DELIVERING EVERYTHING EVERYWHERE IN THE HOME: WHOLE HOME NETWORKING

William Garrison
Thomas du Breuil
Motorola, Inc., Broadband Communications Sector

Abstract

This paper will describe the requirements for an in-home network. Specifically, it will address the data rate requirements for the various services and their delivery. Detailed descriptions of QoS requirements and the relationship between the Entertainment and Data devices and services will be given. Various wired and wireless networking technologies currently in the marketplace as well as new technologies that might serve this need will be covered Finally, a view of life in this home of the future will be explored.

INTRODUCTION

With the growth of broadband data services, many consumers have found it useful to install a data network. According to a 2002 Parks Associates report, 7.2 million homes now have a data LAN and this number will grow to 21.2 million in 2006. The primary application for these LANs is to share the broadband data access with multiple PCs in the home, but it is also used for printer sharing and file sharing.

Consumers are now buying PVRs and quickly realizing the benefits of video access via a hard drive. An obvious extension of this will be to access to this video content anywhere in the home. Wouldn't it be nice to view a program stored on your PVR downstairs on a TV upstairs? And consumers will want to add other media, such as music and photos, to this network as well as merge it with their data applications.

So why not just use the existing in-home data network for this new video application? Well, the reason is that requirements for an in-home data network are much different from an in-home entertainment network. An in-home entertainment network needs to support multiple entertainment streams (some at HDTV rates) with excellent QoS (Quality of Service). This network also must support other types of traffic, such as music, Internet, data and photo transport. Once this in-home network is in place, Voice-over-IP, i.e., telephony, and video telephony can be easily added. Cable operators have a unique opportunity in these in-home networks because they understand delivering audio and video best. But what is required to deliver these services?

REQUIREMENTS

Data Rates

A whole home network should be an infrastructure built to serve for a long time. Just as with AC power, you would never want to rewire your house just to add a new appliance – even if that appliance did not exist at the time you wired your house. Therefore both current and future needs must be considered when defining this network.

Relatively few homes currently have a HDTV display. Approximately 4.5% of all television households have a HDTV display now. However, 26% are expected to have at least one HDTV display by 2008. Currently, the average household has 2.7 TV sets and by

2008 some of those homes will have multiple HD displays. Table 1 outlines the typical services that may be expected in a fully networked home and their bandwidth requirements.

Application	Qty	Rate each Mbps	Total Rate Mbps
HDTV stream	1	19.4	19.4
SDTV stream	3	4.5	13.5
CD Stereo Audio	1	1.5	1.5
Multichannel Audio 5.1	1	4.5	4.5
DVD Audio, 6 channel	1	10	10
IP Data	2	1	2
IP Telephony	4	0.032	0.128
Total			**51**

Table 1. Home Network Bandwidth Requirements.

Quality of Service

Video requires a much higher QoS than data. Many networks provide reliable service by retransmitting a packet until it is successfully received. This is the correct approach to use for delivering data. However, video has a timeliness factor measured in milliseconds (or less!). If the video data is not delivered by the presentation time, it would be better to skip this packet and move on to the next.

In addition, a MPEG-2 TS (Transport Stream) has a jitter tolerance measured in nanoseconds. A common “solution” to the jitter problem is to use a large buffer at the receiver. This is demonstrated by most current PC streaming media players, where 5-10 seconds of video is buffered prior to playing. However, entertainment video is often interactive, so “solving” the jitter problem with a large buffer at the receiver will result in a system that seems ”sluggish”. Again, this is the typical experience with streaming media today on the PC where it takes several seconds to start playing or to resume play after pausing. And even with a large buffer, video glitches are common today in the streaming environment.

IEEE 802.11e is currently being developed as a standard QoS mechanism for wireless systems and promises to provide a QoS which meets entertainment video requirements. IEEE 802.11p exists for CAT-5 wired LANs, and HPNA 2.0 includes a prioritized QoS, but these schemes do not support entertainment level QoS. HomePlug 2.0 does not support entertainment level QoS. However, HomePlug AV (the next version of HomePlug) does plan to support entertainment level QoS.

Data and Entertainment

Data delivery is focused on accuracy and video is focused on timeliness. Video decoding is purposely designed to conceal errors while data transfers require perfection. Can both of these coexist on the same network? What tradeoffs need to be made between these?

HOME NETWORKING TECHNOLOGIES

Existing

If a home has an existing network, it is likely to be either a wired 10/100 Ethernet or a wireless 802.11b Ethernet. Unfortunately, neither of these is suitable for a whole home entertainment network. While 100 Mbps Ethernet is fast enough, it does not offer QoS. Plus, as a practical matter, few homes have Cat 5 cable running to all of the places where you would like to network. 802.11b offers neither the QoS nor the data rate required by an entertainment network. So, what else might be used for a whole home entertainment network?

Wired

Wired networking generally offers the highest data rates and the lowest device cost. A wired network could use dedicated wires (like Cat 5) or reuse existing wires (like phone line, power line or coax). Unfortunately, none of the currently available wired networks offer the bandwidth and QoS required by an MPEG-2 Transport Stream. HomePlug AV is the only proposed wired standard that promises to address this need, but the standard has yet to be defined and first products will not be available until Summer 2004. There are several proposed proprietary solutions for networking-over-coax that meet whole home networking requirements for Bandwidth and QoS, but none of these are adopted industry standards.

Wireless

Current wireless technology includes IEEE 802.11a, 802.11b and 802.11g. If an adequate QoS could be layered above it, IEEE 802.11b could theoretically support a standard definition video service with a stereo audio service. However, it certainly can not be the backbone of a home with the requirements of Table 1.

The data rate for 802.11a and 802.11g is adequate for most of the service set shown in Table 1, although they too will not handle the full service set. Why won't 802.11a or 802.11g handle 51 Mbps when it is advertised as a 54 Mbps standard? Because the effective payload rate is less than the advertised PHY rate. The advertised raw data rate does not subtract the MAC overhead and other inefficiencies. Table 2 shows the effective data rage for common networking technologies.

Home Networking Technology	Media	Raw Data Rate, Mbps	Approx. Effective Streaming Throughput, Mbps
100 Mbps Ethernet	Cat 5	100	90*
HPNA 2.0	Phone Line	10	6*
HomePlug 1.0	Power Line	14	6*
802.11b	2.4 GHz	11	5*
802.11a	5 GHz	54	20* - 34**
802.11g	2.4 GHz	54	13.5* - 34**
Magis Air5™	5 GHz	54	40**

Table 2. Existing Home Network Technologies

*ExtremeTech™ test results
**Theoretical limit

Also note these wireless standards do not include any provisions for Quality of Service, so in practice, they can not deliver a satisfactory media delivery experience without a large decoder buffer. 802.11e specifically addresses QoS through a prioritization scheme and may solve much of the QoS deficiency when it is approved. Meanwhile, proprietary solutions, such as Magis Network's Air5™ were designed specifically to meet the needs of video and audio distribution reliably.

Wired or Wireless?

Wireless networking is a must for portable devices. Every networked home will have portable devices and so every home will need a wireless network. So does a home already equipped with a wireless network also needs a wired network?

The likely answer is you will need both. Wireless is required for portable devices, but it may not reach all parts of the home, it may

not be able to deliver enough throughput, and is subject to interference. This is acceptable for a portable device, but not for the backbone of a home entertainment system. In addition, portable devices are normally battery powered, which limits their processing power and hence the bandwidth they need from their connection to the home network. Wired devices generally have no such limitations and their bandwidth requirements will only grow with time.

EVOLUTION OF THE NETWORKED HOME

Where are we today? Today, many homes have RF distributed by coax and data networked by Ethernet or 802.11 wireless. In addition, more and more homes have an Entertainment Gateway that uses a hard drive to store various content that is received, usually referred to as a PVR in the current configuration.

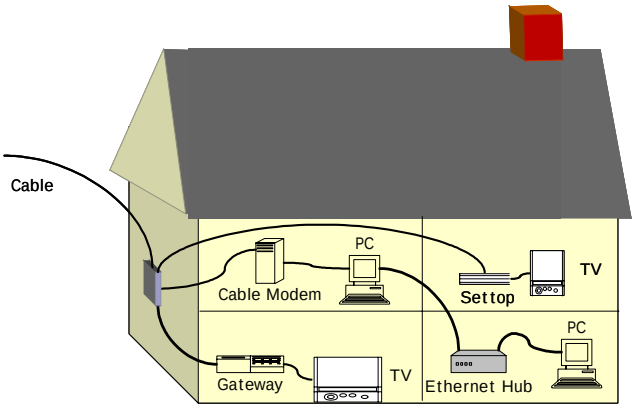

Figure 1 – The Current Home Network

There is a loose coupling between the RF and data worlds, in that the PC connects to a cable modem in order to connect to the Internet. However, for most purposes the two worlds of entertainment and data remain two separate worlds. Their closest linkage might be the DVD disk that can be played in either the entertainment center's player or the PC.

So, what does the networked home of today offer? As shown in Figure 1 in an Ethernet configuration, the consumer has these capabilities:

- Shared broadband for multiple PCs
- PC printer and file sharing
- Stand-alone PVR
- Digital Television and HDTV
- VOD and Impulse Pay-Per-View
- Audio sharing – MP3 to home entertainment center, digital audio to PC, etc.

AN INTEGRATED DATA NETWORKED HOME

The next step for home networks will be to add the entertainment devices to the data network. While this is less than ideal, it will add value to both the entertainment and data devices at very little cost.

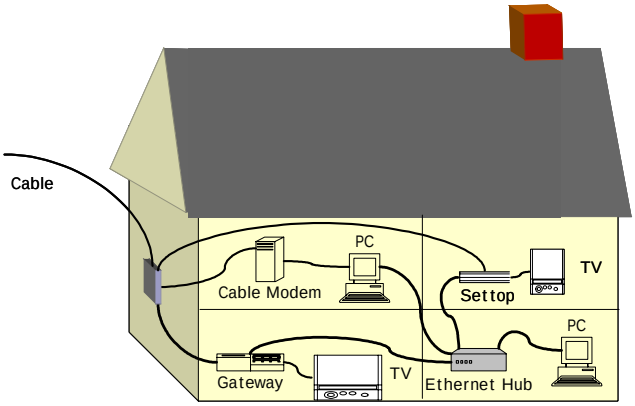

Figure 2 – The Integrated Data Home Network

What will the integrated data networked home of Figure 2 offer?

- Low bit rate video (< 1 Mbps) between PC and Gateway (with latency and some glitches)
- Archival storage – when your PVR disk is full, use unused capacity on your PC
- Remote access – move content in slower-than-real-time from one PVR to another for delayed remote viewing

- Pictures stored on the PC displayed on the TV

A FULLY NETWORKED HOME

In a fully networked home as depicted in Figure 3, the network backbone is robust enough to support any in-home application. Entertainment, data and voice applications are fully supported. Location does not matter. If your favorite program is recorded somewhere in the house, you can watch it anywhere in the house. If your favorite music is on any device in the house, you may listen to it on any device in the house. Format conversions are handled seamlessly.

What will the fully networked home offer?

- Quality video to/from the Gateway and PC, including high definition content
- Multiple high quality audio streams, including home theater
- Watch high definition TV on your PC even if you don't have a high definition TV
- Watch high definition TV on a standard definition TV via Gateway format down conversion
- IP telephony/video telephony

And what about your car? Why wouldn't you want to be able to listen to your favorite MP3s while on the road? Your car could automatically download the most recently played songs plus any ones you specifically designate every time you return home.

Note in Figure 3 the number of wires and devices goes down. This is because the best network is an invisible one. Communication can be via a coax network, wireless, Power Line or any combination of acceptable home entertainment networking .

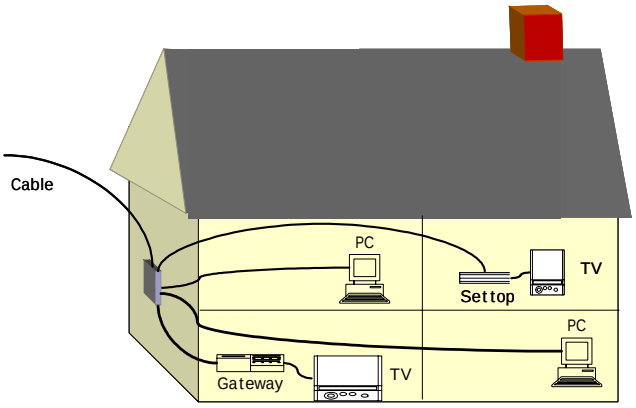

Figure 3 – Fully Networked Home

Where did the cable modem of Figure 2 go? Well, the home is sharing the cable modem that was already built into the Gateway. Future devices will have multiple network interfaces to make connecting as easy as possible for the consumer.

Whole Home PVR Scenario

You have just returned home and need some entertainment. So you plop down in the nearest chair and pick up the remote. Let's see, what is available? You want *Video, Recorded Programs, News*. Your home system knows that you like to get the latest news, and always records the most recent network news show for you. You don't know which device in the home recorded it (my PC? my settop?) and there really is no reason why you should care.

After you make your selection, the news starts. Well, after the first headlines, all you want is the sports. So, you fast-forward to the sports and see how your favorite team did. They blew the big play? You quickly go back to the menu and access the "Everything on Demand" system offered by my MSO, find the game, and Fast Forward to see that play. Yeah, they really blew it.

What Was Going On Behind The Scenes?

Your home devices have been autonomously recording content, based on your preferences. Some of your preferences were specifically enumerated when you set the system up, others were inferred by monitoring how you used the system. But when you plopped down, a content manager that was cognizant of every device in the network put it all together for you in one place.

After you made your selection, the first thing that happened is your current display device negotiated with the device that held the content. What is the best format to use? What is the best data rate? What QoS is available. As an example, presume the news was recorded in HD, but the in-home network is busy and only 5 Mbps is available with the QoS that you need. So, the network reserves 5 Mbps for this session and source device down-converts the news to a new data rate under 5 Mbps.

You start watching the news and decide to Fast Forward. The local device sends a message to the source, which starts the Fast Forward. Because the QoS minimizes the amount of buffering required at the display device, you see the news speed up within 200 milliseconds.

When you decide to go look at the big play, you are leaving you home network. Or are you? Your home system can record everything, so when you want something that is not available locally, you can fall back on your MSO to get the content. But the MSO might have known that many of their customers were going to look at that game, and so "pushed" the content to your home ahead of time. From your chair, it should not matter.

However, from the network's perspective, it does matter. For content from outside the home, the home network had to negotiate with a video server in the MSO's to select the content and setup the session. Playing that content now requires QoS all the way from the MSO's headend to your TV. Not a small challenge, because it spans multiple network domains.

Did the video come over a wired or wireless network? If the person flopped in the chair knows, then we have failed. The network needs to work seamlessly and invisibly.

CONCLUSION

The biggest remaining question is "When will all this happen?" The current home network isolates the entertainment and data networks. However, new products (such as Replay's and TiVo's latest generation devices) are starting to link the data and entertainment worlds. This is a start, and will likely grow over the next few years.

Full whole home entertainment quality networks are probably 3-4 years off. The devices required to build such a network will be available to early adopters at boutique prices early in 2004, but mass marketable whole home networks are probably still a few years out. Standards have to be established and production volumes must ramp up before price and ease of use meet mass market requirements. And there is a lot of software development required to make the network invisible and user friendly. The average consumer must be able to take a new device home and plug it in and find that it will simply work – like magic.