks.

Finally, challenges are posed for IPTV over WiMAX due to multicasting under a diversity of feeding conditions. It is a strategic but challenging leverage to glimpse the potential of IPTV by using WiMAX as the access network.

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