DigiPoints

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Home Networks

Introduction

Home networks, also known as in-home networks, are emerging as a consumer technology for interconnection of digital devices at a subscriber residence or home office.

These networks are scaled-down versions of local area networks used in businesses.

Two facts contribute to their attractiveness to consumers: they allow peripherals such as printers and files to be shared by several computers in a residence, and they provide a way to share applications, such as gaming or internet access via either a cable modem or a telephony modem.

The number of installed home networks is growing for two reasons: the growth of on-line households and the growing number of homes with two or more computers.

According to one study[1], more than 47 percent of U.S. households are expected to have Internet access by 2002, with about 20 percent of this group having a need to share access to the Internet. As of 1998, more than 15 million of the 100 million homes in the United States had two or more PCs. Considered by itself, this group is growing at a rate of 30 percent per year.

More than one-third of U.S. households currently have devices capable of Internet access. It is estimated that by the year 2002, 15.3 million households will depend on their in-home networks to provide a means for communications between multiple PCs and other terminal devices.

Cable service technicians and installers will, therefore, be doing their jobs more often in homes that have some type of network installation. Many of those networks will be built using pre-existing electrical or phone wires as the interconnection medium. Some of them may actually be a set of two or more interconnected networks that each serve specific functions, such as a home entertainment network based upon IEEE 1394 technology, and a home office network of PCs and peripherals using IEEE 802.3 or a variation. (See Figure 1.)

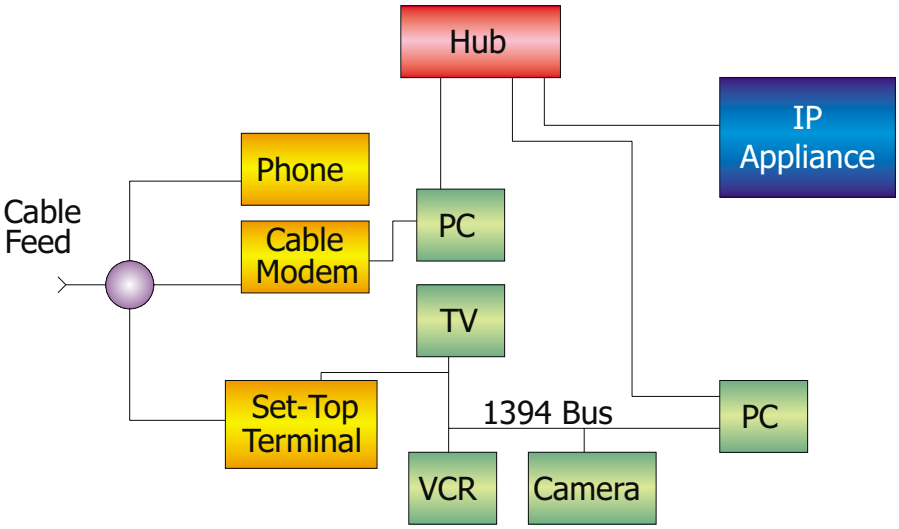

Figure 1: Interconnected In-Home Networks

This issue of *DigiPoints* will look at the state of home networks used to connect PCs, their peripherals, and modems. We will be presenting some of the ways cable telecommunications personnel will be connecting existing and new terminal equipment to those networks. Our review is a "snapshot" of technology as of the end of 1999, and it doesn't take much imagination to see that the overall picture will change with evolving technology. The discussion includes both technical background and practical connection and troubleshooting information. Understanding the technical background, especially the overview of the protocols used by various technologies, will be helpful to technical personnel in solving potential data flow incompatibility problems in both current and future networks that interface to a cable operator's system.

1 Jupiter Communications study quoted in June 1998 white paper by the Home Phoneline Networking Alliance.

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Residential Wiring Systems

There are four major interconnection media for in-home networks: the home's electrical wiring, the home's existing telephone wiring, dedicated wiring, and wireless media. Although dedicated wiring and wireless medium generally offer more bandwidth, longer distance between terminals and a more reliable connection, they are more difficult for a consumer to install and maintain. The use of pre-existing phone or electrical wiring provides a network media that is pre-installed, but which is limited because it was optimized for another purpose. We will first look at the use of existing home wiring as a media for in-home networks, and then discuss the use of dedicated media.

Home Wiring Viewed as a Data Network Topology

There are three pre-existing wired networks in most residences: the phone system, the electrical distribution system and the coaxial cable installed to distribute signals to home entertainment devices. Before discussing how these pre-existing networks can also be used as data networks, it is helpful to understand their topologies.[2]

Existing Coaxial Cable as a Network Medium

Because most *DigiPoints* readers are familiar with cable telecommunications, we will only summarize the key points of existing in-home coaxial cable. Cable distribution is a tree-branch network up to the point of entry to the home. From the entry point, the coax in most homes forms a mesh network, which is actually a star-tree hybrid topology. Splitters are used to join the branches of the tree to the rest of the star. The recommended cable is either Series-6 or Series-59, terminated by an F connector. In most cases, coaxial cable will be the media used to interface an in-home network with a high-speed data connection to a cable system or a video signal from an external source.

Although coax is a broadband media, it could be challenging to use all or part of the existing coax as the medium for an in-home network. The relative placement of devices on the cable with respect to the splitter affects the attenuation between any two or more devices trying to communicate. Any network design would, therefore, have to account for the uncertainties of where the various branches might occur, as well as the forward and reverse characteristics of the splitters. An interface device that performs ranging similar to a cable modem's operation might be a solution, but cost and complexity could become an issue. Furthermore, if the network were to be connected to a high-speed data service over the same coax, there would need to be some way to isolate the in-home data from the operator's network.

2 *DigiPoints* readers who want a refresher on network topology should read *DigiPoints Volume One*, Chapter 10.

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Existing Phone Wiring as a Network Medium

The phone system can be wired as a star, a bus, or a hybrid. The recommended TIA/EIA 570A practice is to wire each phone outlet as a "home run" to a terminal strip in a cabinet near the telephone company's demarcation point, and then complete the run for each line from the terminal strip to the network interface unit (see Figure 2). This results in a star topology (see Figure 3). By having a home run to each outlet, the possibility of electrical interference is minimized, and it is easy to change phone lines associated with individual outlets. In actuality, few homes are wired per the TIA/EIA specification.

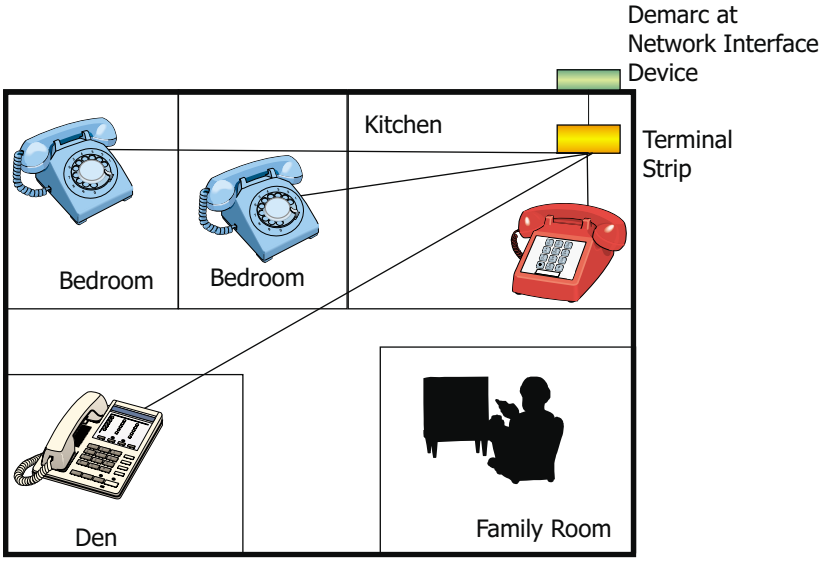

Figure 2: Residential Phone Wiring Per TIA/EIA 570A

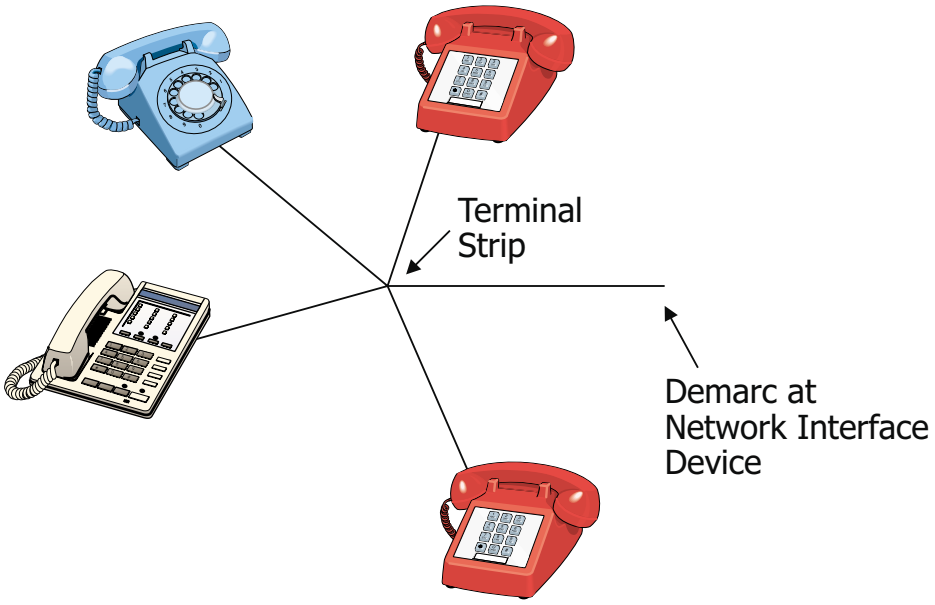

Figure 3: Topological Equivalent of TIA/EIA 570A Wiring

The more common method of phone wiring is some form of "loop wiring," where each outlet is connected to the previous one in a chain that begins at the demarcation point. The term "loop" is used because each outlet is at the end of a loop to another. This method of wiring is easier and less costly for the building contractor. Loop wiring is actually a bus topology, as shown in Figures 4 and 5.

In actual practice, home phone wiring is often a hybrid of star and loop (star and bus to the data professional), especially in older homes where additional lines to outlets may have been added after the initial installation.

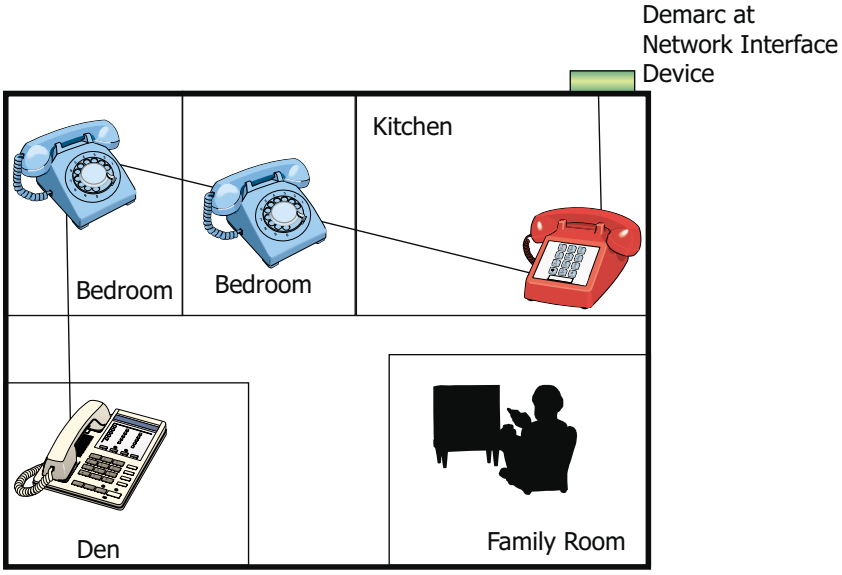

Figure 4: Residential Wiring (Loop Method)

Figure 5: Topological Equivalent of Loop Wiring

Existing Electrical Wiring as a Network Medium

The electrical distribution system is even more complex than the phone system. The basic topology is a mesh hybrid of star and bus where each branch circuit is one leg of the star and each outlet on the branch is a port on a bus connected to the leg of the star (see Figure 6). Because of the several light switches in an electrical distribution system, the network is highly unbalanced (e.g., one of the wires going to a port may be open while the other is a complete path to the port).

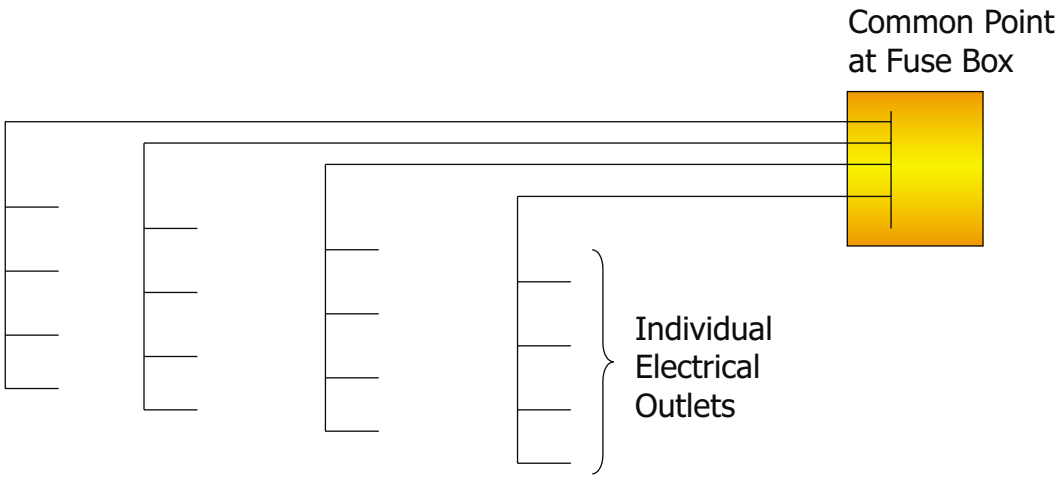

Figure 6: Home Electrical Distribution Topology

Obviously, none of the existing wiring systems, coaxial cable, the phone system or the electrical distribution system, are optimized for use as a data network. We will later discuss how in-home network technologies overcome these limitations.

Home Wiring Media Standards

Traditionally, home phone wiring has been 22- or 24-gauge copper pair.[3] Depending on the manufacturer of the wire, it may be twisted or untwisted pair.[4] Home electrical distribution wiring has traditionally been 12- or 14-gauge copper or aluminum wire, although the appliances connected to the outlets often continue the circuit with lower gauge wire, such as 18-gauge.

While not much has changed over the past decade in home electrical distribution topology, there have been many changes in standards for phone system and cable telecommunications wiring. The newest recommendation by TIA/EIA provides a dedicated wiring system for new forms of

3 Gauge is a measurement of wire diameter.
4 "Twisted" does not mean just a random twist. To qualify as twisted pair, the twist must be applied at a specified number of twists per length. Wire categories, such as Cat 3 or Cat 5, indicate the specific twist and other characteristics.

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information distribution, as well as the conventional wiring system. It recommends two grades of residential "information outlets."

- Grade 1 provides for basic telephone and video service. The standard recommends one four-pair Category 3 or better unshielded twisted pair cable and one Series-6 cable to each information outlet.
- Grade 2 provides for enhanced voice, video, and data to the residence. The standard for Grade 2 recommends two four-pair Category 5 unshielded twisted pair (Category 5 UTP) cables and two Series-6 coax cables. One of the Category 5 cables is for voice and the other is for data. One of the Series-6 cables is for satellite service and the other is for CATV or local programming received via a residential antenna.

It is interesting to note that common Series-6 coaxial cable is not necessarily the optimal medium for all home video applications. In particular, for baseband video and audio, a coax cable with an all-copper center conductor and high-coverage copper braid or foil plus braid shields provides better transmission quality at baseband. In applications where baseband outputs are connected to baseband inputs over a relatively long distance, the use of this alternative type of cable might be preferred. Examples might be connections of video cameras to recorders, recorder to recorder, or security camera to recorder, which span several rooms or floors in a dwelling. Another alternative for transport of baseband signals could be Category 5 UTP terminated with special adapters called baluns.[5]

Other Standards and Protocols for Home Wiring

There are two other standards worth noting when discussing home wiring for in-home networks. IEEE has developed the 1394 FireWire standard, and EIA has developed the EIA-6000 CEBus Standard for Consumer Electronic Bus. *DigiPoints* Volume III, Issue 5, explained the IEEE 1394 standard and its applications in detail. The CEBus standard currently has most application as a defining protocol for remote control of heating and lighting systems. Since the focus of most cable telecommunications is on entertainment and data applications, CEBus will not be covered in detail in this issue.

Technologies that Use Existing Residential Wiring as a Network Backbone

Although the EIA/TIA 560A standard provides a comprehensive solution to wiring a home, it is not widely implemented and is more easily applied to new construction than to existing homes. Other solutions are being offered that promise to be easier, if not as flexible.

5 Balun stands for Balanced-Unbalanced. It is an impedance-matching transformer. For this application, the balun interfaces a balanced Cat 5 UTP cable with unbalanced audio and video sources. Admittedly, this use of Cat 5 UTP is an unusual application, but it may be a good alternative if the Cat 5 wiring is available between otherwise unconnected rooms.

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Sharing the Electric Line

Existing electrical power wiring can be used as an interconnecting medium for in-home networks. A power line system is one of the easiest for a consumer to connect, but it generally has limited application. The technology for sharing the power line limits network speeds to 350 Kbps, and as of 4Q99, only one vendor, Intelogis, appears to be actively promoting a product based on the technology. The Intelogis product is called the *PassPort Plug-In Network*.

The PassPort Plug-In Network is relatively simple to install. Each device to be networked needs to have its parallel port connected to a small adapter that plugs directly into an available electrical outlet. The power to each networked device must be filtered through a separate outlet strip to prevent interference from the PassPort Plug-In signal. Once connected, each device must be rebooted and software drivers added via screen prompts generated by installation software on a floppy disk that comes with the product. The section on Computer Software covers general points on driver installation that apply to the Intelogis PassPort Plug-In product.

The Protocols that Make the System Work

The Intelogis PassPort Plug-In Network is based on a set of

Wiring Termination and Connectors

Cable installers and service techs will find several types of connectors used in home wiring. Since these connectors will be used to interface with in-home networks, it is helpful to recognize the various types, as illustrated in Figure A.

RJ-45 Jack

RJ-45 Connector

110-Volt AC Outlet

RJ-11 Jack

RJ-11 Connector

Figure A: Connectors and Terminations

Because of its widespread use by even non-technical personnel, most people will readily recognize the 110-volt AC outlet. When cable personnel are working with home networks using electrical wiring as the distribution system, it is good practice to verify that each outlet that is part of the network has been wired per the appropriate electrical codes.

The RJ-11 and RJ-45 jacks are very similar, and because of this similarity, it is easy to confuse one with the other. It is worth noting that:

- The proportions of the length to width of the two jack types are different.
- Both jack housings are capable of being equipped with a different number of contacts, for different applications. This is the reason that an installer who uses existing jacks as part of any network must verify that both the number of contacts and the connections to the contacts are correct for the particular application.
- Even when a particular jack has the correct number of contacts for the application, it may not be wired for that application. The RJ-45 jack, for example, can be used as a connector per EIA specification T568A, or per EIA 6000 CEBus. Each specification connects sets of twisted pair wires to different combinations of contacts.

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proprietary PLUG-IN protocols that span five of the seven layers of the OSI protocol model. For this discussion, the most important layers are the PLUG-IN Power Line Exchange (PLX) Protocol and the PLUG-IN Digital Power Line (DPL) Protocol. The PLX protocol spans the network, transport, and data link layers, while the DPL protocol correlates with the physical layer of OSI.

The DPL protocol is based on frequency division multiplexing (FDM) combined with Frequency Shift Keying (FSK) technology. FDM assigns the FSK frequencies away from the 60 Hz used for commercial AC. Intelogis has designed the system to operate in a range of frequencies that it claims is also outside the band where most noise is produced on an electrical power line, but below the range where the topology of an unbalanced, hybrid network will cause severe signal attenuation. The current single-channel, single-carrier version of the product limits its speed to 350 Kbps. Intelogis has stated that future versions of the product will be capable of 2 Mbps.

The main function of the PLX protocol is to provide control at the Media Access Control (MAC) level. PLX protocol uses a MAC protocol consisting of two separate access mechanisms — Datagram Sensing Multiple Access (DSMA) and Centralized Token Passing (CTP). The DSMA portion acts like Ethernet for resolving multi-node contention on the medium by sensing datagrams and randomly backing off if one is detected. It is used for initial insertion of a datagram on an inactive network. Once a node is established as the active node (network server), multi-node contention and collision are avoided by a centralized token-passing scheme. Any node on the network is, therefore, capable of establishing itself as the network server, responsible for arbitrating requests for the token.

Independent tests of the Intelogis PassPort Plug-In Network by *PC Magazine* indicated a decrease in throughput when electrically noisy appliances, such as a dishwasher, are running. In addition, it is necessary to be certain that all devices are on branches of the electrical line that have electrical continuity with each other.

Sharing the Phone Line

Systems that share the phone line have far more vendor and standards support than the one based on sharing the electrical power distribution line. The Home Phoneline Networking Alliance (Home PNA) is a group of more than 100 vendors that has developed specifications for interoperable, home-networked devices using in-place phone wiring. The technology is currently capable of network operation at 1 Mbps and promises to develop to a 10 Mbps and beyond.

Installation of a network that uses the phone line media is also relatively simple. The first step is to make sure that all the phone outlets that will be used for the interconnection have electrical continuity with each other. Obviously, all the outlets must have the same phone number associated with them. Less obvious, however, is the need to check each outlet to be sure it is an active phone outlet and that the phone wires are connected properly to the jack. An active line can be determined by plugging a regular phone into the jack and listening for dialtone. Polarity tests can be done with simple test devices that plug into a phone outlet and indicate by the color of an LED display whether the phone line is correctly installed or has been crossed.

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The next steps are similar to those used to connect a network that is based on the electrical line. Two connections to a PC are possible: via the parallel port of the PC, or via a PC card interface. With the parallel port connection, the parallel port of each device to be on the network must be connected to a special adapter that, in turn, plugs into the phone outlet for the network media and the electrical outlet for power. Finally, each device on the network must be rebooted and special software installed to recognize that the device is part of a network. The software installation will be covered in the section titled, "Computer Software for Home Networks."

The Protocols that Make the System Work

At the physical protocol layer, the Home Phoneline protocol uses FDM. The home network operates in the frequency range between 5.5 MHz and 9.5 MHz. Passband filters attenuate frequencies below 5.5 MHz to eliminate interference with other services sharing the wire. (See Figure 7.)

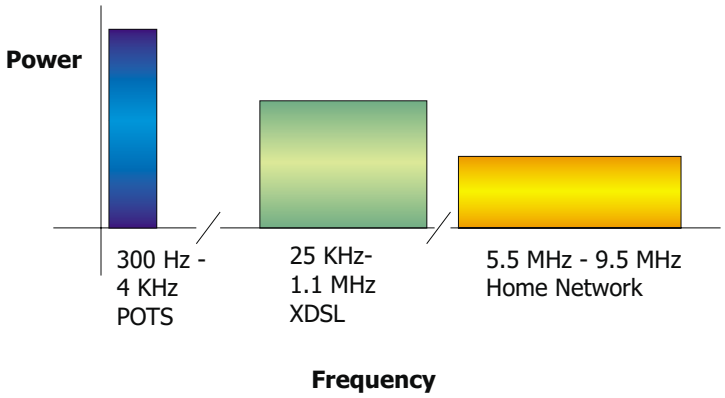

Figure 7: Frequency Ranges of Signals on Phone Lines

To increase data throughput, the home phoneline networking technology uses a proprietary time modulation coding method developed by Tut Systems, one of its members. Multiple data bits are encoded per symbol (pulse) on the line. Tut's patented mechanism incorporates an adaptive circuit that is able to adapt to varying noise levels. In addition, both transmit and receive circuits continually monitor line conditions and adjust signal strengths according to conditions.

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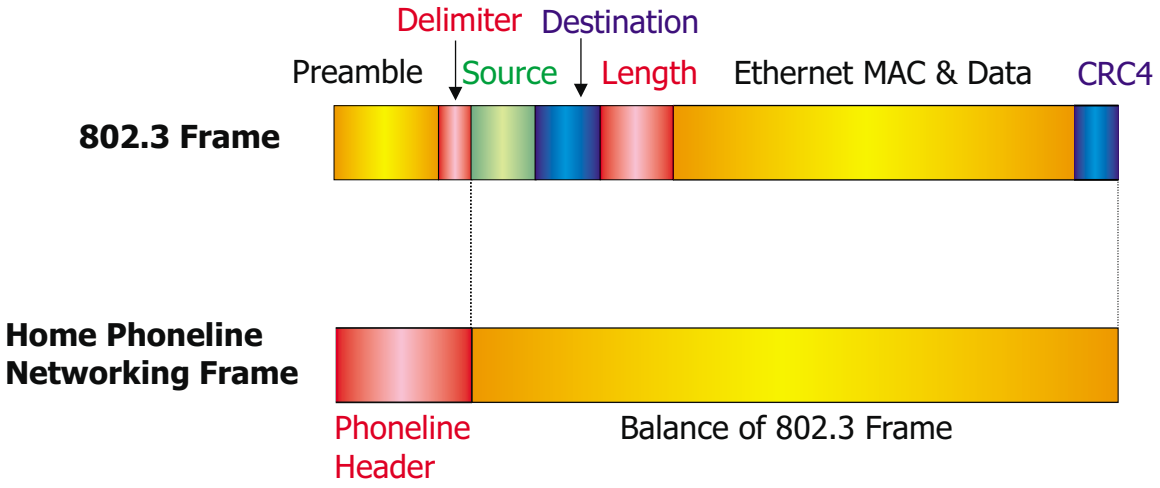
Another member of Home PNA is proposing a next generation Home Ethernet technology that would extend network speed initially to 10 Mbps and later to 100 Mbps. Per a white paper published by the Home PNA,[7] Home Ethernet is to be dynamically rate adaptive, instantaneously adjusting to the changing electrical characteristics of the phoneline communications channel. It will also provide performance options for error control and multimedia Quality of Service.

At the MAC protocol layer, home phoneline networking uses a modified Ethernet data frame. Figure 8 shows how data originating from applications within the computer is formed into standard 802.3 Ethernet data frames, then passed to the phoneline physical layer (PHY). The PHY circuitry strips off the first eight octets of the Ethernet frame (the preamble and delimiter fields) and replaces it with a PHY header designed for phoneline networking.

At the receiver, the reverse process is performed. The PHY header establishes the validity of the frame and is then stripped off and replaced by conventional 802.3 preamble and delimiter fields.

Silicon implementations of the Phoneline Ethernet LAN controller are offered by Intel and Lucent Technologies.

Figure 8: Home Phoneline Networking Data Frame Compared to 802.3 Data Frame



7 White paper, the Home Phoneline Networking Alliance, “Simple, High Speed Ethernet Technology for the Home,” June 1998.

Technologies that Depend Upon a Dedicated Medium

10BaseT Ethernet

A small, but growing, number of homes are being wired for information services. Although cost considerations typically keep homebuilders from completely following the TIA/EIA 570A practices, many technologically astute homeowners have run at least some Category 5 Unshielded Twisted Pair to selected rooms, separate from telephone wiring.[8] Residents in these homes can install an in-home network that is very similar to a corporate LAN in a small business.

The price of hubs and routers are rapidly reaching consumer price points. On the high end of home networks, a full 10BaseT Ethernet LAN complete with a home office router can be put into service using existing wiring for less than $2000. Smaller networks that are built around a switchable hub rather than a full router are available for under $200. Given prices for a total network that are comparable to or less than the cost of an additional computer, 10BaseT is a viable option for many families with multiple computer users.

Connecting a 10BaseT network is, however, more complicated than connecting the networking options we mentioned earlier. Several vendors sell networking kits that usually consist of two network interface cards (NICs), driver software, cables, and a network hub. The NICs, hub, and devices on the network must then be interconnected via Category 5 UTP cable, and software drivers added to the devices on the network.

NICs must be installed in the device that will be attached to the in-home network. In most cases, this involves opening the device, finding an available card slot, and inserting the card.[9] Most kits provide NICs that can be inserted into desktop computers. The network builder must purchase any NIC for laptop use separately. NICs may support 10 Mbps or 100 Mbps Fast Ethernet.

Typically, a vendor will provide a hub that matches the speed of the NICs. However, the network user needs to be aware that if he or she connects a laptop that has a NIC used in another network, speeds may be incompatible with the in-home network installation, making it impossible to add that laptop with its existing NIC to the in-home network. (There are other compatibility problems associated with bringing a laptop home from the office and connecting it to an in-home network.

8 There is also a trend to install Category 5 wiring for all upscale residential telephony service in anticipation of future integration of data and telephony in one device. In some cases, this wiring can be split into two separate networks at the demarcation point, and the part that is split off from the standard telephone network can be used for a 10BaseT LAN. The technician should verify that the two networks are completely isolated from each other using a toner or other device that verifies continuity.

9 The details of adding a NIC card to a PC are covered in Chapter 3 of the forthcoming book, *DigiPoints Volume Two*.

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Configuration parameters typically set when the NIC is first installed will probably differ between the networks.)

The speeds supported by various hubs differ by manufacturer and model. Similar to NICs, hubs can support 10 Mbps or 100 Mbps networks. Some will even recognize the speed capability of the connected device and automatically adjust their port to accommodate the input. Four- and six-port hubs are common. If more ports are required, hubs may be linked to other hubs.

Devices are interconnected with standard Category 5 UTP cable. If the in-home network is completely located in one room, the cables supplied by the network vendor may be sufficient to interconnect the devices. However, if the network spans an entire home, the user will need to connect between rooms. For homes wired with Category 5 UTP, it may be possible to use existing phone wiring with appropriate RJ-45 connectors. Otherwise, dedicated wiring will need to be installed. The distance limitation is 328 feet from the hub to each device.

A word of caution regarding wired media is in order here. Category 5 UTP wiring is not just cable. It is a total system that includes connectors and termination of the cable. When troubleshooting data problems in an in-home network that uses Category 5 UTP, it is a good practice to verify that all parts of the medium conform to Category 5 wiring specifications before looking at other parts of the system. TIA (Telecommunications Industry Association) bulletin TBS-67 specifies four tests — attenuation, cable length, near-end crosstalk, and wire map — that installed cable must meet. How to conduct those tests is beyond the scope of this issue of *DigiPoints*; however, there are several vendors that sell Category 5 test equipment that will verify that a system falls within the TIA specifications.

The Protocols that Make the System Work

Since these networks are essentially 10BaseT Ethernet LANs, the reader is referred to *DigiPoints Volume One*, Chapter 10, for a detailed discussion of Ethernet, IEEE 802.3 protocols, and networking hardware. Remember that 10BaseT is a variation of Ethernet that uses a star topology, rather than a bus. The hub is the central connection point for all devices on the 10BaseT network.

Wireless Networks

Wireless networks solve the problems of device mobility and running new wiring between rooms, but the standards are relatively new, and practical in-home network products are just beginning to emerge. A typical wireless system consists of PC or laptop interface card with an attached antenna and optional accessories for additional connectivity to wired Ethernet networks. Most wireless systems operate at data rates up to 1 Mbps. The range of the system depends on the vendor and varies from 125 feet on the low end to 1000 feet for high-end systems. Like their wired counterparts, wireless networks include software drivers for the devices on the network.

The Home RF Working Group is emerging as the defining standards body for in-home wireless networks. This group has specified operation in the 2.4 GHz band. Some vendors, however, are

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offering systems that operate at either 900 MHz or 2.4 GHz. In addition, another industry group called Bluetooth is developing a competing specification for low-cost, short-range radio links between mobile PCs, mobile phones, cameras, portable headsets and speakers, and other portable devices.

The Protocols that Make the System Work

The Home RF Working Group (HRFWG) has specified a Shared Wireless Access Protocol (SWAP), which is based on parts of the IEEE 802.11 standard for wireless networks. SWAP is a networking protocol that has provision for mixing asynchronous, high-demand packet traffic with isochronous, high-quality voice traffic. Theoretically, this will make it possible to connect cordless phones and wireless headsets to the same in-home network as data devices.

The main difference between Ethernet and SWAP is at the lower levels of the SWAP protocol stacks, where SWAP has modified the contention mechanism and the way it acknowledges packets. Both changes were designed to minimize the probability of packet collisions. To higher-level protocols, SWAP devices will look like Ethernet adapters, which provides interoperability with applications that work with Ethernet.

The HRFWG is working on ways to increase the data rate to 10 Mbps within the existing 2.4 GHz band, while retaining backwards compatibility with the original specification.

Computer Software for Home Networks

To make an in-home network operational, it is necessary to install software at devices that will be connected to the network.[10] This discussion assumes the devices on the network use a version of the Microsoft Windows operating system.

Fortunately, Microsoft Windows 95 and all the Windows software that came after it have a “plug and play” feature that automatically recognizes that a new hardware component, such as a network interface card, has been added to the system. This feature removes the need to configure many basic parameters, such as port type, IRQs, and DMAs.[11] However, certain communications software and drivers must still be configured for the specific network attached to the device. These unique parameters are often the reasons why a laptop computer that works on one network, such as an office LAN, cannot simply be plugged into a second network, such as the in-home network used in a work-at-home office.

10 In general, network software must be installed at any device that has an operating system. This excludes most printers, for example, since they are peripherals to other devices, such as desktop computers. The peripheral, however, can still be a resource to other devices on the network, but only through the device to which it is a peripheral.

11 IRQ is part of the computer’s interrupt priority during task execution by the operating system. DMA stands for Direct Memory Access. Both are discussed in detail in *DigiPoints* Volume II, Issue 3, “Practical High-Speed Data Installation.”

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Configuration Steps from the Network Window of the Windows Control Panel

Clicking on the Network icon in the Windows control panel causes a Network window to be displayed. The window should have three tabs: Configuration, Identification, and Access Control. (See Figure 9.) Sometimes, the Identification and Access Control tabs will not be present. If this is the case, the File and Printer Sharing service has not been enabled and must be added by clicking on the Add and Services buttons, and following the prompts to add file and printer sharing.

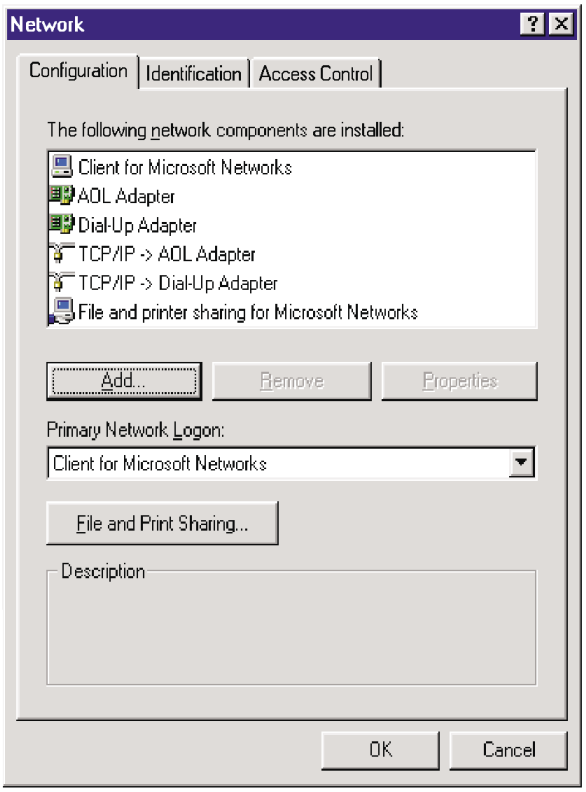

Figure 9: Windows 95 Image of Network Window

The Configuration tab in the Network window contains a list that should include the adapter for the Network Interface Card that is installed, and the TCP/IP protocol. Again, if these items are not listed, they will need to be added by clicking on the appropriate Add button and following the prompts.

The last item in the list of network components should be file and printer sharing. Clicking the button titled File and Print Sharing leads to a screen that lets users check whether either or both files and printers on their machines can be shared. Enabling sharing will allow all devices on the in-home network and others on a connected network to have access to any files on the device

being configured. Access can be limited to users with an appropriate password by clicking on the Access Control tab of the Network window and so indicating.

The Identification tab of the Network window contains the mechanisms for setting parameters that most likely have not been automatically set, but must be enabled for the device to function on an in-home or other network. Specifically, a unique computer name must be selected and entered for the device, and the device must be assigned to the workgroup that correlates to the network.[12]

Configuration Steps from the "My Computer" Window of the Windows Desktop

Although at this point, the person configuring the device has indicated files and printers can be shared, it is still necessary to indicate which drives and printers will be shared. Clicking on the My Computer icon in the Desktop causes icons of each drive and a Printers icon to be displayed. Right clicking on the appropriate icon causes a pop-up menu to be displayed that includes a Properties item. Clicking on Properties displays a window that has a Shared tab. Within this tab, the options for sharing the selected drive or printer can be chosen.

Configuration Steps from the Start Button of the Windows Desktop

In the case of printers, each printer on the network must be installed as a network printer. This is done the same way as adding any printer in Windows, by clicking on the Start button and choosing Settings, Printers, and Add Printer. The method of printer attachment must be chosen as "Network printer."

In-Home Network Vendors

The following list is a summary of in-home network products on the market, as of 4Q99. It is not intended to be a complete list nor an endorsement of any vendor's product or technology. Rather, it is provided so that cable telecommunications personnel can recognize various networking products and associate the product with its underlying technology when they are found in subscriber homes.

12 Workgroup, like computer name, can be arbitrarily chosen by the person configuring the network. However, all devices on the network must be assigned to the same workgroup name.

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Electric Line-Based Products	
Intelogis	
PassPort Plug-In	350 Kbps
Phone Line-Based Products	
Compaq Computer	
Compaq Home Phoneline Networking	1 Mbps
Intel	
AnyPoint Home Network	1 Mbps
Wireless Products	
WebGear	
AviPRO Wireless Network–2.4 GHz	2 Mbps, 1000 feet between nodes
Aviator Wireless Networking Kit–900 MHz	1 Mbps, 125 feet between nodes
Aviator 2.4–2.4 GHz	2 Mbps, 1000 feet between nodes
ShareWave Inc.	
2.4 GHz	
Proxim	
Symphony–2.4 GHz	1.6 Mbps, 150 feet between nodes

Connection to the Internet

One of the main reasons consumers want to have an in-home network is to share the modem connection to the Internet. While sharing is indeed possible, it is important to understand exactly what is being shared. At a minimum, all the in-home network configurations we have discussed can allow any device on the network to access an Internet connection. Not all the configurations easily allow access via a cable modem without additional hardware. Some of the devices allow multiple users to access simultaneously. Even with simultaneous access for multiple users, the ability to perform certain functions may be limited by the accounting restrictions of the Internet Service Provider. This section discusses some of the constraints in shared access to the Internet connection.

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Simultaneous Multi-User Access to the Internet

In order to have simultaneous multiple-user access to the Internet, each device on the network must be associated with an internet address. This association can either be through a translation from a private address known only to the system, through a permanently assigned public Internet address, or through an Internet address that is dynamically assigned with each connection. The individual hardware and software configurations determine which method is used.

A network that includes a router, for example, can theoretically have public Internet addresses permanently associated with each device on the network. Because public Internet addresses under Internet Protocol version 4.0 are relatively limited, this method is generally not used. Instead, Internet addresses can be leased to devices using the DHCP protocol, if the router is configured as a DHCP server. Several hubs also have DHCP capability.

Intel's AnyPoint Home Network provides simultaneous Internet access for each device connected to the network without a router or hub. This is accomplished by its proprietary AnyPoint Internet Sharing Software. Several proxy server software packages that can be loaded onto a PC are also available to manage Internet address assignment on a network.

Even when multiple, simultaneous user access is possible, certain services of various ISPs may not be available to all the users at the same time. For example, America On-Line allows multiple access to the Internet, but will only let one account log-on to features specific to AOL at any given time. For example, two or more users on the in-home network could simultaneously browse the Internet, but the only AOL e-mail that could be retrieved would be for the name used for the log-on.

Cable operators must seriously consider the implications of allowing simultaneous connections from one user site to the Internet, due to the possibility of high traffic that could congest the network. An extreme example would be a residential subscriber in a multi-dwelling unit who decided to become an ISP for the building over an in-home network.

Connection via a Telephony Modem

This type of connection is the most versatile in that it is based upon a totally separate, dial-up access with minimum possibility of conflicting networks. All of the technologies we have discussed allow users to connect via a dial-up connection to the Internet. The limitation, of course, is the modem and line speed of the dial-up connection. While devices on the in-home network will be able to exchange data at full network speed, communication with the Internet will be limited to the access speed of the modem and the telephone line.

Telephony modem connections are not necessarily limited to the traditional phone company. Several cable operators are offering circuit-switched cable telephony service, in addition to high-speed data service. The possibility exists that a subscriber may elect to connect to the Internet via a dial-up connection (although this would probably be the exception rather than the rule for a subscriber who has invested in a high-speed in-home network).

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Connection via a Cable Modem

In general, the limitation in connecting an in-home network to the Internet is that most network software only allows a device to connect to one network. Since in-home networks are generally based on variations of Ethernet, communications software may treat the cable modem connection and the in-home network connection as two separate networks and, therefore, not allow both at the same time.

The technology used by vendors in the Home Phone Network Alliance has been designed to work with a cable modem. On the other hand, 10BaseT networks will require a router or bridge between the cable modem and the rest of the in-home network.

In-Home Network Access to the Internet Via a Cable Telephony System

There are two scenarios in the evolving cable telephony environment where a subscriber's telephony equipment could be interfaced with an in-home network to provide outside network and Internet access. Historically, the first type of system provides access to circuit-switched telephony and also has provision for data access. The second type, which is in early trials and introductions in 2000, is an IP telephony system. Because the IP telephony system is essentially a form of high-speed data access using a DOCSIS-compliant cable modem, we will not separately discuss this solution to Internet access. All the considerations mentioned in the discussion on connection to the Internet via cable-modem access apply to an IP telephony system. This discussion will focus on the unique considerations that pertain to connecting an in-home network via a circuit-switched cable telephony system.

Two vendors of circuit-switched cable telephony systems, Tellabs and ADC, currently offer a high-speed data access option. Technologically, other vendors could modify their products to offer a similar option, if their view of the market justifies the effort. The key point of the system architecture is the ability to perform three functions: 1) dedicate a part of the bandwidth going to the subscriber as data bandwidth, 2) recognize that part of the bandwidth at the Host Digital Terminal (HDT) as dedicated to data, and 3) route information on that part of the bandwidth to data access equipment rather than to the circuit switch.

The Tellabs architecture as shown in Figure 10 illustrates the concept. The network interface at the subscriber residence (the RISU) is equipped with an optional data module. At the headend, the CableSpan Element Management System provisions data bandwidth to a given number of timeslots to the particular subscriber as dedicated to the data module in the RISU. This can be varied from 128 Kbps to 2 Mbps. At the HDT, data packets are sent directly to the data network

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without going through the local telephony switch. The subscriber's voice telephony service is not affected by the dedicated data bandwidth.

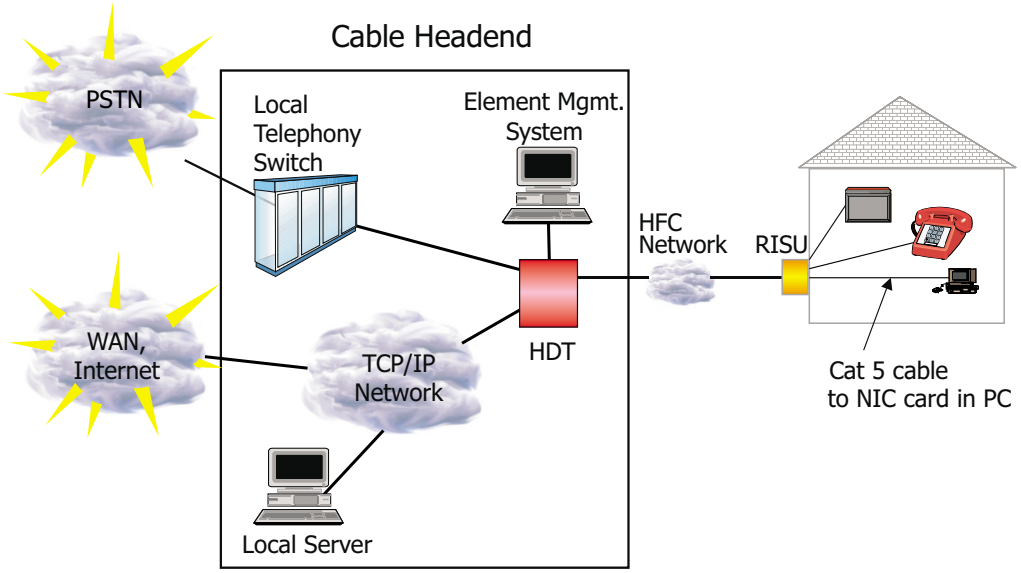

Figure 10: Tellabs CableSpan®/EXPRESS/path™ Architecture

The subscriber equipment interfaces to the in-home network via standard network interface cards for a 10BaseT Ethernet. Communication options in the software on the associated hardware devices are set for whatever network parameters are specified by the remote network. In essence, the in-home network becomes a part of the remote network, rather than being seen as a separate Ethernet network. This eliminates the problem of end devices not being able to be members of two networks at the same time. If more than one device is on the in-home network, a hub or router is the common connection.

When data is sent in the timeslots designated for data, equipment in the HDT automatically recognizes that the particular information is to be routed to a data router or other data network access rather than to the digital switch.

Note that, unlike the connection of an in-home network to a cable modem, this type of solution for an in-home network requires the connection to the subscriber RISU to be made from a hub, rather than from one of the devices on the network. Simultaneous access to the remote data network by multiple devices is possible, if devices on the in-home network are assigned separate internet addresses. One way of doing this is to use the Dynamic Host Configuration Protocol (DHCP) that was discussed earlier.

Two main differences exist between this architecture and one that provides access via a cable modem. First, bandwidth is limited to the total number of channels from the RISU to the headend, rather than having a full 10 Mbps. In the Tellabs system, this limitation is 2 Mbps. Second, at the headend, the termination is the Host Digital Terminal rather than a Cable Modem Termination System.

Answers to Typical Questions from Subscribers about In-Home Network Connections to a Cable System

Q "I have a home network that provides shared internet access via a telephone modem. Now that I have cable modem service, all I need to do is unplug the telephone modem and hook my network to the cable modem—right?"

A *Not quite. You need to check that your in-home network uses technology that is compatible with a cable modem. In particular, a 10BaseT Ethernet network may not be able to work with a cable modem without adding a router to the in-home network to avoid the appearance of one device on two Ethernet networks.*

Q "I want to be able to browse the internet at the same time my daughter is browsing the internet. Can I do this with one cable modem?"

A *Only if both your machine and your daughter's machine have unique internet addresses. This can be accomplished through a device on the network that assigns addresses dynamically using DHCP.*

Q "Now that I am connecting to a high-speed data service from the cable company that you advertise at 10 Mbps, will I be able to download files at this speed at all the devices on my network?"

A *No, because the speed of your network limits the actual download speed at the device. For the computer that is directly connected to your cable modem, you will see the maximum download speed specified by the cable operator. (That download speed is a function of the MAN—Metropolitan Area Network—provided by the cable operator and is subject to its specification of how much bandwidth it will guarantee. The cable modem configuration file can set the maximum data rate allowed to the subscription level the customer has requested.) All other devices on the in-home network will be limited by the speed limitations of the connecting network.*

Q "I have some phone jacks that are never used. It seems that I could just disconnect them from the phone wiring and use them for wiring an Ethernet network."

A *That depends on the wiring to those jacks and the speed of your network. Although standard phone wiring can be used for an Ethernet 10BaseT network, Category 5 Unshielded Twisted Pair is needed for a 100BaseT (100 Mbps) Ethernet. In addition, existing phone wiring may be non-standard, or improperly wired. In some cases, it may be adequate for simple voice applications, but it would not be capable of service on even a 10BaseT network.*

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Q "I have a system that uses adapters plugged into the electric line to give me extra phone jacks without rewiring. Can this work with an in-home network?"

A *This depends on the type of in-home network. Mixing electric and phone distribution for other applications for a network that uses the electric or phone wiring media is not recommended. An Ethernet network may be OK.*

Q "My printer has an Ethernet port. Can it be used with my in-home network?"

A *This depends on the type of network. Most likely, a 10BaseT Ethernet network will be compatible. The power line- and phone line-based systems, however, generally require the network connection to be via a parallel port.*

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Correcting Some Basic Field Problems: Troubleshooting

It has been said that once you open the subscriber's PC, you "own" its problems and the responsibility for troubleshooting. Likewise, once you connect a cable system to a subscriber's in-home network, you will be getting questions that are unrelated to the installation. From a practical customer service standpoint, an operator is wise to be aware of the answers to some common problems and, as part of the service, provide simple troubleshooting assistance. The following are some common problems that may surface in an in-home network.

Problem: "My printer communicates fine with the rest of the network in the evening, but during the day, I can't access it at all."

Solution: *If the media for the in-home network is the electric power distribution for the home, a light switch may be turned off, interrupting continuity between devices in the network.*

Problem: "The network works fine when plugged into one outlet in the room, but when I use another outlet, I can't talk to all the devices on the network from one of my PCs. The funny thing is that I can communicate with the same devices from another room."

Solution: *Check the topology of the medium used for the in-home network. Electric or phone outlets may be in separate branches. With the electric or phone service disconnected, the installer can check for continuity between outlets using a tone device.*

Problem: "My printer doesn't respond to print requests, but the Zip drive works just fine."

Solution: *Most phone line- and electric line-based systems do not support the "pass-through" options for Zip drives on a parallel port. The user needs to dedicate a parallel port to the network connection. This can be done by either adding a second parallel port to the computer, or by interfacing the Zip drive to the computer via an SCSI interface, freeing the existing parallel port. Another possibility is to use an A/B switch, which allows the user to select either the Zip drive or the printer.*

Problem: "I can't print to a particular printer on the network."

Solution: *The host computer for the printer needs to be turned on, and printer sharing must be enabled, for both that host computer and for the particular printer.*

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Summary

In-home networks are rapidly gaining consumer acceptance as a way to share computer resources and provide communication between consumer devices. Existing home wiring, either the phone line or the electrical system, can be used as a medium for an in-home network, although there are distance and bandwidth limitations. Dedicated, new wiring can also be used, but it often requires extensive effort to place the medium within walls, conduit, under floors, or above ceilings. Wireless solutions are evolving that provide a dedicated media without the need for media placement. Most of the in-home network protocols are derived from the 802.3 Ethernet standard and are compatible with 802.3 networks.

In general, devices can only be members of one 802.3 network at a time, and each device on the network must have an internet address. Some in-home networks have made provision within the protocol to recognize a cable modem connection as different from a regular 802.3 node, therefore allowing a device to be on both the cable network and the 802.3 network. The problem may also be solved by software that provides a bridge between networks. Internet address allocation is managed by software solutions such as Dynamic Host Configuration Protocol (DHCP).

Although sharing Internet access between devices on the network is a prime motivation for implementing an in-home network, simultaneous access may be limited by the Internet Service Provider or the network operator. Control of network traffic is one reason an operator may limit access to one device at a time; however, economics are often a factor. The operator or service provider may charge extra for the ability to have more than one device at a time on-line to the Internet.

Cable technical personnel provide valuable services to the operator by being able to answer typical subscriber questions about the interface of in-home networks to the cable operator network. Often, troubleshooting will be a matter of understanding the normal operation of various in-home network solutions and explaining that operation to the subscriber.

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Learning Just Enough to Be Dangerous: Glossary

Bluetooth—An industry group that is developing a specification for wireless links between mobile PCs, mobile phones, cameras, portable headsets and speakers, and other consumer devices.

Category 5—A rating for a type of unshielded twisted pair cable that can be used in 100 Mbps Ethernet networks.

CEBus—EIA standard for Consumer Electronic Bus. Applications of CEBus include remote control of heating and lighting systems.

CTP—Centralized Token Passing. Part of the MAC layer protocol used within the PLX protocol.

DHCP—Dynamic Host Configuration Protocol. A protocol that defines a way to dynamically assign (lease) internet addresses to devices on a network for pre-specified time periods.

DPL—Digital Power Line Protocol used in Intelogis PassPort Plug-In Network.

DSMA—Datagram Sensing Multiple Access. Part of the MAC layer protocol used within the PLX protocol.

EIA—Electronic Industries Association.

Home PNA—Home Phone Network Alliance. Group of vendors that has developed specifications for interoperable home-networked devices using in-place phone wiring.

HRFWG—Home RF Working Group. An industry group that is developing a 2.4 GHz wireless specification for home networking.

PHY—Physical layer of the Home PNA protocol.

PLX—Power Line Exchange Protocol used in Intelogis PassPort Plug-In Network.

RJ-11—Standard jack for telephony applications.

RJ-45—Standard jack for data applications.

TIA—Telecommunications Industry Association.

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Testing Your Knowledge

1. What are some characteristics of existing wiring systems that make them less than optimal for data distribution?

2. What is the designation for the unshielded twisted pair wiring that is specified for 100 Mbps Ethernet applications?

3. What are the two grades of residential information outlets recommended by TIA/EIA 570A, and what types of information do they accommodate?

4. What are the major differences between an RJ-11 jack and an RJ-45 jack?

5. What can be different between otherwise identical RJ-45 jacks?

6. How do in-home networks using existing phone wiring co-exist with voice telephone service?

7. What are the two contending standards for wireless networks?

8. What are two constraints that might limit simultaneous Internet access by multiple network devices?

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Answers to Questions in Issue 3-6

1. What transmission methods are used to transport EPG data to set-top terminals?
   EPG data may be carried in-band in the vertical blanking interval (VBI) of an analog channel or on an RF data carrier called an out-of-band carrier.

2. What are the competing standards for carrying EPG data in MPEG-2 digital video?
   In the United States, the Advanced Television Systems Committee (ATSC) standard is used, entitled ATSC A/65 Program and System Information Protocol (PSIP) for Terrestrial Broadcast and Cable. *In Europe, the DVB specification is used.*

3. What standards govern the carriage of EPG data in NTSC analog video?
   The standard that governs EPG data carried in the VBI is an extension to the Vertical Blanking Interval data standard, EIA-608A, and it is called EIA-752.

4. Name two vendors of EPG application software.
   StarSight Telecast and PreVue Interactive.

5. Name three vendors of TV scheduling data.
   TVData, Tribune Media Services and PreVue Interactive.

6. How does an EPG control a VCR?
   The EPG transmits control signals to the VCR via a tethered IR transmitter connected to the set-top terminal. VCR control codes are downloaded to the set-top from the headend.

7. Explain MPEG-2 Program Specific Information (PSI) Sectioning and Versioning.
   In MPEG-2 PSI data streams, sectioning information is used to improve error resilience; if a data packet is lost from a long table, the corrupted packet doesn't disturb the entire table, potentially causing the receiver to wait for the beginning of the table and restart the data decoding process. The versioning information allows the receiver to be notified that the data being transmitted has been changed (it has a new version number).

8. What is Huffman coding?
   Huffman coding is a method of data compression that assigns shorter codes for the characters that appear more frequently. This compression technique approaches a 2:1 compression efficiency over straight ASCII coding.

9. What determines how far forward in time an EPG can look?
   The amount of RAM memory available in the set-top.

10. What features typify an "Intelligent" EPG?
    Advanced sorting methods that anticipate a viewer's interest, "Timeshifting" via integration with a digital VCR and integration with other software applications such as internet browsers.

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