IPTV Distribution Technologies in Broadband Home Networks

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***Abstract*— Understanding the pros and cons of different distribution technologies is the first step in designing efficient future broadband home networks for IPTV service delivery. In this paper, we survey the emerging wired and wireless communication technologies, including powerline, phone line, UltraWide Band (UWB), millimeter wave (MMW), etc., which are promising candidates for distributing broadband signals in home networks. Their characteristics such as data rate, QoS support, deployment cost, etc., are compared. The comparison can provide important guidelines for future home network architecture and protocol design.**

I. Introduction

Internet Protocol TV (IPTV) is becoming the new standard in offering TV over the existing telecos broadband network. Next generation networks will support data, voice and IPTV/Video on demand (VoD), so called triple play service. However, IPTV has stringent delay, jitter, bandwidth and QoS requirements, which bring great challenges to the last meter home networks.

Home networks need to efficiently and effectively manage network resources to guarantee a high level of user-perceived Quality of Service (QoS) for triple play service. Intelligent broadband home network architectures need to be developed. The first step in designing these architectures is exploring and comparing the current and emerging technologies that can be used for traffic distribution in the home network.

A comparison of broadband home network distribution technologies is given in [1]. This comparison was done in 2003 and lacks the consideration of some of the emerging technologies such as UltraWide Band (UWB) and Millimeter Wave (MMW) wireless communication technologies. Furthermore, the comparison was done when many new technologies were in their early stages of development, and is therefore missing updates to existing technologies. For example, powerline communications can achieve data rates up to 200 Mbps instead of the 10 Mbps listed in [1].

The remainder of the paper is organized as follows. In section 2, we provide a brief introduction to the IPTV network. In section 3, we discuss the existing and emerging broadband home network technologies, followed by the concluding remarks and the list of future work in section 4.

II. The IPTV Network

The IPTV network consists of four main components as shown in Figure 1: video headend, core network, access network, and home network.

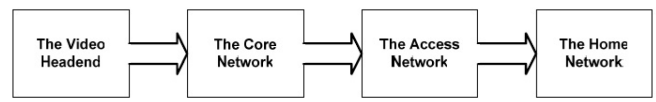

Fig. 1. The telcos IPTV network

All programming content is captured at the video headend. This includes linear TV programs and Video on Demand (VoD) contents. Typically, the video headend ingests this content through satellite or terrestrial fiber networks. It is also responsible for encoding the video streams into MPEG-2, MPEG-4 or H.264 formats [2]. The content is broken into IP packets that are sent through IP multicast or IP unicast connections to the core network.

The core network groups the encoded video streams into the respective channel line up. The core network is unique to the service provider, and often includes equipment from multiple vendors. IPTV traffic can be separated from other non real time data traffic to guarantee the high level of its QoS requirements.

The access network, also known as the last mile, contains the Broadband Remote Access Server (BRAS), which is responsible for maintaining user policy management, such as authentication, subscription details, etc. In addition, the BRAS provides user Point-to-Point (PPP) or IP sessions over Asynchronous Transfer Mode (ATM) or Ethernet [3]. The BRAS also enforces QoS policies for the IPTV traffic. Furthermore, the BRAS aggregates traffic from Digital Subscriber Line Access Multiplexer (DSLAM) and routes it to the core network. The DSLAM is used to aggregate data traffic from multiple end users to a single point. End users connect to the DSLAM through twisted copper with Digital Subscriber Line (DSL) technologies or even fibers with Fiber-to-the-x (FTTx) technologies.

The home network, also known as the last meter, serves the purpose of distributing traffic in the end user's home. The home network integrates the delivery of data, voice and video (IPTV) traffic. On average, a typical home has

$2 \sim 3$ television sets on average. If each set is to watch one channel and view another picture-in-picture channel, then the home network should at least support 2 High Definition TV (HDTV) channels and 3 Standard Definition TV (SDTV) channels simultaneously. Each SDTV channel and HDTV channel requires approximately $1 \sim 2.5$ Mbps and $5 \sim 8$ Mbps, respectively, depending on the video codec used [4]. Furthermore, for high quality video streaming services, such as IPTV, the packet loss ratio (PLR) of 10^{-4} to 10^{-7} or less, latency on the order of 100 ms and jitter on the order of 10 ms can be tolerated [5].

III. Broadband Home Networks

We focus on the home network. The major wired and wireless in-home distribution technologies that are available now or will be available in the near future are discussed and evaluated according to the following criteria:

- **Maximum data rate**: The maximum raw data rate that the respective technology can theoretically achieve is considered.
- **Cost**: Because we focus on the home network, cost here refers to the cost that the end user will face in order to make use of the technology. We assume that the cost to rewire a home is prohibitively high. We also consider the cost of purchasing additional equipment such as adaptors, access points (APs), etc.
- **Interference**: For broadcast wireless and wired technologies, interference not only affects the channel quality, but also limits the network capacity.
- **Quality of Service**: This criteria evaluates whether the technology under consideration contains mechanisms that guarantee QoS for the transmitted signals.
- **In-home availability (wired)**: In-home availability considers how many outlets are available on average in a typical home.
- **Transmission distance (wireless)**: This determines the distance that a wireless device can provide coverage for.
- **Frequency allocation (wireless)**: This criteria lists the operating frequency that the respective wireless technologies can operate at. It is important because certain frequency ranges are more crowded than others. Also, as the operating frequency increases, certain characteristics, such as oxygen absorbtion may come into effect.

A. Existing home network technologies

Currently, most home networks are based on Ethernet and narrowband wireless technologies, such as IEEE 802.11b/g. These two technologies have served home networking a great deal, but they also have their shortcomings.

1) Ethernet: IEEE 802.3 [6] has seen a huge success in the Local Area Network (LAN) field. The main reasons for this success is the low cost, high data rate (1 Gbps) and wide support of this technology. Ethernet employs CSMA/CD techniques at the MAC layer, which help in achieving low interference reliable connections.

However, Ethernet outlets are not common in existing homes. This means using Ethernet for broadband in-home distribution requires the rewiring of existing homes. This is too costly to implement. In addition, Ethernet does not support QoS and isochronous transmission [1]. These three major drawbacks severely degrade the potential use of Ethernet technology as a solution to the broadband in-home distribution problem.

2) IEEE 802.11g: IEEE 802.11g [7] can provide data rates up to 54 Mbps within a range of up to 100 meters. In addition, as in the case of Ethernet, this technology also lacks the QoS guarantee. The cost of using IEEE 802.11g for distribution in the home network is very low. This is mainly because of the wide popularity of IEEE 802.11g and recent significant drop in IEEE 802.11g equipment prices.

IEEE 802.11g operates in the 2.4 – 2.5 GHz frequency band. This frequency range is very crowded. It is used by other narrowband technologies such as IEEE 802.11b and other equipment such as cordless phones. This results in the high level of interference that IEEE 802.11g faces.

B. Wired technologies

Powerline, Phoneline, and Coax technologies are discussed due to their unique characteristics that are very attractive for use in the home network.

1) Powerline technology: Powerline technologies have been under development by different standardization bodies for more than ten years [1]. The HomePlug Powerline Alliance [8] is promoting cost effective, interpretable and standards-based home powerline networks and products. HomePlug's members include some key players in the home networking field such as Sony, Intel, Motorola and Samsung.

The latest powerline technologies have been able to achieve a maximum raw data rate of up to 200 Mbps [9]. Furthermore, powerline is the most widely available connection in the home network. Such solution requires no home rewiring. This is a priceless advantage for the end user. However, the cost of the powerline adaptor is considerably higher than that of any of its competing technologies. This makes the cost of implementing such a solution moderately high.

Powerlines were not designed to operate at high frequencies. They were originally designed to operate at frequencies of 50 or 60 Hz [10]. However, communication signals operate at frequencies of 20 or 30 MHz. In terms of interference, the powerline channel possesses attributes which are very similar to that of the wireless communication channel. Aside form the severe noise that the powerline channel acquires due to switches, motors and power supplies, the channel also suffers from fading, multipath and interference. Current powerline MAC protocol does not guarantee QoS of multimedia traffic [1]. This is a significant drawback.

2) Phone line technology: The use of phone line technology in the home network is promoted by the Home Phoneline Networking Alliance (HomePNA)[11]. The HomePNA alliance develops triple-play home networking solutions using existing coax and phone lines. This alliance is supported by companies like Motorola, Samsung and AT&T. HomePNA takes advantage of the existing phone line and coax connections to distribute broadband signals in the home network.

With their latest standard HomePNA 3.0, the HomePNA were able to achieve a maximum raw data rate of 240 Mbps with guaranteed QoS [11]. Using phone line does not require rewiring existing homes. Also, the cost of the HomePNA adapters is very reasonable. However, Since phone line was not designed for the delivery of broadband signals, most phone line outlets are not located in positions where they can reach TV sets.

3) Coaxial technology: Established in 2004, the Multimedia over Coaxial Alliance (MoCA) [12] is an industry driven initiative promoting the use of existing coaxial cable for networking of digital video and entertainment [13]. Members of MoCA include Broadcom, Samsung, Siemens, AT&T and Texas Instruments.

Coax can achieve data rates greater than 200 Mbps. Coax outlets are available in existing homes, therefore, no rewiring is required. However, on average coax outlets are not as widely deployed as phone line and power line outlets. As in the case of phone line, coax provides QoS support. In 2005 MoCA conducted a study on 250 homes in the US [13], the results are listed below:

- Achievable net throughput of approx. 100 Mbps in 97 percent of the tested outlets
- Packet Error Rate (PER) less than 10^{-6}
- Latency less than 5 ms

The results of this study are very pleasing. MoCA has also recently certified last mile products developed by tellabs and Motorola. The certified products support the eight 802.1p priorities, have a latency less than 10 ms for highest priority asynchronous traffic [13].

TABLE I

COMPARISON OF WIRED HOME DISTRIBUTION TECHNOLOGIES

	Ethernet	HomePlug	HomePNA 3.0	MoCA
Max data rate	1 Gbps	200 Mbps	240 Mbps	200 Mbps
Cost	High	High	Low	Low
Interference	Low	High	Low	Low
QoS support	No	Yes	Yes	Yes
In-home availability	Limited	Excellent	Good	Good

Table I summarizes the findings that are discussed in this section. It can be noted that all these wired technologies provide robust characteristics and stand as strong candidates for use in the broadband home network.

C. Wireless technologies

To provide anywhere, anytime internet connection, wireless technologies have proven to be a key component in the success of the home network today. The success of IEEE 802.11b/g technologies is unmeasurable. On the other hand, the evolution of these wireless technologies continues. Technologies such as IEEE 802.11n, UWB and MMW are set to be the new providers of wireless support for the broadband nome network. These technologies are designed to support high data rates and provide strict QoS guarantees to be able to support demanding multimedia applications, such as IPTV. In this section, we describe the emerging wireless technologies that are capable of supporting high data rate multimedia traffic. These include IEEE 802.11n, UWB, and MMW.

1) IEEE 802.11n: IEEE 802.11n is capable of achieving a maximum throughput of at least 100 Mbps and up to 500 Mbps. The expected range of IEEE 802.11n is approx. 50 m. IEEE 802.11n is set to operate at the 2.5 or 5 GHz frequency range. The standard will also incorporates all the security and QoS enhancements in 802.11e. This makes it ideal for indoor or outdoor use in the broadband home network environment.

The drawback of IEEE 802.11n is the fact that an end user has to upgrade their existing router to a new Multiple-Input-Multiple-Output (MIMO) type router. Furthermore, the users need multiple antennas at the receiver as well. This means that users would have to replace their existing equipment, or add new hardware if they wanted to take advantage of these charming features that IEEE 802.11n provides. This converts to higher cost for the end user. In addition, the large transmission range leads to poor frequency reuse. Interference from neighboring IEEE 802.11n devices and other technologies using the 2.5 GHz band will significantly degrade its performance.

2) Ultrawide Band: UWB is classified as any signal with a bandwidth of at least 500 MHz at transmission. The imposed power spectral density limit of 75 nW/MHz (41.3 dBm/MHz) between 3.1 GHz and 10.6 GHz, as per the Federal Communication Commission (FCC). At this power spectral density, the maximum data rate is approx. 480 Mbps at a range of 10 m. There are two competing UWB technologies, Direct Sequence (DS-UWB) [14] and Multiband UWB [15].

In terms of interference, the low power, short range characteristic of UWB is ideal in the home network environment because it reduces the noise to other devices that are operating in the home network (especially narrowband technologies). In addition, service providers do not want their broadband signals to be broadcast to more than one user's home, therefore, the low power, low range characteristics are desired from the service provider's point of view. Lastly, UWB MAC protocols are designed to support QoS.

The low power and low range characteristics of UWB may also be seen as a disadvantage. It may cause increased cost (more APs are needed to cover a certain area). Also, because

UWB APs operate at such low power, objects like walls may cause connection drops or reduced throughput.

3) Millimeter Wave: The IEEE 802.15.3c [16] specifies the Millimeter Waves (MMW) communication technologies, which operate at frequencies between 57 - 64 GHz at transmission power of up to 40-dBm EIRP. This is significantly higher than what is available for the other WLAN/WPAN standards [17]. This is because at such high frequencies, MMW do not penetrate through solid materials (like walls) very well, therefore, a direct LOS is preferred between the transmitter and receiver. Also, MMW signals suffer from oxygen and water vapor absorbtion. In addition, MMW suffer from low diffraction because of the short wavelengths used. For the reasons mentioned above, MMW, as in the case of UWB will introduce increased cost because more APs will be needed to cover a certain area.

However, the wide bandwidth and high allowable transmit power at 60 GHz makes MMW capable of providing more than 2 Gbps bandwidth in typical indoor distances (~ 10 m). The interference level caused or faced by MMW technology is very limited due to the characteristics listed above.

TABLE II

COMPARISON OF WIRELESS HOME DISTRIBUTION TECHNOLOGIES

	IEEE 802.11g	IEEE 802.11n	UWB	MMW
Max data rate	54 Mbps	500 Mbps	540 Mbps	2 Gbps
Cost	Low	High	High	High
Interference	High	High	Low	Low
QoS support	No	Yes	Yes	Yes
Transmission range	100 m	50 m	10 m	10 m
Frequency Allocation	2.4-2.5 GHz	2.5 or 5 GHz	3.1-10.6 GHz	57-64 GHz

Table II summarizes the major characteristics that are discussed throughout the section. Here as well, it can be noted that all these wireless technologies possess unique characteristics that make them strong candidates.

IV. Conclusions and Future Work

We have surveyed the leading wired and wireless technologies for broadband home networks. The pros and cons of these technologies have been compared, in terms of cost, maximum data rate, interference, coverage area, in-home availability, and operating frequencies. Our future work will focus on the broadband home network architecture design using combinations of these wired and wireless technologies and studying the feasibility of using such architectures in the broadband home network.

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