An Application Scenario for IPTV Transmission over WiMAX

Grigor Y. Mihaylov[1], Teodor B. Iliev[2]

Abstract – **IPTV is a system where a digital television service is delivered using Internet Protocol over a network infrastructure, which may include delivery by a broadband connection. IEEE 802.16 standard specifies the air interface of fixed broadband wireless access systems supporting multimedia services.**

Keywords – **IPTV, WiMAX, OFDM, PHY layer.**

I. INTRODUCTION

A general definition of IPTV is television content that, instead of being delivered through traditional broadcast and cable formats, is received by the viewer through the technologies used for computer networks. IPTV is typically supplied by a service provider using a closed network infrastructure. This closed network approach is in competition with the delivery of TV content over the public Internet, called Internet Television. In businesses, IPTV may be used to deliver television content over corporate LANs.

In the past, this technology has been restricted by low broadband penetration. Nowadays many of the world's major telecommunications providers are exploring IPTV as a new revenue opportunity from their existing markets and as a defensive measure against encroachment from more conventional cable television services. [5]

II. IPTV INFRASTRUCTURE

A typical IPTV infrastructure consists of three major building blocks: content acquisition, content distribution and content consumption, constructed in a hierarchy of national, regional, local coverage, to consumer premises. Each part is implemented with different elements and must be able to expand when needed. Figure 1 is a simplified system diagram describing major components of a typical IPTV system. They are: [6]

• Acquisition Servers (A-Server) which encode video and add DRM or metadata;

• Distribution Servers (D-Server) which provide caching and QoS control;

• VoD (Video-on-Demand) Creators and Servers which retain a library of encoded VoD movies to provide Video-on-Demand services;

• IP Routers which route IP packets and provide fast reroute for failover;

• Residential Gateways (RG) which are IP routers for bundled services at home and Set-Top Boxes (STB) which receive video streams for TV sets.

As shown in Figure 1, there are basically two types of content sources for IPTV: broadcast and VoD. Although both can utilize the same regional or local distribution networks, they each have their own special challenges. [7]

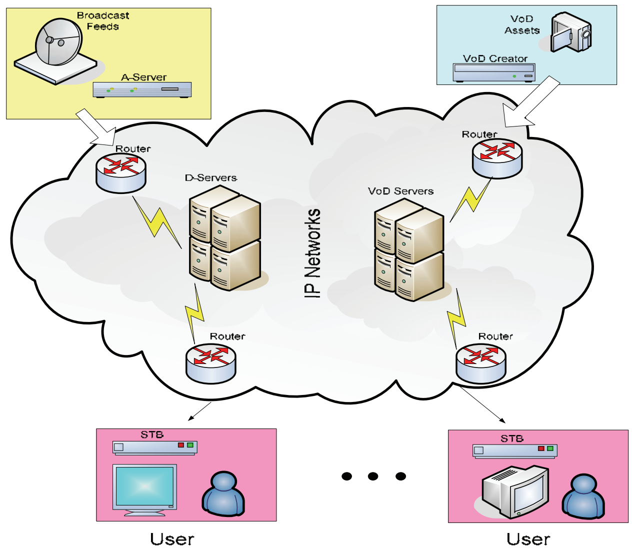

Fig 1. A simplified system diagram of an IPTV system

A. Broadcast Programs

For broadcast programs, each channel is provided by a multicast video stream. This effectively reduces the network bandwidth demand from one stream per viewer to one stream per channel. In this situation, a viewer changes the channel by leaving one multicast group and joining a different group. Switching channels in a digital environment is inherently slower than switching channels in an analog system. The delay is primarily caused by performing IGMP (Internet Group Management Protocol) processing at multicast group change, handling multiple stream (e.g. audio and video stream) synchronization, the wait for an anchor point, such as the start of a Group of Pictures (GOP), or key frame, and the lag at filling the play-out buffer. When the broadcast content is encrypted, decryption key acquisition and management may cause an additional delay. This problem is especially challenging when multiple viewers surf through many channels at the same time.

[1]Grigor Y. Mihaylov is with the Department Telecommunications, 8 Studentska Str., 7017 Ruse, Bulgaria,
E-mail: gmihaylov@uni-ruse.bg
[2]Teodor B. Iliev is with the Department of Telecommunications, 8 Studentska Str., 7017 Ruse, Bulgaria,
E-mail: tiliev@ecs.uni-ruse.bg

In addition to channel switching, there are other stream change cases which make IPTV both charming and challenging. A video server may want to composite multiple video sources to generate anew stream. One example is to replace national content or content from other regions with the content ingested locally. This is particularly useful for the information such as weather or advertisements. A more difficult scenario is to broadcast a sports event with multi-camera streams. [7]

Synthesized video from a selected viewpoint may be generated according to viewer's preference. IPTV opens the door for integrating such multi-view video or free view point TV systems. In Section IV, we will present some further discussions and existing technique solutions on seamless stream switching.

B. VoD Programs

For VoD programs, there are two scenarios: time-shifted and real-time. In the former case, video may be downloaded first and viewed later; In the latter case, video needs to be streamed to the user in real-time, which has more stringent resources requirement for VoD systems. In real-time VoD, multicast may not work, as cases when two or more users request the same movies at the same time rarely happen. Proper bandwidth provisioning is needed to guarantee the delivery of various unicast streams. Apparently, this approach imposes significant pressure on network resources.

Serving a large number of VoD requests with unicast streams can become a nightmare and any new requests may have to be turned down at some point. Actually, some service providers have to use a dedicated VoD infrastructure to deploy VoD services. [6, 7]

As VoD is moving towards "everything on demand" or "infinite content", scalability becomes a major issue for the success of IPTV. Even a dedicated infrastructure just for VoD services faces such a challenge. People seek successful stories from relevant Internet applications and P2P techniques come into sight.

C. P2P for IPTV

An effective way to release servers' workload for VoD is to use peer-to-peer techniques, in which case we assume each STB can contribute its content or part of storage to its local community. There are advantages utilizing P2P resources in managed IPTV environments comparing to related P2P applications over the Internet. [7]

• STB storage management is available to the IPTV service provider;

• Information of peer locality and upload capacity is also known;

• Conventional P2P policies, such as tit-for-tat, may not be necessary and thus P2P overhead can be greatly reduced;

• Homogeneity of peer devices minimizes the control overhead;

• Distribution servers which are located in the content delivery path can easily implement the tracker functions.

Thus new features of P2P for IPTV can bring more advantages for content distribution than conventional P2P [8]. Distinguishes Internet-based cloud model and IPTV-based physical model and analyzes the capacity and profit of peer-assisted VoD systems. With the assumption that a portion of STB storage is manageable by the service provider, researchers consider STBs as networked storage to push or preload content to peers during off-peak hours or when low network utilization occurs. An example study can be found in [2]. As storage cost continually drops, more storage can be expected from individual STBs and more P2P assisted functions can be implemented based on the networked storage system.

III. IPTV TRANSMISSION

With evolution of networks WiMAX is the best choice for delivering IPTV wirelessly.

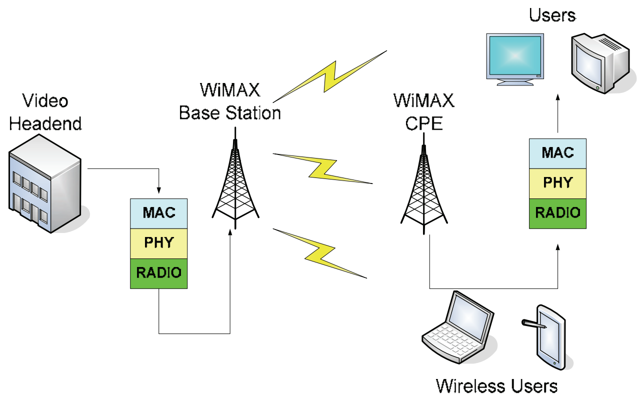

Fig. 2 System Model for IPTV Applications via WiMAX

WiMAX is essentially a next-generation wireless technology that enhances broadband wireless access. WiMAX comes in two varieties, fixed wireless and mobile. The fixed version, known as 802.16d, was designed to be a replacement or supplement for broadband cable access or DSL. A recently ratified version, 802.16e, also can support fixed wireless applications, but it allows for roaming among base stations as well. Thus, the two standards are generally known as fixed WiMAX and mobile WiMAX. The 802.16 standard is beneficial to every link in the broadband wireless chain, such as consumers, operators, and component makers. [9, 10]

In WiMAX, the medium access control layer (MAC) supports a primarily point-to-multipoint architecture, with an optional mesh topology. The MAC is structured to support multiple physical layer (PHY) specifications, each suited to a particular operational environment. [4]

IV. OFDM AND OFDMA

IEEE 802.16 will specify two flavours of OFDM systems: one simply identified as OFDM, the other OFDMA. The first aims at less challenging applications, quite short distance, eventually indoors. It employs fast Fourier transform (FFT) size 256 — a step further from 802.11a, which uses 64 carriers [2]. All carriers are transmitted at once. The downstream data is time-division multiplexed (TDM). The upstream time frame is time-division multiple access (TDMA).

In OFDMA the higher FFT space (2048 and 4096 carriers) is divided into subchannels. They are used in downstream for separating the data into logical streams. Those streams employ different modulation, coding, and amplitude to address subscribers with different channel characteristics. In upstream the subchannels are used for multiple access. The subscribers are assigned on subchannels through Media Access Protocol (MAP) messages sent downstream. [10]

A. Subchannels

The subchannel is a subset of carriers out of the total set of available carriers. In order to mitigate the frequency selective fading, the carriers of one subchannel are spread along the channel spectrum. Figure 3 depicts the principles of division into subchannels. The usable carrier space is divided into a number of N_G successive groups. Each group contains a number of N_E successive carriers, after excluding the initially assigned pilots. A subchannel has one element from each group allocated through a pseudorandom process based on permutations, so N_G is the number of subchannel elements. For $N = 2048$, downstream $N_G = 48$ and $N_E = 32$, while upstream $N_G = 53$ and $N_E = 32$.

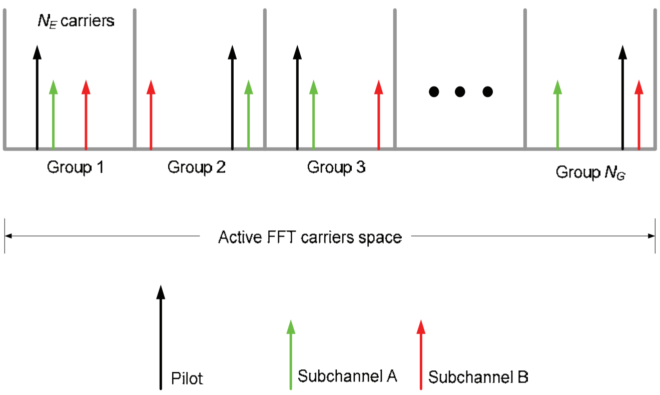

Fig. 3 Division in subchannels

In essence the principle of OFDMA consists of different users sharing the upstream FFT space, while each transmits one or more subchannels. The division in subchannels is a form of frequency-division multiple access (FDMA), where the subscriber transmits $1/N_E = 1/32$ of the available channel bandwidth for the 2048-carrier OFDMA. A low upstream data rate is consistent with the traffic asymmetry where the streams from each subscriber add up in a multipoint-to-point regime, while downstream all the subchannels are transmitted together. So the OFDMA allows for fine granulation of bandwidth allocation, consistent with the needs of most subscribers, while high consumers of upstream bandwidth are allocated more than one subchannel. Figure 4 shows the structure of subchannels in the upstream framing.

The most important aspect of the upstream subchannels is related to coverage. A BWA system involves a high-power transmitter in the head-end and a multitude of low-cost low-transmission- power BWSUs. For the OFDMA option of N = 2048, the BWSU concentrates its power into a subchannel that has 1/32 of the channel bandwidth. For equivalent modulation and coding, this results in 15 dB premium for the upstream link budget against the downstream. For a 6 MHz channel, one subchannel has an equivalent bandwidth of 187 kHz. But this low bandwidth signal does not undergo flat fading since its 53 carriers are spread across the entire channel bandwidth.

Regarding interference, the subchannels constitute a form of frequency hopping spread spectrum (FHSS). In every group a BWSU transmits one pseudo-randomly selected carrier out of N_E possible ones. A BWSU in an interfering cell does the same type of selection, but statistically independent. The probability of collision is $1/N_E$. This is a classic scenario of FHSS with partial band jammer [9]. The hopping scenario repeats for every group in an FFT symbol. For $N = 2048$ there are $N_G = 53$ such groups. The data from carriers with low SNR is corrected through interleaving and coding.

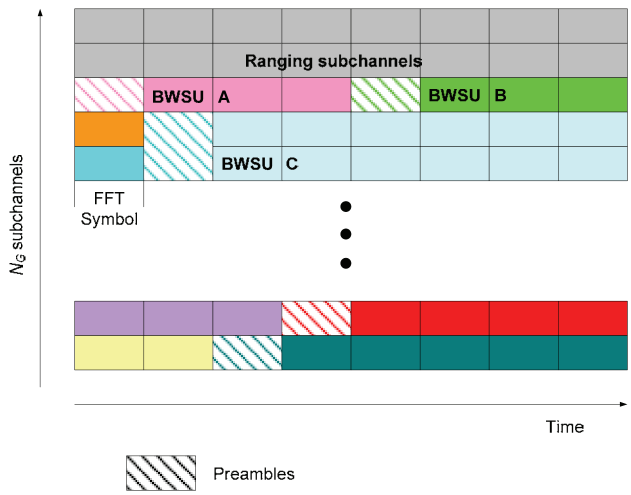

Fig.4 Upstream subchannels

The parameter that characterizes the degree of spreading in a spread-spectrum system is the processing gain, G_P. It can be expressed as a function of W, the group bandwidth R, the bit rate of one carrier and R_S, its symbol rate, by:

$$G_P = \frac{W}{R} = \frac{N_E R_S}{mR_S} = \frac{N_E}{m} = \frac{32}{m}, \qquad (1)$$

where m is the modulation density: 2 for QPSK, 4 for 16-QAM, and 6 for 64-QAM. The processing gain is important in cellular systems because it relates to the interference withstanding of the modulation and coding scheme, or the carrier-to-interference ratio in quasi-error-free operation (C/I), which is the major capacity limiting factor:

$$\left(\frac{C}{I}\right)_{atBER=10^{-6}} = \frac{RE_b}{WN_0} = \frac{1}{G_P}\left(\frac{E_b}{N_0}\right) \qquad (2)$$

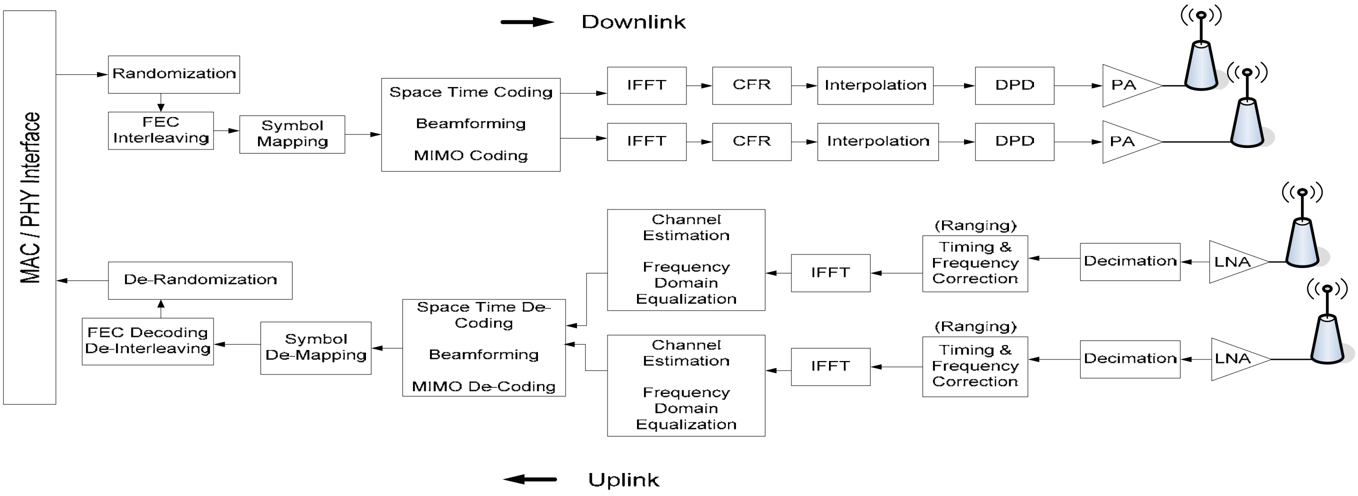

Fig.5 PHY Layer functions in a typical WiMAX base station

There is no upstream interference within the cell since its subchannels are orthogonal: each group element is used by only one subchannel.

Figure 4 illustrates the OFDMA upstream signal space. Some subchannels are reserved for physical layer (PHY) processes such as ranging, while others carry subscriber data according to the MAP allocations. Each transmission starts with the preamble. [3]

V. WiMAX Physical Layer

The WiMAX physical layer is based on orthogonal frequency division multiplexing. OFDM is an elegant and efficient scheme for high data rate transmission in a non-line-of-sight or multipath radio environment.

Apart from the usual functions such as randomization, forward error correction (FEC), interleaving, and mapping to QPSK and QAM symbols, the standard also specifies optional multiple antenna techniques. This includes space time coding (STC), beamforming using adaptive antennas schemes, and multiple input multiple output (MIMO) techniques which achieve higher data rates. The OFDM modulation/demodulation is usually implemented by performing Fast Fourier Transform (FFT) and inverse FFT on the data signal. Although not specified in the standards, other advanced signal processing techniques such as crest factor reduction (CFR) and digital predistortion (DPD) are also usually implemented in the forward path, to improve the efficiency of the power amplifiers used in the base stations. The uplink receive processing functions include time, frequency and power synchronization (ranging), and frequency domain equalization, along with rest of the decoding/demodulation operations necessary to recover the transmitted signal. [1]

VI. Conclusion

The ability to stream video over a broadband IP connection will profoundly change the video industry. With WiMAX offering high data rates to both mobile and fixed users, and the desire of users to watch real-time TV or VoD services make the implementation of IPTV over WiMAX an exciting killer application. Realization of IPTV will enable users to have VoD services as well as to subscribe whichever channel of their choice giving them a great deal of flexibility.

Acknowledgement

This work is a part of the project DMU-02/13-2009 “Design and performance study of an energy-aware multipath routing algorithm for wireless sensor networks” of the Bulgarian Science Fund at the Ministry of Education, Youth and Science.

References

[1] Mihaylov, G., Iliev, T., Hristov, G., “Analysis of the Physical Layer in IEEE 802.16(e) Standard”, ICEST 2010 Proceedings of Papers, Volume 2, pp. 505-508, Bitola, 2010.
[2] Koffman, I., Roman, V., “Broadband Wireless Access Solutions Based on OFDM Access in IEEE 802.16”, IEEE Communications Magazine, April 2002.
[3] M. Chatterjee, S. Sengupta, and S. Ganguly, “Feedback-Based real-time streaming over WiMax,” IEEE Wireless Communications Magazine, February 2007.
[4] Andrews, J., Ghosh, A., Muhamed, R., “Fundamentals of WiMAX”, Prentice Hall, 2007.
[5] Cooper, W., Lovelace, G., “IPTV.Guide”, informitv, 2006.
[6] Jiang, T., Xiang, W., Chen, H., Ni, Q., “Multicast Broadcast Services Support in OFDMA-Based WiMAX Systems”, IEEE Communications Magazine, August 2007.
[7] O’Driscoll, G., “Next Generation IPTV Services and Technologies”, John Wiley & Sons, Inc, 2008.
[8] Hrudey, W., Trajković, L., “Streaming Video Content Over IEEE 802.16/WiMAX Broadband Access”, white paper.
[9] IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems, IEEE Std 802.16™-2009 (Revision of IEEE Std 802.16-2004), IEEE, May 2009.
[10] WiMAX Forum, Available online: http://www.wimaxforum.org