IPTV Status Report

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Internet Protocol Television (IPTV) is experiencing rapid growth as one of the newest channels for distributing television content to consumers. Service providers around the world have announced and started to install systems that will provide service to millions of consumers by the end of the decade. This article begins with an overview of IPTV and related technologies. Then a short summary of some current market data and of some potential areas where this technology could have an impact on broadcasters will follow. The article will conclude with a look at some of the current technical work in the IPTV area.

Defining IPTV

Problems can occur when new terminology is created and not everyone agrees on the meanings. Case in point: the term "IPTV." While it is true that all IPTV installations send video over IP networks, it is not true that any kind of video sent over the public Internet is IPTV. For the latter, the term "Internet Video" is often more descriptive.

IPTV is simply a way to deliver traditional broadcast channels to consumers over an IP network in place of terrestrial broadcast, CATV, and satellite services. Even though IP is used, the Internet doesn't actually play much of a role. In fact, IPTV services are almost exclusively delivered over private IP networks, such as those being constructed by telephone companies.

In a typical IPTV network, SD video signals are usually compressed to 2.5 Mbits/sec or less, and HD signals between 6 and 10 Mbits/sec. At these bit rates (which are comparable to those being used by DBS satellite and digital CATV systems), video quality is good, but delivery over the Internet is pretty much out of the question for most consumers. A set-top box (STB) is installed at the viewer's home to take an incoming IPTV feed and convert it into a standard video signal that can be fed to a consumer television.

Some main characteristics of IPTV:

- Continuous streams of professionally produced content (such as TV network feeds)
- Hundreds of 24 x 7 channels
- Uniform content format (all channels on a single system typically share one compression method and use roughly the same bit rate for SD and another for HD)
- Delivered over a private network, such as a telco Digital Subscriber Line (DSL)
- Viewed on consumer televisions by way of an STB

Internet Video is used to supply video content to viewers over the Internet. In a typical internet video installation, service providers set up a website portal that can be reached by anyone with a standard browser. At this site, there will be a list or index of the various pieces of content that are available. Once the user has selected some content, it is delivered to the viewer's PC, where special media viewer software can be used to view it, or where it can be downloaded to a portable viewer.

Some main characteristics of internet video:

- Discrete content elements, ranging from clips lasting a handful of seconds to full-length movies
- Millions of content offerings
- Widely varying content formats, including dozens of different types of video compression, rights management technologies, and image resolutions
- Delivered over the public Internet
- Viewed on PCs with special software or on portable video players

Of course, the lines between these two categories will tend to blur, as technologies become more robust and flexible. For example, when Apple introduced the Apple TV device, it was targeted for playing back video files that were wirelessly downloaded from an iTunes library stored on a PC. However, recent announcements have indicated that Apple TV will now support streaming of video content over the Internet from YouTube. Similarly, more "channels" of continuous programming are appearing on the public Internet (both free and subscription-based) that allow a PC to display a continuous broadcast feed instead of a series of content files that must be individually requested by a viewer. One example of the latter is NASA TV, which provides live coverage of all the space shuttle missions, and a variety of other live and pre-recorded programming.

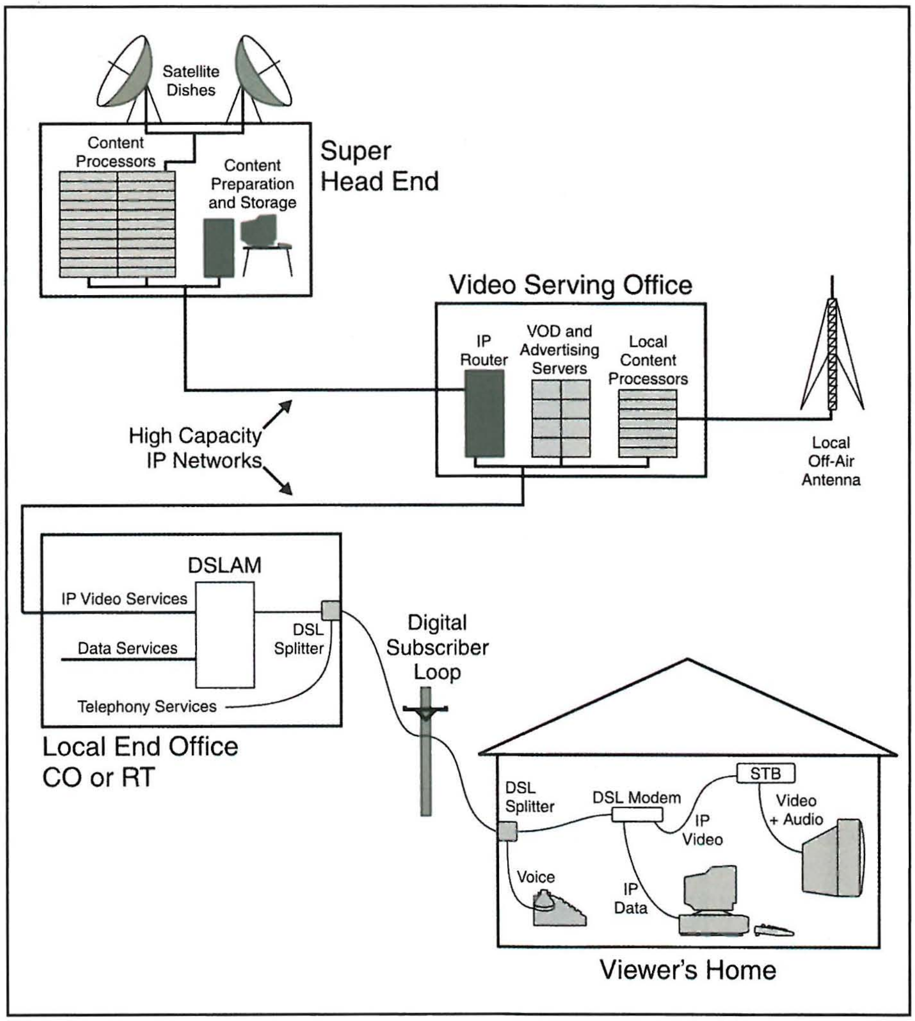

Figure 1

IPTV Basic System Architecture

At the core, an IPTV system is made up of four major subsystems:

- A headend, where video content is gathered from a number of sources and then converted and compressed into a common IP format for distribution to viewers.
- A delivery network, which transports the content packets to the viewer locations.
- An STB installed at each viewer's location that is responsible for receiving the incoming content packets, unpacking and decompressing the video signals, and delivering them to a viewing device.
- A variety of software to support a wide range of functions that are essential to the operation of an IPTV system.

Figure 1 shows the functional layout of a typical IPTV system that could be used for a large IPTV system. At the top is a super head end that is used to gather content of national scope, such as premium movie channels, news channels, sports channels, or other special-interest channels. From the super head end, high-speed IP links are used to deliver compressed content to video serving offices located in each local IPTV service area. These offices have the responsibility of gathering content from local programming sources, compressing it, and formatting it into IP streams that can be delivered. For networks that provide video on demand, the video serving office will frequently be used for housing the VOD servers along with the IPTV subscriber management systems. The output of the video serving offices is delivered via high-speed IP links to a number of local end offices, which are often located in telephone company central offices or remote terminals. Inside each central office or remote terminal, a DSL access multiplexer (DSLAM) is used to deliver video, data, and voice services over twisted-pair copper cable. At the viewer's home, each of the different services contained in the incoming line are separated by a DSL splitter and processed by a DSL modem before being sent to the viewer's devices.

Head ends can be large or small, and centralized or distributed. For very large systems, two super head ends may be located in separate geographic areas and connected via redundant IP links to a number of local head ends. Another model in use today involves a centralized head end that is linked via satellite to a number of small IPTV providers, who pay a monthly fee to the satellite provider for this service. In both scenarios, the local end offices need to play an active role in forwarding the correct video packet streams to the delivery networks.

Many IPTV delivery networks are based on DSL technology, but that is not a requirement. In fact, almost any IP network can be used for IPTV delivery, provided it has adequate bandwidth and there is a mechanism in place to ensure that the video packets are not blocked by other data. In many cases fiber optics extend from the local end office to each DSLAM location, and then copper twisted pairs connect to each subscriber. Note that the bandwidths that are available on DSL lines are highly dependent on the modulation technologies used (ADSL, VDSL, etc.) and the lengths of the copper loops, so proper DSLAM placement is critical to success.

At viewer locations, several functions are needed. These can be contained in separate units, or they can all be combined into one device. First, the DSL line (or other IP transport network) needs to be terminated by a DSL modem or similar. Second, the incoming packets must be decoded and used to generate a suitable SD or HD video output, which is then sent to the viewer's display device. Third, there must be some kind of mechanism to receive commands from the user and send them upstream to the IPTV head end for processing. In many typical installations, the DSL modem is located near the point of termination for the DSL circuit, and IP data is transmitted via Ethernet or similar links to one or more STBs that are located close to their associated display.

Software (primarily in the form of Middleware) is essential to the operation of an IPTV system. Middleware has a number of significant roles to play, including the following functions:

- Subscriber Authorization
- Content Encryption
- Electronic Program Guide (EPG)
- Channel Change
- Video on Demand

To understand the crucial role that middleware plays in the overall system, consider the series of steps needed to accomplish a channel change. Keep in mind that many IPTV delivery networks (such as DSL) have limited bandwidth, so only one IP video packet stream at a time can be delivered to each set-top box:

1. First, the viewer needs to receive information about the content that is available for viewing. This is accomplished by the EPG, which forwards data from centralized servers to each STB for display to the viewer.
2. The user interacts with their local STB to decide which program to view. This process can be based solely on data that is stored inside the STB, or the process can be hosted on a centrally located server, or a combination of the two.
3. Once the user makes a selection, a command is sent from the STB to instruct servers at the head end to stop sending the current program stream and begin sending a new one in its place.
4. Whenever the head end receives a request for a new channel, a check must be made to ensure that the viewer is authorized to receive the requested content. Also, if the content is encrypted, a suitable decryption key must be generated and delivered to the viewer's STB.
5. Based on the user's request, the central server will take one of several actions. If the viewer has requested a broadcast channel that is already being delivered to the DSLAM serving the viewer (and that DSLAM is multicast-aware), the STB can simply be instructed to issue a command to leave its current video packet stream and join the new one that is already in progress. If the stream is not present, then the server needs to create the stream (say, from a VOD storage server) and deliver it to the proper DSLAM before the STB can be instructed to join the stream.
6. In many IPTV systems, video compression GOPs having up to two seconds between successive I (Intra-coded) frames are often used. Since the decoder must wait until an I-frame has been received to properly decode a picture, channel change times can be excessive. To compensate for this, some IPTV systems are designed to transmit

a burst of IP packets containing video data that can be used by the decoder to create an image while waiting for an I-frame. Typically, one of these packet bursts must be created for each STB after each channel change, due to the asynchronous nature of the channel change requests.

7. Finally, the IPTV system must ensure that any stream that is no longer being viewed is removed from the system, so that bandwidth is not unnecessarily tied up.

Clearly, middleware that is robust, flexible, and scalable enough to handle channel changes from thousands of subscribers simultaneously is a significant development effort for any company.

The Impact of IPTV on Markets and Broadcasters

From a market perspective, IPTV represents a new channel for delivering video programming to consumers, alongside CATV, satellite, and terrestrial broadcasting. As such, these new systems will provide additional competition to the established companies, both in the form of price competition and customer features and functionality. In many markets, IPTV will be one of the first delivery platforms to offer true VOD capability, including pause, fast-forward, and rewind under complete viewer control. In addition, IPTV systems will be able to offer service to viewers who are not served or poorly served by the other delivery networks, particularly in rural areas.

As with any new technology, market forecasts for the penetration of IPTV subscribers range widely from study to study. There seems to be fairly good consensus that the IPTV market had between three and five million subscribers at the end of 2006. That number should double or triple during 2007, as more systems ramp up deployment. Going further, subscriber projections for 2010 to 2011 range from 40 to 80 million subscribers.

The immediate impact of most IPTV systems on broadcasters will be fairly minimal, as these can simply be treated as another distribution channel alongside CATV and DBS satellite. As time progresses, some differences in the ways broadcasters operate may appear. Two areas where IPTV may drive broadcaster innovation include compression and interactivity:

Compression for delivery. Because of the limited bandwidth of many IPTV delivery networks, highly efficient compression technology is essential. In most cases, standard MPEG-2 compressed feeds created by broadcasters for digital terrestrial broadcast are being converted to lower bit rate MPEG-4AVC or other high-efficiency compression formats. This can be accomplished either through transcoding the compressed signals from one compression format to another, or by decompressing the broadcast feed into raw video and then recompressing the video using a different encoder.

Of course, any change of compression technique can have a significant impact on the end-of-line viewing experience, and might be of concern to broadcasters. This is particularly true if low-quality devices used in smaller IPTV installations are used to perform high amounts of compression. To counteract this, broadcasters may decide to simply perform the high-efficiency compression themselves, and distribute the signals directly to IPTV systems. For broadcasters, the expense of acquiring and maintaining extra encoding equipment and extra distribution bandwidth will need to be balanced against the benefits of increased control over the way that video images are delivered to viewers.

Drive towards increased interactivity. A major advantage of IPTV systems over satellite systems (and some CATV systems) is the amount of interactivity that they can provide. IPTV STBs need to have a direct, realtime data connection to the central server to support channel changing and other routine activities. This link can easily be adapted to support user interactivity, such as ordering VOD services, voting on television contests, home shopping, and other actions requiring user feedback. In contrast, CATV systems with older STBs have limited upstream communication capability, and satellite systems need to rely on external data links, such as dial-up modems.

If IPTV providers are successful in stimulating viewer demands for interactivity, broadcasters may be forced to react, if only to keep up with competitors. This can impact the way programs are produced and the types of programs that are successful.

Ongoing Developments

Many diverse areas are subjects of current research, development, and standardization efforts in the IPTV arena. Some high-profile areas include:

- Scalability of IPTV software and operations systems is a concern, particularly for large system operators. The impact of tens of thousands of viewers simultaneously changing channels is hard to model, and real-world tests are expensive. As these systems grow, care must be taken to add processing power and eliminate transactional bottlenecks to ensure a satisfactory viewing experience for new customers.

- Research continues into compression technology. Anytime the number of bits required to provide a satisfactory image to viewers for either SD or HD content can be reduced, the IPTV provider benefits in two ways. One way is by freeing up bandwidth that can be used for other services by the provider, such as additional channels to each home or more internet bandwidth. The other way is by allowing a provider to increase the longest permissible local loop, since the maximum bit rate of DSL (and some other) lines decreases with increasing length. Longer loops allow a reduction in the number of locations where DSL multiplexers need to be installed to cover a given territory.
- During the joint SMPTE-VSF conference in January 2007, held in Orlando, FL, Michael Isnardi of Sarnoff labs reported on a new technique that had been developed to reduce the bit rate of compressed MPEG signals using "tweening" and other technologies. The results indicated a significant reduction in delivered bit rate, with no loss of picture quality. It is not known if work is currently under way to incorporate this technology into an actual IPTV system or other compression device.
- Another way to reduce bandwidth requirements on IPTV systems is to improve the quality of the signal that is being compressed. With an improved source signal, the amount of compression can be increased without impacting the viewer's perceived image quality. The economic tradeoff between video contribution quality and video delivery quality is an interesting area for further analysis. This topic is the subject of ongoing investigation by the author of this article.
- Digital video recorders (DVRs) have become popular television accessories around the world, primarily because of their ability to automatically record content at one time and play it back at another. These devices are very popular with consumers who have them, but much less so with content owners who are justifiably worried about thousands of digital copies of their content sitting on hard drives in viewers' living rooms. They are even less popular with advertisers, whose commercials can be skipped by viewers during playback or become outdated if viewers wait several weeks before viewing what they have recorded. One potential solution to these concerns is the network DVR, whereby a video service provider records the programs on a central server for later playback for viewers—this addresses security concerns, and also allows a service provider to insert new commercials into the content that can't be skipped by viewers. Unfortunately, when one service provider (Cablevision) attempted to do this without the permission of the content owners, the result was a series of lawsuits. Interestingly, a major content supplier (Fox) has begun to explore the possibility of using network DVRs specifically to insert new commercials into the recorded content. The long-term fate of the network DVR is far from certain at this point.
- Interoperability and standardization of IPTV have not yet become a major issue with carriers, as most of the current deployments are focused on getting systems to work with one, or at most two, technology partners supplying each of the critical subsystems. As the market matures, IPTV providers will be looking to organizations such as the International Telecommunication Union (ITU), which created a focus group in April 2006. The first meeting was held in Geneva in July 2006 and work continues, with meetings held every three to four months, as contributions warrant.

Conclusion

IPTV is a robust technology serving a growing market. As this technology matures and reaches measurable levels of end-user penetration, a number of issues will need to be addressed. A top priority is the scalability of the deployed networks, particularly for complex, frequent operations such as channel changing. Another priority will be the drive towards industry standards and interoperability. A third area of particular concern for broadcasters will be the impact of IPTV's ability to provide large libraries of VOD content and viewer interactivity at unprecedented levels. The way that these issues are resolved will have a huge bearing on whether IPTV continues to grow at the expense of other delivery technologies or remains a niche player in the future.