THE THREE DIMENSIONS OF HOME NETWORKING

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Abstract

Home networking is a lot more than "wired vs. wireless." Home networking also includes both the command/control language to search for and play content within the home and defining how applications are run and managed. Keeping an eye on all three dimensions is needed to promote plug and play interoperability of home equipment.

INTRODUCTION

Business Case

It started with Personal Video Recorders (PVRs). Now those PVRs can both be networked within the home, and over a high-speed connection to sources outside of the home. The home is becoming a source of stored content and services.

With content in the home, users will need not only better and faster connectivity within the home, but also the means to search the home for content and play it back to the audio/video device of their choosing over a reliable home network.

Home networks will interconnect both entertainment devices and general computing devices. This will allow services like a home calendar and shopping list to be integrated onto the same platform as entertainment services.

Just like cable is providing many services over one network (video, voice, data), it makes sense that users will want a single network in their homes to serve their needs. This network will connect many and various devices for services such as entertainment, communication, energy management and home control.

To accomplish all this, the home network will need to be easy to install, easy to connect devices to, easy to upgrade, adaptable, low cost, and secure. Quite a wish list indeed, but we are just at the beginning of home networking.

This paper discusses in technical terms specific functions needed on the home network in order to have different devices and services work together. All of the topics discussed in this paper are available today from more than one supplier, though not always in an interoperable fashion. In order to have widely available plug and play interoperability, the industry will have to converge around a select few of the initiatives currently available.

Three Dimensions

This paper discusses three distinct dimensions of home networking, all of which are critical to understand from both a technical and a business perspective. Understanding what happens in these three dimensions is important to understanding how home networking really works.

The three dimensions are:
Datalink Technology, e.g., 10/100Base-T, IEEE 802.11a/b/g, HomePNA, IEEE 1394, HomePlug, etc. These are all technologies

that move electronic bits. Some are wired and some are wireless; some are synchronous and some are asynchronous; some work over existing wires and some require new wires. Each has inherent advantages and disadvantages that will be discussed.

Interoperability Software to do functions such as device discovery and content search and playback. All of these functions are sometimes known as “plug and play.” This very important dimension defines how the home devices learn about each other without prior provisioning and how they work together to offer useful services. In order to use these “plug and play” protocols, the devices are connected using some kind of datalink (wired or wireless) to carry the bits that make up the message used by the interoperability software. Suites of protocols such as UPnP™ (Microsoft), Rendezvous (Apple), JXTA™ (SUN), DENi, etc., solve these issues in their own ways. Other companies such as Ucentric, Motorola and Scientific-Atlanta are creating solutions in this area. While many claim to be “standards” or standards-based, the reality is there is a very fragmented marketplace right now with several solutions vying for the top position. This is the key area to ensure service interoperability among devices on the home network.

Applications Frameworks to allow the development and execution of machine-portable applications within the home.

A well-known framework is PersonalJAVA™ although there are many others. These environments allow an application to be run on any of several computing platforms, for instance a Personal Digital Assistant from one supplier and a multimedia personal computer from a different supplier.

Overall System View

The discussion begins with a simple network consisting of two devices, one that has content (PVR) and one that wishes to search through and play a piece of content (Set Top Box [STB]). These devices are shown in Figure 1.

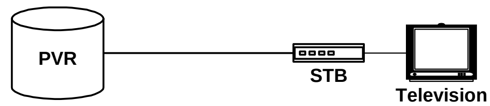

Figure 1 – Simple System for Home Networking

Note that a television is also shown in Figure 1. The STB could be embedded in the television but the two are shown as separate devices here because STB/TVs are not generally available (yet). As well, the PVR could have been embedded in the STB (or visa versa). Note also that the STB is not necessarily connected to a HFC Cable network, rather, the STB is just connected to the PVR and converts content to a form that can be viewed on the television.

This example alone is useful as new paradigms for devices on the home network will arise as multiple suppliers enter the market and consumer choice begins to dictate what devices do. Traditional suppliers and traditional devices will have to adapt.

For the time being, assume the PVR and the STB are connected via some kind of datalink. The datalink technology is important from the standpoint that maybe the STB can only accept analog video, or perhaps it can only accept digital video. The datalink technology has to support carrying data in the format that is needed to be useful. If digital video is used, the system has to know if the datalink supports a 3.5 Mbps

Standard Definition (SD) bit rate or a 20 Mbps High Definition (HD) bit rate.

If the datalink is a dedicated connection between the PVR and the STB (that is, not shared with any other device) then maybe it does not need to support Quality of Service (QoS). If the datalink is shared by other devices, perhaps QoS is needed to ensure the bit stream sent to the STB arrives there uninterrupted and without loss. Raw bit rate, support for QoS, and the ability to be shared are some of the characteristics to consider when studying datalinks.

When the PVR and the STB are first networked together, they will use some method to discover each other. That is, devices on the home network should be able to learn of each other without the need to be explicitly programmed by the user. In this way devices from various suppliers can be placed on the same network and learn about each other without user intervention. This complex task is handled by interoperability software running on all the devices on the network.

Once discovered, the STB has the capability to search the content on the PVR and play some of it back, including pause, fast-forward, and rewind capabilities. Highlights of this process are shown in Figure 2.

To complete the exchange shown in Figure 2, the PVR and STB have to talk the same interoperability protocols. Regardless of supplier, if the devices on the network use the same interoperability software then they can coexist on the same home network and function in a plug and play manner.

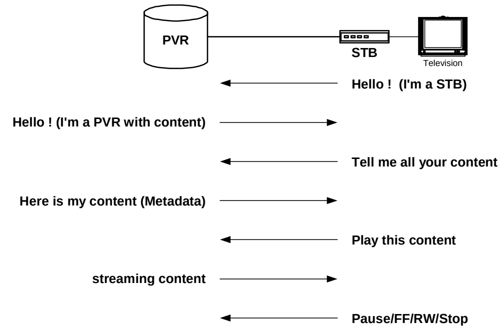

Figure 2

The first two lines in Figure 2 (the “Hello’s”) are what allow devices from different suppliers to recognize each other on a home network. While these two lines are highly simplified, they show that when devices are connected to a datalink they advertise what kind of device they are and what kind of services they offer. This information is generally broadcast around the home network to allow all the other devices on that network to learn about each other without user intervention.

The latter exchanges shown in Figure 2 look somewhat similar to a Video on Demand (VOD) session; searching content and controlling playback. The home will have its’ own sources of content and devices on the home network need the capabilities to search for content and play it back. An issue to be solved includes allowing a user to seamlessly search for content on both in-home devices as well as devices in the service providers network.

In order to introduce the third dimension of home networking, applications, a new piece of equipment is added to the system diagram as shown in Figure 3.

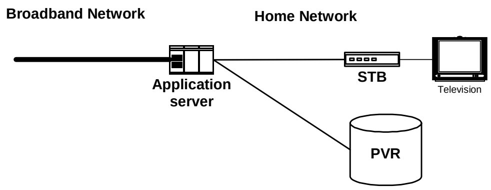

Figure 3

This new piece of equipment is labeled "Application Server" for lack of a better term. It could be a STB, or a home media center, but it has the characteristic that applications from a service provider can be placed there and function as expected regardless of what the physical device is. The subscriber can use these applications to add value to their home networking experience. Also out of convenience, the high-speed connection to the home is shown connected to the application server.

If one wanted too, the Application Server, STB, and PVR could all be collapsed into one device. The cable industry has an example of such a device and it is called the OCAP hardware platform. This is a monolithic, fully integrated, higher cost solution. What if the hard disk in the PVR needs to be changed out? What if more memory is needed to run applications? What if the user wants to add HDTV outputs on the STB? In the monolithic case, the entire device has to be switched out. With a modular home networking approach, the user can mix and match equipment from several suppliers and upgrade the equipment as driven by either personal choices or changes in available technology. The three dimensions of home networking provide the necessary connectivity tools and environments to allow devices from multiple suppliers to interoperate on a home network.

DATALINK TECHNOLOGIES

Introduction

Datalinks are technologies that move bits on a wire, or in the case of wireless, across the air. The bits could represent MPEG frames, Ethernet frames, IP packets, ATM cells, or some other type of protocol data unit. The datalink does not care what it carry's, rather it just makes sure the bits get from one end of the connection to the other. There are dozens of datalink technologies available; every day examples include wired 10Base-T and wireless IEEE 802.11b. Additional examples are given in later sections.

Home networks can have more than one type of datalink, for instance using a wired connection to get to various rooms within a home but then using wireless within the room.

The datalink has to carry two basic types of information, interoperability software messages and content. The datalink does not care about this type of information, it is just moving bits around and the bits can be just about anything. But there are some datalinks that will do a better job than others. For instance, if the datalink can only support 1 Mbps, it will not be able to carry digital video at a rate of 3.5 Mbps.

When all said and done, the two key items of concern with a datalink are having enough throughput (bits per second) to carry the services and easily being able to make connections in the rooms where subscribers want them.

Two of the most debated aspects of datalinks are "wired vs. wireless" and bit rate. These will be discussed in the following sections.

Wired Datalinks

One of the key questions is, which wire? Datalinks exist for home power wiring (HomePlug™), for home telephone wiring (HomePNA), for home data wiring (Cat-5 10/100Base-T, USB, IEEE 1394) and for optical fiber (SPDIF). There are even several companies working on turning the in-home coax cable into a datalink.

The pro's of wired datalinks include higher speeds, more consistent speeds, and the knowledge that there is a physical connection. Con's include the possibility of having to install new wires.

Wireless Datalinks

These technologies include Bluetooth™, HomeRF, the IEEE 802.11 series, Magis Networks, etc. These datalinks have the benefit of "no new wires," however, they may not have the bit rate needed to support several streams of HDTV along with high-speed Internet applications like peer-to-peer and gaming.

The pro's of wireless datalinks include no new wires and relatively higher speed throughputs that are coming to market e.g., IEEE 802.11g. Con's include speeds that can fluctuate based on distance and concerns over security.

Datalink Bit Rate

There is a debate of how much bandwidth is needed on the home network to support services that consumers want. A key driver to get at the answer will depend on the compression used for video services. Entertainment quality video takes a fair amount of bandwidth, in the megabits per second range, that must be delivered consistently and reliably.

If there is not enough raw throughput at the datalink, QoS technologies may be needed. QoS is needed when there is the need to give one service better treatment than another when there is congestion on the datalink. With enough raw throughput available, an arguably simpler datalink can be offered, one that does not need QoS. On the other hand, there are different types of QoS too, specifically prioritized versus parameterized. Parameterized QoS is more complex, having many parameters to guarantee exactly the QoS needed for that particular service. Prioritized QoS is relatively simpler, giving certain services higher priority than other services on the datalink. Prioritized QoS does not give guaranteed bandwidth, but sometimes a simple higher priority is sufficient to support the needed service. Of course if QoS is needed, that means some services will get better treatment than others, and the ones that get the "less better" treatment may not be happy.

INTEROPERABILITY SOFTWARE

Introduction

Interoperability software enables plug and play architectures where devices and services can be introduced into a network without configuration hassles. In addition, interoperability software is an important step toward eliminating manually installed drivers, relying instead on standard interfaces to put devices in touch with other devices and the services they offer to the network.

Interoperability software is a very important step, one that will free the consumer from having to understand the technical details of each piece of equipment and manually provision them to interoperate. The protocols and procedures included with the interoperability software allow devices on a home network to learn each other's capabilities and to interact in a way to provide services.

Interoperability software can work completely in the background; the user does not have to configure the equipment to make it work. These protocols are device-to-device, and can occur autonomously once a device is connected to the home network. Other devices on the home network that understand and talk the same interoperability software will respond autonomously as well.

There are two main architectures for interoperability. One is peer-to-peer, where all devices communicate with all other devices on the network to learn about services. Individual devices create their own internal database of the devices and services available on the network. A second architecture is centralized, where a device is "elected" to be the centralized repository of information. This centralized device then periodically broadcasts its presence for new devices coming on the network and all the while aggregates information about all other devices and services on the home network. Other devices then query the centralized device when they need specific information about other devices and services on the network.

Home networking interoperability software provides several key functions, including device discovery, service discovery, and playback control. These issues will be described in the following sections.

Device Discovery

Device discovery is the process by which a device learns about other devices on the home network. At the device level, the information exchange is on the order of Ethernet Media Access Control (MAC) addresses and Internet Protocol (IP) addresses. By learning the addresses of each device on the network, the devices are able to contact each other and request content and services.

Service Discovery

Service discovery provides a means for devices to advertise the services they can offer to other devices on the home network. For instance, a device could advertise that it stores content, or that it is a printer, or that it is an audio and/or video playback device.

Consider the case where a user wants to playback audio to a set of speakers in the kitchen. Service discovery information is used to create a list of playback devices that is categorized by audio speakers. The user would choose the speakers in the kitchen. In the case of looking for a networked printer, the user would call up a list of all printers. From there, the user could further differentiate the printers based on service characteristics such as black and white printers versus color printers.

Playback Control

Once all the devices are connected, and all are discovered (including their services), the fun can begin for the consumer. Interoperability software also includes the mechanisms to search and play content. Searching can be implemented seamlessly across devices. When a user requests a list of all the digital photographs available, they are presented a list of all the digital photos on the network, regardless of the specific device on which they are stored. This is the scenario that is closest to the VOD service of today, except that the service is entirely in the home. With content on various storage devices in the home, other devices can search that content and play it back using normal controls such as fast-forward and rewind. To continue the VOD analogy, its like having movies cached both locally and centralized. When the user searches the VOD titles, they are not aware of where a particular title is stored, just that it is available for viewing.

Industry Initiatives

As stated earlier, various industry initiatives, such as UPnP and Rendezvous, are promoting their solutions for interoperability software. There are no less than eight initiatives out there and several suppliers are developing additional solutions.

The key about all these initiatives is that they are not interoperable. While they generally all use the same underlying standard protocols and procedures (e.g., DHCP, SLP, SOAP, XML, etc.), they do so in ways that are not interoperable. As explained a bit later in this paper, CableHome is positioned to take advantage of the innovations in this space.

APPLICATION FRAMEWORK

Description

The application framework is the third dimension of home networking and allows applications to be device independent. That is, an application can run on any appropriate device regardless of supplier, operating system, underlying hardware, etc. The relationship of the Application Framework to the rest of the device is shown in Figure 4.

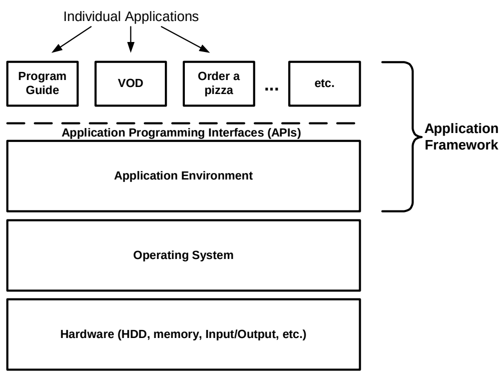

Figure 4

The application framework consists of the Application Environment, the APIs, and the individual applications. This software is portable to different types of devices running different operating systems.

Individual applications are written to run within a specific application framework. The framework itself is ported to various operating systems. In this way, the application, which the service provider cares about, works on various supplier boxes that have implemented the application framework. For instance, a particular application framework (including all the applications) should be able to run on a device with an Intel processor running a Microsoft operating system or a device with a SUN processor running the Solaris operating system. It is this device portability that makes an application framework so powerful. The operator no longer has to worry about the underlying hardware device, rather, the operator just manages the applications that run on that device.

Application Environment

The application environment is a place where software applications are allowed to run. The environment supports both one or more programming languages that developers use to write applications and various tool to manage those applications. A widely recognized application environment is PersonalJAVA™, which is an environment for applications written in the JAVA™ programming language.

The application environment includes tools that are specific to the programming language. This support can include complex technical tasks such as transaction management, state management, resource pooling and security checks for all the applications running within the environment. This is very technical stuff the consumer should never know about, but it ensures the integrity of the applications running within the environment, especially since several applications can be running simultaneously.

Application Programming Interfaces (APIs)

APIs can be thought of as standard subroutine calls that developers use to create applications. These calls include everything from mundane tasks such as writing to memory to more exotic tasks such as drawing a graphics overlay on a display device. The APIs are the "Rosetta Stone" of portable applications. The underlying operating system and hardware speak a low-level machine programming assembly language. The applications speak a high-level programming language. The APIs translate between these two languages allowing humans to write in a high-level programming language and allowing the machine to operate on low-level assembly language.

Security and Rights Management

No discussion of home networking would be complete without including security and rights management.

Security is fairly straightforward, the data carried on the network should be private such that it cannot be snooped, especially in the case of wireless datalinks.

Rights management is an important topic that is currently being debated not only within the cable industry, but also by other industries as well including broadcasters, consumer electronics, content producers and satellite. There are several examples or rights management technologies available, including DFAST (Dynamic Feedback Arrangement Scrambling Technique) and HDCP (High Definition Copy Protection).

For the purpose of this paper, suffice it to say that rights management is needed and there are many groups working on a consensus solution that hopefully can be presented in the not too far distant future.

CableHome™ Positioning

The CableHome initiative, which seeks to extend cable-delivered broadband services throughout a customer's home, issued key specifications for the 1.0 version in April 2002. Also in 2002, CableHome achieved international standardization at the International Telecommunications Union (ITU).

Whereas most Interoperability Software industry initiatives are concentrating specifically on connectivity within the home, CableHome started with a focus of first connecting the home to a high-speed data connection over cable using a residential gateway. This is illustrated in Figure 5.

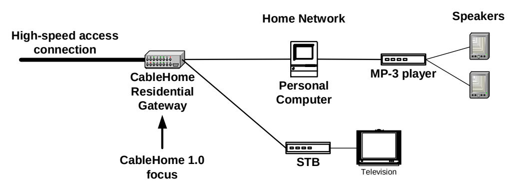

Figure 5

It is expected that the other initiatives will eventually focus on the high-speed connection as well, and CableHome in turn is beginning to focus on solutions for device and service discovery and the accompanying security issues of rights management and content protection.

Among the residential gateway features provided by CableHome 1.0 are mechanisms for secure remote management and configuration of residential gateway capabilities that include DHCP, DNS, NAT/NAPT, LAN test tools and a firewall.

CableHome key features:

- CableHome helps ensure customer privacy because it does not provide cable operators with the ability to probe or configure consumer devices, such as PCs, within the home.

- CableHome also helps protect customer privacy by providing cable operators with the tools that assist in mitigating unauthorized snooping of Wi-Fi based home networks.

- Consumers only use this additional CableHome functionality (e.g., remote diagnostics) if they have voluntarily chosen to subscribe to a cable operator's home networking service. CableHome equipment will be deployed in those households where consumers have elected to pay for this additional functionality because they see value in having the cable operator manage the technical complexity associated with the deployment and operations of a residential gateway.

CableHome is a tool to extend cable-delivered services to the home.

<u>Summary</u>

Home networking is a complex topic. There are three clear and distinct dimensions that comprise home networking, and each dimension provides a new set of technologies and a new set of suppliers.

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