Multimedia in Home Networking

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ABSTRACT

The basic challenge of home networking is to connect devices anywhere in the house in a way that is simple, reliable, inexpensive and secure. Increasing interaction with computers and other electronic & electrical devices in our day to day life has fueled the demand for an increased performance of home networks. With multimedia becoming an integral part of our lives, establishing a reliable home network to support multimedia is of great interest. Starting with the discussion of various home networking technologies and their QoS, middleware considerations and network security, this paper specifically deals with PHY and MAC layer description of home networks that support multimedia**.**

Keywords: Home Networking, Multimedia, QoS, Network Security, Middleware.

1. INTRODUCTION

A *Network* is a collection of terminals, computers, servers and compatible devices which are interconnected so as to allow easy flow of data and sharing of resources between one another. Such a network established in a home is called a *Home Network*.

The interaction with electronic devices has been increasing in our home environment in the past few decades. The number of multi-computer households is also on the rise. The concept of having a networked home is fast becoming the hotbed for networking related research work. It would be convenient if our computers could talk to each other, share resources such as printers, internet connection, files etc., and allow multiple users to play games over the network. Thus, emerges the need for simple, reliable and flexible Home Networks [2], [8].

Recent years have seen increasing adoption of home networks. The Yankee Group [28] forecasts that the number of networked homes in the United States will grow to 32.3 million by 2007 from 6.7 million in 2002. The current generation home networks are designed to support data networking. With the advent of DVDs, HDTVs, interactive games, VoIP and Audio CDs there has been an increasing demand for Home Networks to provide high quality multimedia broadcast and storage solutions [1], [2], [16].

This paper deals with different kinds of feasible home networks for multimedia communication in particular. Section 2 describes various home networking technologies. Section 3 provides details on two popular Home Networking solutions, IEEE 802.11b and HomePlug 1.0. Section 4 deals with QoS considerations for multimedia home networking. Section 5 discusses the network security. Section 6 explains the middleware for multimedia in home networks. Section 7 concludes the paper by discussing multimedia in home networking specifically.

2. HOME NETWORKING

A Home Network can be established using various technologies like phone line [3], wireless [4], [5], power line [6], [7], [9], Ethernet [8] etc. A detailed explanation on each one of these technologies is given below.

Phone Line Networking

Phone-line networking also referred to as HomePNA, is based on the specifications developed by the Home Phone Networking Alliance (HPNA) [3]. Phone-line networking is based on the idea of "no new wires". It uses the existing phone line infrastructure within the home for networking. This eliminates the need for any extra wiring. It is convenient to use and is inexpensive. An internal HomePNA card (PCI) or an external HomePNA adapter can be used to network computers.

HomePNA 1.0 employs frequency division multiplexing (FDM). HomePNA 2.0 makes use of frequency diverse quadrature amplitude modulation. HomePNA 1.0, which supports data rates of about 1Mbps is considered very slow for transmitting high bit rate applications like DVD video of 3-8 Mbps, HDTV at 20 Mbps or MPEG video at 4-8 Mbps. HomePNA 2.0 boosts the speed up to an average of 10Mbps and up to 32Mbps. The third generation technology of HomePNA, which is HomePNA 3.0, reaches an unprecedented data rate of 128 Mbps with optional extensions reaching up to 240 Mbps. HomePNA 3.0 products are expected to hit the market by later this year.

One main disadvantage is interference with voice after installation on HomePNA. Also, it needs a phone jack near every unit and there is a physical limit of 1000 feet of wiring between devices.

Ethernet Networking

Ethernet is a popular networking technology used today [8] to connect computers in a LAN. It was originally developed by Xerox Corporation. Ethernet uses co-axial cables or special grade twisted pair for communication. Cables are classified as, 'RBaseC', where, R is the data rate in Mbps, C is the category of cabling and Base signifies base band transmission, for example, 10BaseT, 100BaseT, 10Base2 etc. Ethernet is by far the fastest networking technology. There have been three generations of Ethernet - Ethernet, Fast Ethernet and Gigabit Ethernet. Ethernet works at 10Mbps, Fast Ethernet has data rates of 100Mpbs and Gigabit Ethernet, as the name suggests works at data rates up to 1Gbps. Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is the protocol used in the Ethernet to regulate communication among nodes.

Ethernet based networks can be a simple network, with network interface cards (NIC) and a cable. If the number of devices in the network is huge, hubs, bridges, and routers will be needed. The number of devices that could be connected on the Ethernet network is unlimited. The first time set up and configuration could be difficult as well as expensive. The cost of installation depends upon the number of computers in the network and the distance between the computers. For every 328 feet of cable, a device called repeater has to be used. It boosts the network signal faded over distance.

The major drawback is that it would require retrofitting the house with specialized cables (e.g., Category 5), along with hubs, routers and NIC Card. This is quite an expensive proposition as it could involve drilling holes in the walls. Another drawback of Ethernet is the lack of proper QoS provisions that are very critical for any Multimedia in-home networking

Power Line Networking

Power-line networking is also based on the concept of "no new wires". It uses the existing electrical wiring for networking the home [7]. In contrast to phone line network, powerline networks are ubiquitous with several power outlets in every room (a typical house in US has 44 power outlets). An internal card (PCI) or an external adapter can be used to network computers. The total cost of power-line networking is comparable to HomePNA.

In the past, power lines were considered unacceptable for signal transmission, since the channel was subjected to noise, interference and fading. But, the advancement of signal modulation technologies, digital signal processing and error control coding has helped reduce channel imperfections and high speed communication on the power line is now feasible. Power line communication (PLC), as specified by HomePlug 1.0 standard [11] provides a data rate of 14Mbps. It also has a built-in QoS protocol, making it attractive for real time streaming applications. Further generations of PLC will provide data rates up to 100 Mbps, to support high quality digital multimedia.

There are two power-line technologies. The original technology is called *Passport*, by a company named Intelogis. A new technology called *PowerPacket*, developed by Intellon, has been chosen by the HomePlug Alliance [11] as the standard for power-line networking. Intellon's PowerPacket technology [13] uses an enhanced form of orthogonal frequency-division multiplexing (OFDM) with forward error-correction. OFDM is a variation of the frequency-division multiplexing (FDM) used in phone-line networking (HomePNA 1.0). The latest generation of PowerPacket technology supports data rates up to 14 Mbps. This is much faster than the current phone line and wireless technologies. But this data rate is not sufficient to support multimedia in home networks. HomePlug alliance is working on a new technology called HomePlug AV, which is designed specifically to support multimedia.

HomePlug AV will be designed to support distribution of data and multi-stream entertainment throughout the home, including High Definition television (HDTV) and Standard Definition television (SDTV). The main objective is to provide high quality, multi stream, environment oriented networking over existing AC wiring, while also addressing the interoperability with HomePlug 1.0. It would provide the best connectivity at the highest QoS, with data rates of 60 – 80 Mbps. It would also provide solutions for data and network security, which would include encryption and password protection. HomePlug AV will be capable of interfacing with other technologies like Ethernet, IEEE 1394, DSL, USB, IEEE 802.11, Bluetooth etc. It will also be cost competitive.

Wireless Networking

This is one of the many ways in which a Home Network can be established. In this kind of connectivity, no wires are used [4]. Communication between devices is carried out using RF (Radio Frequency) signals. Some of the types of wireless networks are Bluetooth, HomeRF and Wireless LAN [8].

Bluetooth is a short range wireless digital technology that allows any sort of electronic equipments to make its own connection. It is a radio frequency standard. It communicates on a frequency of 2.45 gigahertz. Bluetooth 1.2, also called Medium Data Rate Bluetooth (MDR) supports data rates up to 3Mbps and the next generation of Bluetooth, Bluetooth 2.0 called High Data Rate Bluetooth (HDR) supports data rates up to 10Mbps. It uses a technique called Frequency Hopping Spread Spectrum (FHSS). Bluetooth devices are very inexpensive. Since Bluetooth shares the 2.4-GHz radio spectrum with 802.11b, HomeRF, and many other consumer appliances, such as cordless phones, microwave ovens etc., there is significant potential for interference between these devices. Bluetooth avoids this interference by transmitting very low power signals. This restricts the range of a Bluetooth device to about 20 – 50 feet. It is not compatible with other technologies. These are some of its conspicuous disadvantages.

HomeRF (Home Radio Frequency) Working group was formed in 1998 and some of its key companies include Proxim, Siemens, Motorola and Compaq Computer. HomeRF 1.0 was designed specifically for home networks. It uses Shared Wireless Access Protocol, also developed by HomeRF Working Group. It can achieve data rates up to only 1.6Mbps in the 2.4GHz range. It has a very short range of about 70-80 feet. Physical obstructions such as walls and metal objects can interfere with communication. This is suitable for sharing printers and transferring moderate size files on the network, but is not the best choice for sharing broad band internet connection or for multimedia transmission in home networks. HomeRF 2.0 increases the data rates up to 10Mbps, which makes it comparable to Wi-Fi and Ethernet.

Wireless LAN [26] term is used when referring to any kind type of 802.11 network, whether 802.11b, 802.11a, 802.11g or 802.11n [5].

IEEE 802.11 is the first wireless LAN standard. It can achieve data rates up to 2Mbps in the 2.4GHz range. It uses FHSS or DSSS (Direct Sequence Spread Spectrum) technique. Because of its low data rate, 802.11 wireless products are no longer being manufactured.

IEEE 802.11b is by far the most popular home networking solution available in the market. It can achieve data rates up to 11Mbps (equivalent to 10BaseT Ethernet) in the 2.4GHz range. PHY is based on a DSSS modulation scheme. MAC is based on the standard 802.11 MAC architecture. It has an operating range of up to 400 feet. It features an interoperability mark called Wi-

Fi, which is earned via 3rd party interoperability testing. All Wi-Fi certified products would interoperate with each other. Due to the lack of QoS support in IEEE 802.11 and the limited bandwidth, multimedia streaming cannot be supported. Since the operating frequency is 2.4GHz, it is also very susceptible to interference with devices that operate in the same range, such as microwave oven and cordless phone.

IEEE 802.11a communicates in 5GHz range and can transmit data rates up to 54Mbps. Physical Layer (PHY), based on an Orthogonal Frequency Division Multiplexing (OFDM) modulation scheme rather than DSSS or FHSS. Media Access Controller (MAC) is based on the standard IEEE 802.11 MAC architecture which is consistent across 802.11a, 802.11b and 802.11g. Due to the lack of QoS support in IEEE 802.11 MAC, multimedia streaming cannot be supported. IEEE 802.11 Task group E is currently working on a new standard called IEEE 802.11e that enhances IEEE 802.11 MAC by adding features to support QoS. The high bandwidth of IEEE 802.11a and the enhanced QoS features provided by IEEE 802.11e could be combined to support multimedia streaming in the near future. It can stream content like HDTV and multiple MPEG-2 (DVD quality) video streams because of its high through put. It has a relatively shorter range, but is less susceptible to interference because of the unique 5GHz operating frequency. Cost wise, it is slightly more expensive than 802.11b. 802.11a products will not be directly interoperable with the large and growing base of 802.11b networks.

IEEE 802.11g combines the best of 802.11a and 802.11b technologies. It can achieve data rates up to 54 Mbps in the 2.4GHz operating range. It uses either OFDM or DSSS modulation scheme. DSSS is particularly used to communicate with 802.11b devices. IEEE 802.11g is backward compatible with 802.11b. As with IEEE 802.11a, IEEE 802.11g can also use the enhancements provided by IEEE 802.11e to support multimedia streaming in the near future.

IEEE 802.11n is an emerging Wi-Fi standard that is still under development. The estimated time line calls for a finished standard by the end of 2005. 802.11n is designed to provide enhancements to both IEEE 802.11 MAC and PHY so that strict guarantee on QoS can be supported. The targeted minimum data rate at the MAC layer is 100Mbps. All 802.11n devices will be backward compatible with at least 802.11 a/g. This means it should be able to run in both 2.4GHz and 5GHz bands.

Magis networks' [4] next-generation technology *Air5* is based on a high performance implementation of the PHY defined in the 802.11a specification. Utilizing the 5-GHz spectrum, the 802.11a standard and enhanced MAC technologies, Air5 enables multimedia services such as video, audio and data to be delivered with QoS guarantees. With these capabilities, a single wireless network can distribute multimedia services throughout a house. Through enhanced RF design and advanced signal processing techniques, Air5 delivers large data payloads of up to 40 Mbps at real-world distances of up to 250 feet. Range is vital because a home typically has only one access point responsible for distributing wireless information throughout the entire house.

Ultra wideband [27], also known as UWB can be defined as any signal that occupies more than 500MHz in the 3.1 – 10.6 GHz band. It is a wireless technology which is used for transmitting large amounts of digital data over a wide spectrum of frequency bands. UWB is the next "big thing" in wireless networks since it supports data rates up to 252Mbps, with low power consumption. It is also capable to carrying signals through objects like doors and walls, but at limited bandwidth and at the cost of higher power. A significant limitation is its 30 feet operating range.

HiperLAN is an abbreviation for High Performance Radio Local Area Network. It is a set of Wireless LAN communication standards mainly used in European countries. It is developed by the European Telecommunications Standards Institute. It is similar to the 802.11 WLAN networks as mentioned previously. There are two types of HiperLAN. HiperLAN1 provides data rates up to 20 Mbps in the 5GHz operating range, where as HiperLAN2 can achieve data rates up to 54Mbps in the same band. It uses the OFDM modulation scheme. HiperLAN2 is very similar to 802.11a with regard to data rate and operating range. But they use different QoS protocols as described in Section 4.

3. WIRELESS Vs. POWER LINE

As shown above, there are several options for planning the home network.

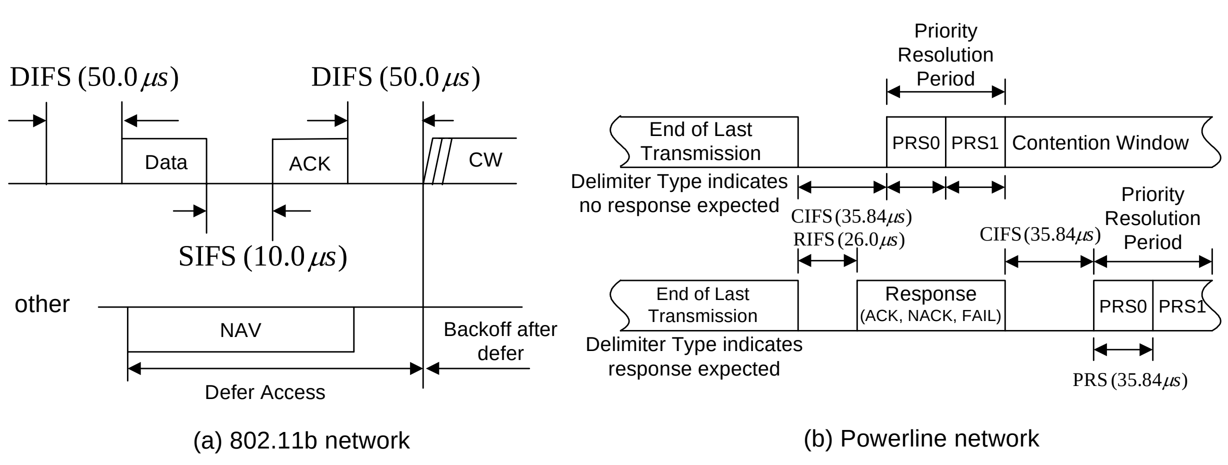

Figure 1 – Wireless vs. Powerline MAC

In here, we provide short description about PHY and MAC layers for the most popular home networking technologies which are wireless and power line home networking

IEEE 802.11b Protocol

This section gives an overview of the IEEE 802.11b wireless network protocol. Since there are many descriptions elsewhere, we only give a short description here.

Physical Layer

The IEEE 802.11b standard uses the 2.4 GHz band (2.4000 GHz to 2.4835GHz) to achieve a maximum raw data transmission rate of 11Mbps through air. There are two types of modes for 802.11b, the Ad Hoc and the Infrastructure mode.

Ad Hoc Network - Every station can communicate with the others directly without an access point. In this mode, each station will directly talk to any other node that it can see. This is typically intended for use in a conference room kind of environment where all the attendees can directly share information.

Infrastructure Network - Stations communicate with each other through an access point. In this mode, each node will talk to the base station. Since the data exchanged between the stations will have to go through the base station, the effective throughput is going to be less.

The modulation type used in 802.11b is DSSS which can support 1, 2, 5.5, and 11 Mbps raw data rates. The NIC card adjusts the data rate according to the sensed transmission medium condition. IEEE 802.11 technology only supports the 1Mbps and 2 Mbps with FHSS or DSSS. An 802.11 device using DSSS is compatible with an 802.11b device operating at 1 Mbps or 2 Mbps, but an 802.11 device using FHSS is not because it uses a different modulation scheme [29].

Medium Access Layer

The access methods of 802.11b are DCF (Distributed Coordination Function) and PCF (Point Coordination Function). The Ad Hoc network works with DCF and the Infrastructure network works with DCF and PCF. The basic approach of DCF is Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). DCF is suitable for a delay-insensitive network while PCF is suitable for a delay-sensitive network. Figure 1 shows the basic DCF Access mechanism.

802.11b uses physical carrier sense and virtual carrier sense to avoid collisions. The physical layer senses the network activity to check whether a network is busy or idle. This is called physical carrier sensing. Frames contain a duration field, which specifies the ending time of the current transmission. The other machines update their local NAV (Network Allocation Vector) when they receive a frame with a duration field. Thus, no machine listening to the network will attempt to transmit a packet while another transmission is going on. This is called virtual carrier sensing and is done by the MAC layer. 802.11b has a contention-free period (in PCF mode) and a contention period. The basic concept of PCF is polling. Polled stations can access the transmission medium without contention. This requires a base station, also known as an access point (AP), to coordinate bandwidth assignment to the mobile stations [30]. Hidden node problem in IEEE 802.11 networks is overcome by the use of Request to Send (RTS) and Clear to Send (CTS) mechanism.

HomePlug 1.0 protocol

Since the HomePlug protocol is relatively recent and little information is available on it in the open literature, this section will describe it in moderate detail. Power line networks operate on standard in-building electrical wiring and as such consist of a variety of conductor types and cross sections joined almost at random. Therefore a wide variety of characteristic impedances will be encountered in the network. Further, the network terminal impedance will tend to vary both with communication signal frequencies and with time as the consumer premises load pattern varies. This impedance mismatch causes a multi-path effect resulting in deep notches at certain frequencies [33]. In a typical home environment the attenuation on the power line is between 20dB to 60dB and is a strong function of load. The major sources of noise on power line are from electrical appliances, which utilize the 50 Hz electric supply and which generate noise components that extend well into the high frequency spectrum. Some common sources of electrical noise are certain types of halogen and fluorescent lamps, switching power supplies as well motors and variable resistance dimmer switches. Apart from these, induced radio frequency signals from broadcast, commercial, military, citizen band and amateur stations severely impair certain frequency bands on the power line channel. Reliable data communication over this hostile medium requires powerful forward error correction (FEC) coding, interleaving, error detection and Automatic Repeat Request (ARQ) techniques, along with appropriate modulation schemes as well as a robust medium access protocol (MAC) to overcome these impairments.

Physical Layer

OFDM [34], [35], [36] is one of the most promising techniques for data transmission over power lines [37]. OFDM has the following advantages:

1. Has excellent mitigation of the effects of time-dispersion
2. Is very good at minimizing the effect of in-band narrowband interference
3. Has high bandwidth efficiency
4. Is scalable to high data rates
5. Is flexible and can be made adaptive; different modulation schemes for sub carriers, bit loading, adaptable bandwidth/data rates are possible
6. Has excellent ICI performance, so complex channel equalization is not required.

The OFDM system specified by the HomePlug 1.0 standard uses 128 equally spaced carriers from 0 Hz to 25 MHz for center frequency. Among them, only 84 carriers (65% of the total number of carriers) are used to transmit data. This means that a net bandwidth of 5MHz to 20MHz is used. First, the binary information goes to the encoder, which consists of a Reed-Solomon encoder, a convolutional encoder, and an interleaver. Second, it goes to the modulator. The modulation types for data are BPSK, DBPSK, DQPSK or ROBO, which is a robust form of DBPSK. Third, data are changed from serial to parallel for the 256-point IFFT processing, which changes the single carrier modulation to multi carrier modulation. After IFFT, the parallel data stream is changed to a serial data stream by summation, and a cyclic prefix is applied for synchronization (see Figure 2).

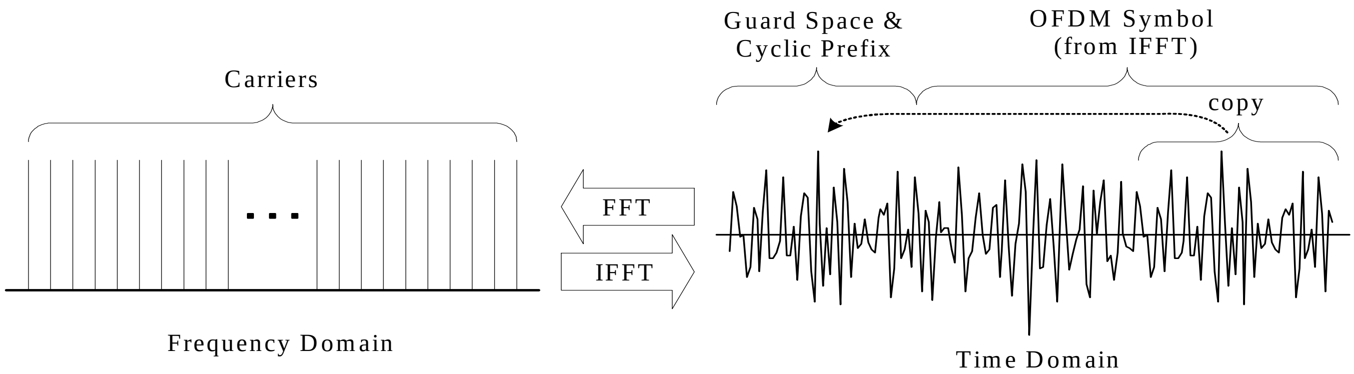

Figure 2 - Transform from frequency to time domain and addition of cyclic prefix

The receiver side arrangement is the reverse of the transmitter except for adding a synchronization detector and channel estimator. When a connection is established between a pair of nodes, they first determine which sub carriers are usable, and what form of modulation and error correction should be applied to the channel. This produces a `tone map,' for the pair, which is used for subsequent communication between them. All broadcast communications use all sub carriers with the most robust modulation and coding available (ROBO mode). This mode is used for the frame delimiters so that all nodes may interpret them, while the rest of a unicast frame will use the higher speed specified by the tone map. The HomePlug standard provides Ethernet-class networking over typical power lines, using a PHY protocol based on OFDM in conjunction with concatenated Viterbi and Reed Solomon coding with interleaving for payload data and Turbo Product Codes for control data. High bandwidth digital communication devices operating on the power line share a common physical medium, and in the HomePlug Standard, these devices use the PHY protocol briefly described above. A more detailed description of the operation of the PHY protocol can be obtained from Garner et al. [38] and Minkyu Lee et al [40].

Medium Access Layer

With wired lines devised for communication, low noise and attenuation allow collision detection, so CSMA/CD may be employed. However, the large attenuation and variation of noise on power lines prevents detection of collisions, so HomePlug 1.0 uses CSMA/CA for its MAC protocol. The frame structure of HomePlug 1.0 is depicted in Figure 3.

Like an IEEE 802.11b transmitter, a power line modem checks the medium and determines if it is idle or not, using virtual carrier sense (VCS). If it is idle, the station can send the segment without contention. If it is busy, the transmitter waits for CIFS (Contention Inter Frame Space) or RIFS (Response Inter Frame Space) after the end of the current transmission. The delimiter informs the listening nodes' VCS when the transmission will end and whether or not a response is expected, so all nodes can synchronize. The receiving station sends a response (ACK, NACK, or FAIL) signal after RIFS when it is needed, taking priority over regular data transmission. An ACK signal indicates successful delivery, while a NACK indicates an error detected at the receiving station. FAIL indicates that the receiver was unable to buffer the segment.

The CIFS comes after the RIFS or the end of the last transmission. Stations that want to send data wait until the end of the CIFS period and then send a priority signal in the priority resolution period to gain access privilege. In the priority resolution period, the highest priority level is selected, and lower priority levels defer to send the transmission. The RIFS, CIFS, priority resolution period are described in Figure 1. In the case of frame control errors or collision, stations have to wait for EIFS (Extended InterFrame Space) before accessing the medium.

The priority resolution period establishes which nodes will compete for the medium (i.e., those with the highest priority frames). These nodes contend for the medium during the contention window using a randomly selected delay. Initially, there are eight contention resolution slots, and upon collision, nodes increase this to 16 then 32 according to a backoff schedule [39], [40].

4. MULTIMEDIA QoS CONSIDERATIONS

The term multimedia describes a number of technologies that allow visual and audio media to be combined in new ways for the purpose of communication. In simple words, multimedia technology is the broad term to describe video, graphics, animation, sound, text and binary code based information. Its applications spread across diverse fields, including entertainment, education and advertising. Nearly every PC built today has multimedia support through hardware devices such as CD-ROM/DVD drives, sound and video cards. Apart from PCs, the increasing adoption of digital audio and video technologies has created a pool of digital Consumer Electronic (CE) device like HDTV, DVD players, etc. Multimedia home networks can be used to seamlessly connect all such devices.

To support multimedia, home networks should be capable of providing *Quality-of-Service* [12]. QoS is measured by the ability to provide the required bandwidth, delay, jitter, and packet loss probability in an integrated manner. *Bandwidth* [17] is defined as the rate at which information can be transmitted over a communication channel in a fixed amount of time. It is the communication speed at the physical layer and is measured in bits per second. *Delay* is the time difference between the transmission and reception of packets of information from the source to its destination. *Jitter* or *delay variation*, [17] refers to the variation in arrival of data packets. Packet loss probability is the probability of a packet getting dropped due to errors or shortage of resources. QoS in general needs to be maintained across the network of interest in an end-to-end manner (source to destination) for it to be effective.

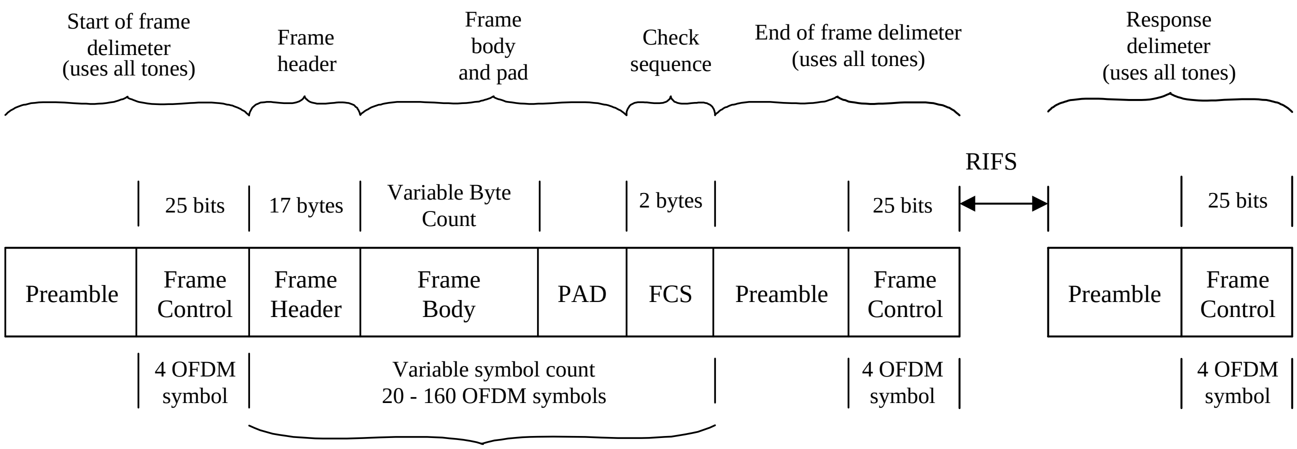

Figure 3 - HomePlug 1.0 Frame Format

Application	Typical Bandwidth (Mbps)	Latency (milliseconds)	Jitter (microseconds)	Packet Loss Probability (PLP)
High Definition (HD)Video Streaming	13-24	100-300	0.5	10^{-9}
Standard Definition (SD) Video Streaming	3-6	100-300	0.5	10^{-9}
DVD Quality Video Streaming	6-8	100-300	0.5	10^{-9}
Voice over IP (VoIP)	< 0.064	10	-	10^{-2}
Network Gaming	< 0.1	10	-	10^{-9}
Internet Video Conferencing	0.1-2	75-100	-	10^{-3}

Table 1 - QoS requirements for Home Multimedia applications

It also requires cooperation of all network layers from top to bottom. Applications differ in the level of guarantees on various QoS parameters. The current generations of IEEE 802.11a/b/g standards are not capable of providing QoS. This is mainly due to the limitations in the IEEE 802.11 MAC. To provide enhanced support for QoS, the industry and researchers have been developing QoS protocol for Wi-Fi networks, namely *IEEE 802.11e*. While maintaining full backward compatibility with existing 802.11 a/b/g standards, it differentiates multimedia services into 8 classes. Each Wi-Fi device monitors 8 virtual stations that are processed inside the device according to the priority design and attend outside competition/cooperation via CSMA/CA against other users' message of the same class level. It adds home-focused features to the current business wireless LAN standard. However, many researchers have showed that 802.11e is very sensitive to the parameter values of the 8 virtual stations, which are hard to optimize. The current 802.11e draft specification is based in large part on a joint proposal from ShareWave, Lucent, and AT&T. Final approval is expected sometime in the near future and products will follow that.

Unlike the contention-based 802.11e protocol, HiperLAN/2 uses Time Division Multiple Access (TDMA) for QoS purpose. A problem is that CSMA/CA causes stations to wait for an indefinite period of time, which in communications terms is referred to as asynchronous access. With this mode of operation, there are no regular time relationships associated with medium access. As a result, there is no guarantee of when a particular station will be able to send a packet. The lack of regular access to the medium draws down the efficiency of the system, which is not good when supporting voice and video information. The use of TDMA in HiperLAN/2, however, offers a regular time relationship for network access. TDMA systems dynamically assign each station a time slot based on the station's need for throughput. The stations then transmit at regular intervals during their respective time slots, making more efficient use of the medium and improving support of voice and video applications. Air5 chooses a simplified HiperLAN2 MAC design for QoS support, considering the periodic traffic pattern of many multimedia-oriented applications.

As was discussed above, there are several solutions that are currently available for enabling QoS support in home networks. However, these are at best intermediate solutions more suited for PC centric applications. Future home multimedia networks are required to provide seamless audio and video streaming across consumer electronic device as well as PCs. The demand for bandwidth and other QoS parameters in these applications is going to be very high. For example, a user would expect the same quality of video independent of whether he is playing a movie from a DVD player or it is being streamed from a remote device in the home network. Table 1 shows the bandwidth and

QoS parameters required for future home multimedia applications. Furthermore, future home networks should be capable of supporting several multimedia streams simultaneously to satisfy various demands on the network. This would require a robust physical layer that provides ubiquitous data rate in the range of 60-80Mbps and a MAC layer that uses a TDMA based access for providing QoS guarantees. IEEE 802.11n and HomePlug AV are the most promising candidates for future home multimedia networks.

5. NETWORK SECURITY

A complete network security concept consists of five essential parts: confidentiality, integrity, authentication, authorization and accounting. Intuitively, the term confidentiality means to encrypt any information before releasing them so that only a receiver having a pre-assigned decryption key can interpret the message. A message having passed integrity test is guaranteed of message completeness, not being changed during transportation. By authentication, a user is admitted to a network only after supplying valid user name, password, and/or other required proofs of its identity. What network resource an admitted user may access has to with the authorization procedure. Finally, the accounting function records a user's activity during its lifetime with the network, which could be used for performance analysis, management and evaluation.

There are three encryption algorithms: secret key, public key and hash. Secret key has only one key called shared key between a pair of users, usually being used to encrypt and decrypt long messages. Public key is a more secure scheme than secret key, where each user has two keys, the private-key for encryption and the public-key for decryption; the private-key is never released to others. Public key is not so computation efficient and is best used to encrypt shared keys, and short messages exchanged during an authentication stage. Hash has no key, and is a non-inverse operation; hence, any change of a message will destroy its completeness.

Both AES (Advanced Encryption Standard) and 3DES (triple Data Encryption Standard) are used among the home networks reviewed in this paper. Actually, they are equivalent in terms of security. It is estimated that if a 56-bit DES key generator were able to discover one DES key per second, it would take hundreds of trillion years to crack a 128-bit AES or 3DES key. However, 3DES is sluggish of software; and the recently developed AES has been determined as the best tradeoff among security, performance, efficiency and ease of implementation.

At the beginning of home networks, WEP (Wired Equivalent Privacy, also called Wireless Encryption Protocol) was the only security design because of the simplicity of implementation using a stream-cipher RC4. In the past few years, however, both theoretical work and online practice showed that WEP was not secure at any key length. Its improper utilization of RC4 incurs several serious weaknesses. The reuse of the initial vectors may produce the same key for different messages. The pre-pended initial vector guarantees the existence of weak keys vulnerable to key attack. WEP also fails in authentication because of the trust of devices MAC addresses which are easily forged.

IEEE 802.11i security protocol has been developed recently in order to build robust secure networks (RSN). It combines the advantages of authentication from RADIUS (Remote Authentication Dial-In User Service), encryption from AES, and authorization from IEEE 802.1x protocol. While the ultimate goal is 802.11i, Wi-Fi organization developed an interim protocol, namely WPA (Wi-Fi Protected Access) to fix problems with WEP. WPA is similar to RSN except using TKIP (Temporal Key Integrity Protocol), rather than AES. TKIP also uses RC4, but with significant difference from the way WEP does. A much longer initial vector is used to avoid producing repeated keys. Weak keys are removed by discarding some potential bad initial vectors.

6. MULTIMEDIA MIDDLEWARE FOR HOME NETWORKS

In simple words, the term "middleware" [10] refers to a software layer between an application program and a network. The role of middleware is to ease the task of designing, programming and managing distributed applications. Essentially, middleware hides the complexity of the extra functionality behind a common set of APIs (Application Programming Interface) that client and server processes invoke. As Home Networks are becoming common in every household, the number and variety of devices interacting with each other is also increasing. The devices could be home appliances, consumer electronics, communication devices, multimedia applications etc. This calls for an urgent need for middleware to sustain the growth in 'multimedia home network' based software and applications' development activity.

The main requirements for such middleware with regard to multimedia devices are independence of specific networking technologies, interoperability between devices of different manufacturers, common API, common user interface frame work and plug & play for adding new devices to the home networks. Some of the standards with regard to middleware requirements are Jini [25], UPnP (Universal Plug and Play) [15], [20], [21], [22], [23] and HAVi (Home Audio Video interoperability) [10], [24].

Jini is a Java based standard developed by Sun Microsystems. Jini technology delivers access to services over any network for any platform, any operating system and any application, regardless of network complexity, distance or host device. It enables plug & play network based on TCP/IP. By using objects that move around the network, the Jini architecture makes each service, as well as the entire network of services, adaptable to changes in the network. The Jini architecture specifies a way for clients and services to find each other on the network and to work together to get a task accomplished. HAVi defines a system architecture where audio and video equipment from different vendors can be easily connected to build an in-home audio/video network and interoperate with each other. HAVi specifically defines a set of APIs that the consumer can use to develop devices and applications for home network. UPnP architecture enables pervasive peer-to-peer network connectivity of PCs. It is a distributed open networking architecture that leverages TCP/IP and web technologies like HTTP and XML. UPnP devices can be implemented using any programming language and on any operating system. It is independent of the underlying physical media and transports. As devices like PCs, palm computers, cameras, cell phones and all other multimedia enables devices are increasing, the need for convenient connectivity to networks is also increasing. This created the need for self-configuring networks, which allow devices to join and leave networks automatically. This is where the above mentioned technologies come into play.

7. MULTIMEDIA IN HOME NETWORKING - CONCLUSION

Several technology options are available for enabling multimedia in home networks. However, they differ widely in their cost, ubiquity and QoS capabilities. Ethernet is a proven technology that is widely used in majority of corporate and college networks. Ethernet is reliable, secure and can support data rates of 100Mbps and higher. The main drawback for Ethernet is its lack of ubiquity and poor support for QoS. Ethernet will require new wiring for most homes, which is prohibitively expensive.

Phone lines, with HomePNA 2.0 support data rates up to 10Mpbs and in future with HomePNA 3.0, data rates up to 100 – 128 Mbps would be supported. The main disadvantage of this technology is that phone jacks are not ubiquitous. The emerging UWB networking suffers from small coverage area. However, it is a good choice for Personal Areas Networks. IEEE802.11a/g WLAN can support data rates up to 54Mbps along with excellent portability and moderate mobility. However, they are not good choice for multimedia-oriented application in home networks due to the lack of QoS support and range issues. Hopefully, the ongoing IEEE802.11n standardization work can mitigate this problem. Power lines are easily accessible. The current HomePlug 1.0 technology currently supports data rates up to 14 Mbps. The next generation HomePlug AV technology is intended to provide data rates of 60-80Mbps with built-in QoS support, making them a good choice for multimedia home networking.

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