

# Home Networking

## Definition

Home networking is the collection of elements that process, manage, transport, and store information, enabling the connection and integration of multiple computing, control, monitoring, and communication devices in the home.

## Overview

Until recently, the home network has been largely ignored. However, the rapid proliferation of personal computers (PCs) and the Internet in U.S. homes, advancements in telecommunications technology, and progress in the development of smart devices have increasingly emphasized the last 100 feet of any consumer-related network (i.e., the American home).

Furthermore, as these growth and advancement trends continue, the need for simple, flexible, and reliable home networks will greatly increase. This tutorial addresses the market drivers, the current and future technologies, and the standards (or lack thereof) relative to home networking and the homenetworkingenvironment.

## Topics

1. Market Drivers
2. Wired Home-Networking Technologies
3. Wireless Home-Networking Technologies
4. The Future
5. Home-Networking Standards and Specifications

Self-Test

Correct Answers

Glossary

# 1. Market Drivers

According to Yankee Group estimates, over 30 percent of PC-owning U.S. households are interested in the concept of home networking. Several trends, however, contribute to the growing need and the potential success or failure of home-networking solutions.

## The Changing Face of the Workplace

The Internet elicits many changes in the workplace. These changes, in turn, create a growing need for home networks. Driven by a changing corporate culture, cost-cutting measures, and clean-air acts that demand less travel to and from work, many employers have implemented telecommuting practices. To implement these practices, information technology (IT) managers must not only connect telecommuters to the corporate local-area network (LAN) and intranet but provide voice solutions as well. To conduct business properly, telecommuters must access files and stored network information and therefore require a high-quality, secure voice network able to sustain multiple lines. According to Telecommuting America, between 1995 and 1997 the number of home-based telecommuters grew more than 30 percent to 11.1 million. That number increased another 40 percent to 15.7 million in 1998. If such trends continue, the need for reliable home-network solutions will increase even further.

Also experiencing growth are small businesses, many of which begin in the home. According to Forrester Research, more than 13 million households—12.6 percent of all U.S. residences—contain a business. Projections indicate that 14 percent of U.S. homes will include some type of home business by the year 2003. These start-ups need small-business solutions that work well in a home environment.

## PC-Based Households

Yankee Group research indicates that 43.1 million or 44 percent of U.S. households now have a PC. Of these, 9.4 million have two PCs, and 3 million have three or more. The percent of households with PCs is projected to grow to 54 percent in 2001, with the portion of multi-PC households growing to 24.5 percent.

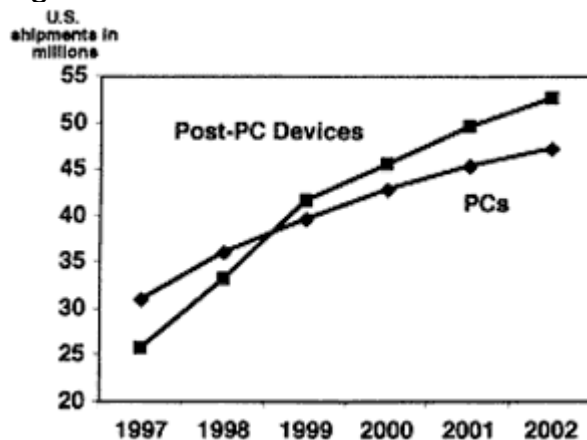
Multi-PC penetration is driven by a number of factors. The widespread availability of PCs for less than \$1,000 and the increasing number of home offices and individuals who bring work home contribute to the trend. Many analysts believe that these factors will drive the number of homes with PCs even higher than current forecasts. Such analysts also believe that multi-PC penetration rates will grow more rapidly than overall PC adoption.

In addition, demand for Internet access in the home continues to climb. According to the Yankee Group, 22 percent of U.S. households subscribe to an on-line service or an Internet service provider (ISP). Many of these households also purchase additional PCs and telephone lines dedicated to Internet access.

## Managing Smart Devices

The American home is also changing. Now in the process of development is an increasing number of smart devices that allow users to control and monitor events in consumer-based appliances, home electronics, and home-security systems. Indeed, 1999 will be the first year that non-PC central processing unit (CPU)-powered devices such as computer games, phones, personal digital assistants, set top boxes, and other consumer goods will surpass PCs in number of units shipped (see *Figure 1*).

Figure 1. Post-PC Devices



As these devices become more common, the need will increase for a home-networking strategy that will allow all data, voice, and smart devices to be accessed at any time from anywhere.

## Simplicity and Reliability Are Essential

Whatever the trends, the key market drivers for home networking are simplicity and reliability. If the process is not maintenance-free, easy to use, and quick to install, it will not likely be embraced. While consumers desire the sophisticated functionality of an LAN—voice networking, shared Internet access, and smart device control—they do not wish to engineer or administer a complex system. They want plug-and-play functionality, believing that only experts require technological know-how and that—much like telephones—PCs should just work.

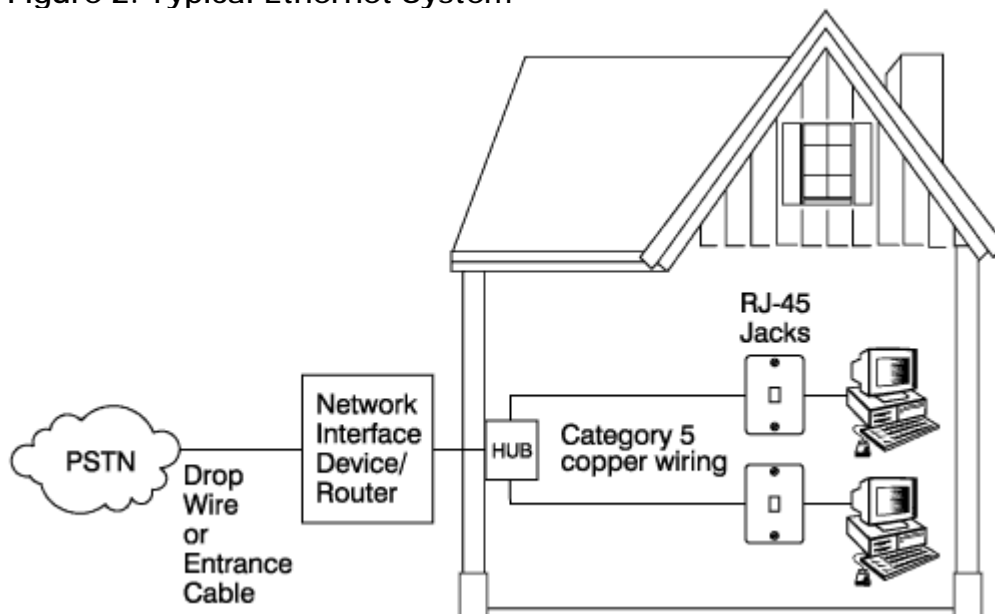
## 2. Wired Home-Networking Technologies

These early networks are bulky, largely point-to-point loop- or star-based systems. For the most part, those with any robust capacity are tethered systems limiting the mobility and flexibility of their users.

### Twisted Copper-Pair or Coaxial-Based Transport Systems (Ethernet)

The typical topology of these systems is demonstrated in *Figure 2*.

Figure 2. Typical Ethernet System

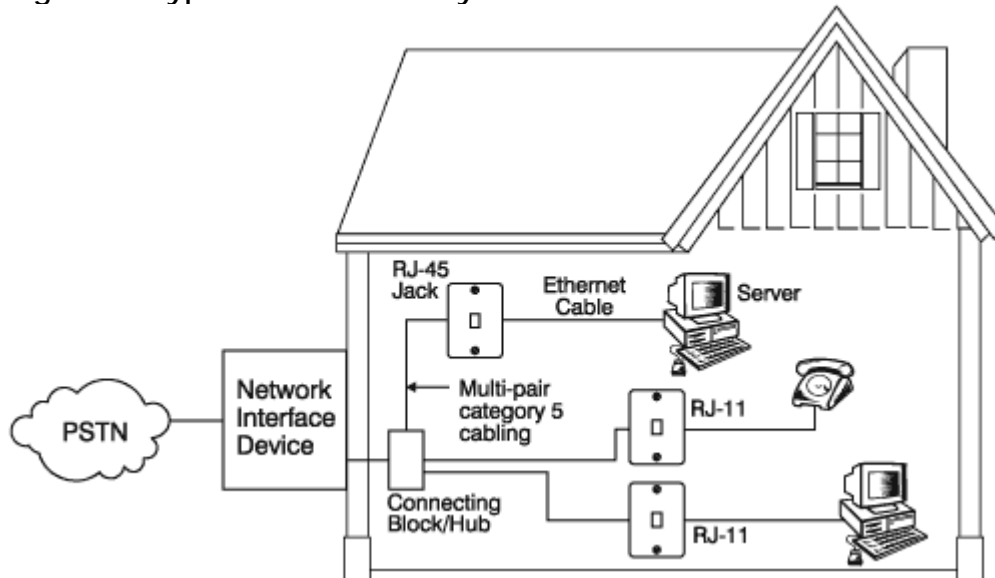


This technology is based on the Institute of Electrical and Electronic Engineers (IEEE) 802.3 standard, which has undergone many revisions since its conception to enable interoperability between many manufacturers. Copper-pair or coaxial-based transport systems are bi-directional, typically have a high degree of reliability, and are thus widespread among businesses as the standard choice for networking office PCs and printers. They require the use of bulky Category 5 (CAT5) cabling, and are typically expensive to install. Some home networks have Ethernet, but because of its expense and difficulty to install, few have chosen to use it.

## Twisted Copper-Pair-Based Systems (Phone Line)

The typical topology of these systems is demonstrated in *Figure 3*.

Figure 3. Typical Phone Line System



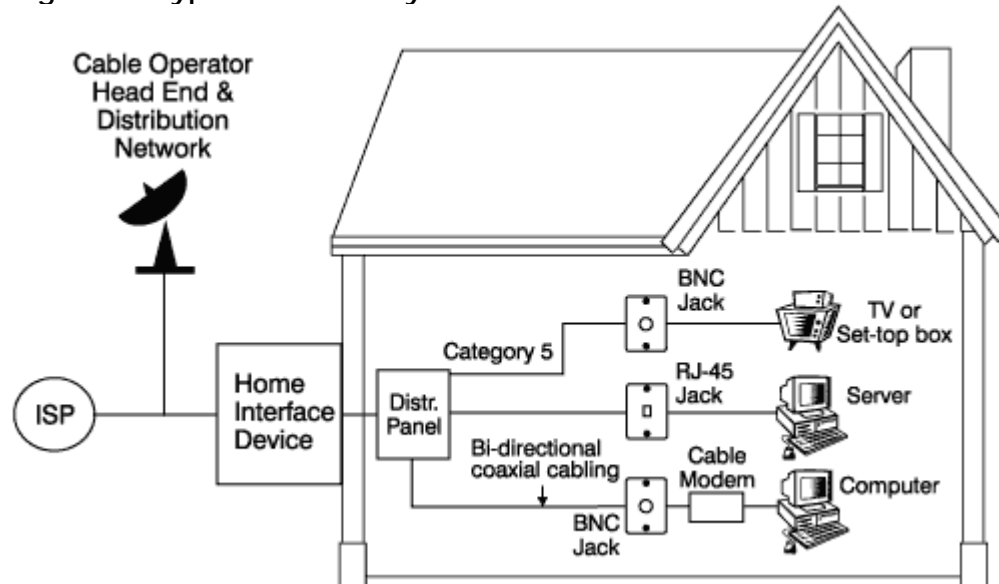
This technology uses the existing phone wiring found in most homes today. In some cases, CAT3 wire elements transport at a data rate of 1 Mbps, and many speculate that it will support up to 10 Mbps in the near future. This technology claims to work simultaneously with regular phone service, without attracting the user's notice. The Home Phone Network Alliance (HomePNA) is one organization dedicated to the development of standards and specifications for interoperable, home-networked devices that use existing twisted-pair phone wiring. Although solid progress has been made toward enhancing the usefulness of this embedded asset, inflexibility and capacity limitations will limit its success. A typical home does not contain many RJ-11 jacks; they are rarely in every room or in the location where access by additional phones, computers, and other devices is required.

In addition, selection of signal characteristics for data transport over this medium is critical to resist interference from other shared devices. These devices include answering machines, fax machines, modems, telephone sets, and other data-transport devices such as the integrated services digital network (ISDN) and digital subscriber line (xDSL) equipment that use the twisted pair simultaneously.

## Two-Way Coaxial Cable–Based Transport Systems (Broadband)

The typical topology of these systems is demonstrated in *Figure 4*.

Figure 4. Typical Coaxial System



This technology uses the same type of coaxial cable that is used by cable TV. It provides a reliable medium for data transport and has long-distance capability. Typically used by cable operators to send data into the home, it terminates near the television and is thus an uncommon means of distributing data through the home.

Selected suppliers of bi-directional coaxial cable–based systems do, however, use coaxial cable to distribute data through the home. One such supplier is Canada Ltd., which offers IBM Info-Structure Wiring™ components. IBM Info-Structure Wiring components consist of three CAT5 and two RG–6 coaxial cables. These start at the basement of a home at a distribution panel similar to the electrical box, connecting the services into a home and routing or directing them to several locations throughout the home. Each location in the home that connects to these services has an info-port. The info-port allows four telephone connections: one connection for a data network within the home and an extra outlet for future fiber-optic cable, distributed cable TV, and distributed satellite services.

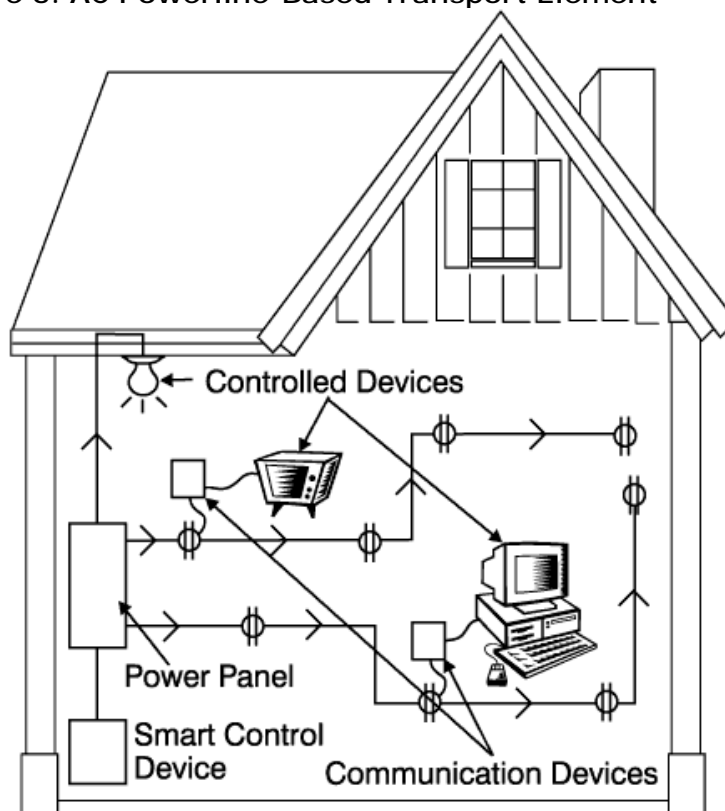
In order for the IBM system to allow PC–to–PC networking, a combination of coaxial cable and twisted pair are used. There are no systems that allow for PC–to–PC communications using only coaxial cable.

These home-network transport systems require preplanning with homeowners, builders, or developers, because the systems are limited to network access by well-placed jack locations. Specific applications are best accommodated with a room-use plan before installation. Postinstallation upgrades for new access locations have limited success or flexibility without surface wiring and jack installation and add substantial additional expense.

## Alternating Current Powerline-Based Transport Element

The typical topology of these elements is demonstrated in *Figure 5*.

Figure 5. AC Powerline-Based Transport Element



Alternating current (AC) powerlines are readily available as network transport elements throughout a home. They are used as transport facilities to send and receive discrete frequency-based control, monitoring, and communications messages to smart devices that manage lighting and environmental systems ("turn off," "turn on," and "dim"). They also are used as voice-communication elements for telephone extensions, computer-modem access, and intercom devices through standard electrical outlets. Throughput for any application requiring higher data rates can be a challenge. In addition, no standards exist to ensure interoperability between manufacturers.

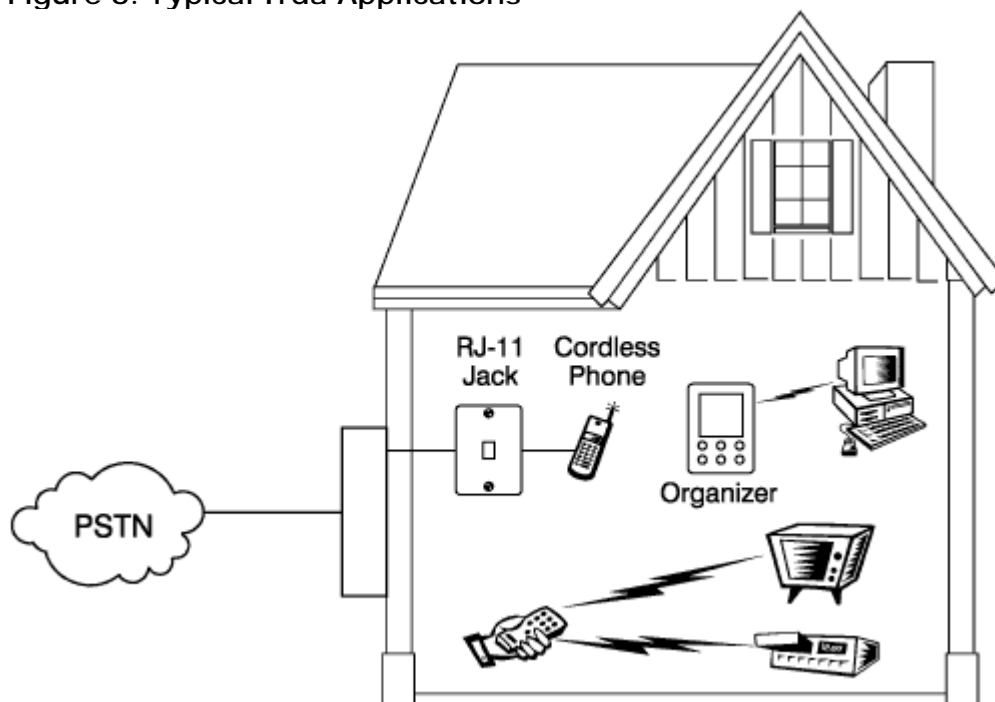
### 3. Wireless Home-Networking Technologies

To be truly wired, you must be wireless.  
—*Wired*, October 1997.

#### Wireless-Based Transport Element (Irda, Analog Cordless Phone)

The typical topology of these elements is demonstrated in *Figure 6*.

Figure 6. Typical Irda Applications



Traditional wireless home-networking technology is used for line-of-sight, infrared, unidirectional, hand-held controller applications. Typical uses today are for VCRs, TVs, and some security and alarm applications. The other obvious wireless technology is the cordless phone. However, neither can be definitively classified as a robust home-network element. The cordless phone still requires the twisted copper pair and a jack as an access point, and today's infrared applications rarely leave the confines of the home.



## Wireless-Based Transport Element (Radio Frequency)

Currently, there are several standards and working groups focused on wireless networking technology (radio frequency [RF]). These include the IEEE 802.11, HomeRF, Bluetooth, and standard wireless access protocol (SWAP). Wireless-based transport element technology can be used to distribute multiple types of information within the home. Some examples use a discrete controller device, some a PC as a controller device, and others no controller device at all (i.e., peer to peer). Wireless RF transmission is the recognized home-networking topology of choice for the emerging network-centric home as a result of its flexibility, mobility, and ability to network without wired connections.

### The RF Transport Network Element

Most emerging home-networking wireless systems utilize spread-spectrum technology. This technology offers high bandwidth capacity and is used widely in the military, as it is secure and reliable. Two types of spread-spectrum radios are in common use today: frequency-hopping spread-spectrum (FHSS) and direct-sequence spread-spectrum (DSSS) radios. These radios will not interoperate, as a result of different frequency bands and vendor systems. System selection is critical, and once the user engages a supplier, it is difficult to transfer to another—even in those cases where industry standards are in effect. De facto or proprietary standards reign.

FHSS is a narrowband carrier with changing patterns of transmission that are recognized by both receivers and transmitters. When the two devices are in synch, they produce one logical communications channel.

DSSS produces bit patterns called chips or chipping codes. Reliability is based on the length of the chipping code or on how many bits of data it carries. Because an error-correcting function is built into radios, it is often not necessary to retransmit data, thus improving performance.

### PC or Non-PC-Based Wireless Systems

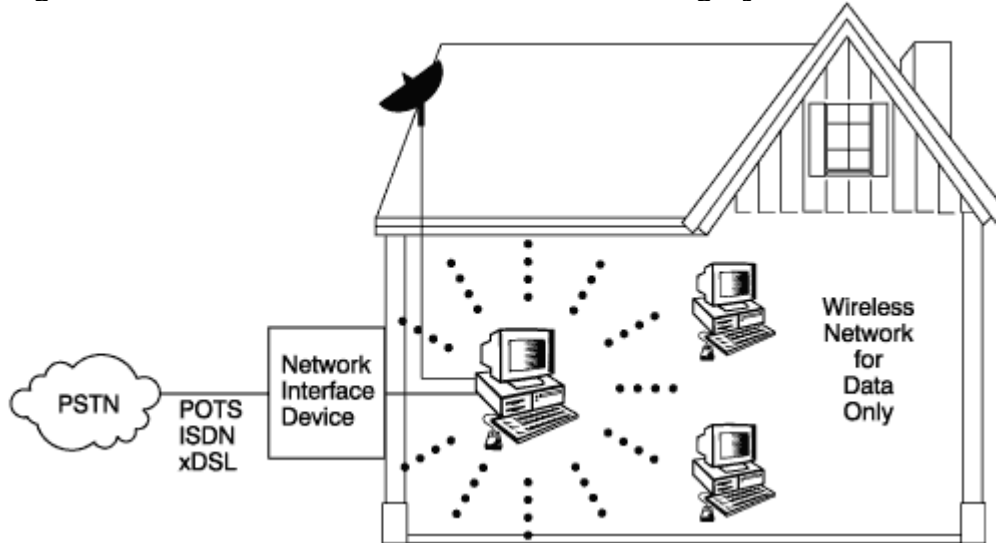
System suppliers use several approaches, two of which are detailed in this tutorial: a PC-centric, data-only application and a data and voice home-networking application.

#### The PC-Centric, Data-Only Network

Some software and hardware suppliers provide home-networking solutions via a wireless LAN, using the home's PC as the central control element. *Figure 7*

reflects a wireless home LAN configuration in which one PC acts as a master to the network. It provides network addressing and routing between the home and the Internet.

Figure 7. PC-Based Wireless Home Networking System



This straightforward approach simply marries familiar PC technology to new home-networking technology. It also represents some consumer-marketplace challenges to ultimate mass-market success.

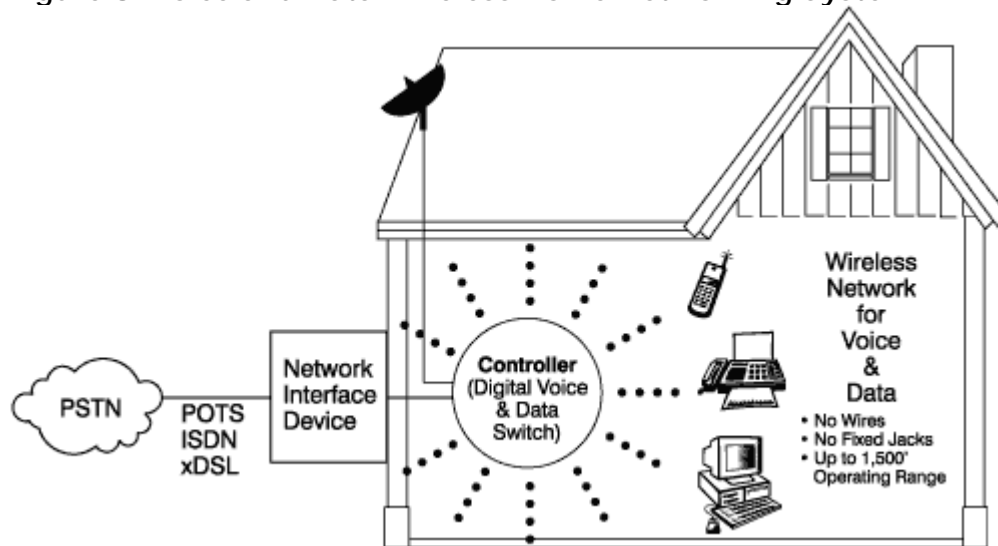
First, a home network built around a master PC implies that the PC will always be on and available for communications. It also implies that no other software or hardware application running on the PC can interfere with its ability to perform its communications tasks. Consumers are somewhat forgiving of PCs that have fatal errors and must be rebooted. They generally do not forgive their communications-network failures, because they expect the network to function smoothly at all times—as it historically has.

Second, a home network built around a master PC only addresses the PC-related network elements in the home such as file and printer sharing, multiuser game playing, and a single shared ISP account. It leaves the other elements such as voice communications and control and monitoring applications without a solution.

## The Controller-Based Data and Voice Home Network

*Figure 8* demonstrates the use of one integrated home-network system available on the market today.

Figure 8. Voice and Data Wireless Home Networking System



In this scenario, the microprocessor-based digital switch acts as the communications server, addressing and routing voice data traffic throughout the home. It also sends the home network–transport element through a powerful on-board RF transceiver. The transceiver is based on patented digital spread-spectrum technology and has an effective reach of several hundred feet from the home.

The controller shown in *Figure 8* supplies a robust home network for voice and data with high bandwidth capacity. It is the bridge between the transport network element serving the home from the customer-selected service provider and the wireless home network. Networked devices require no wires or fixed wired jacks. This system also offers several hundred feet of accessibility within and outside the home. There are no relocation restrictions. Data and voice services, including internal device-to-device communications, are commonplace.

There are four distinct functional areas served by a controller-based, data and voice home-network system:

- **home local-area network**—Networking capabilities provide the home-network user an easy-to-install LAN between all PCs within the home. This allows sharing of computer files, printers, and disk drives and supports multiplayer PC games via a wireless Ethernet and a transmission control protocol (TCP)/Internet protocol (IP) LAN.
- **Internet gateway**—The controller provides an Internet gateway addressing and routing function for sharing a single ISP account and connection with all PCs. All surf the Internet at the same time on only one 56-kbps, 128-kbps, or faster account, with only one monthly charge.

- **wireless voice networking**—Each wireless handset can view and manage up to four plain old telephone service (POTS) lines while the PCs are simultaneously being used on the LAN. The handset displays allow users to access caller ID and voice-messaging status information and make decisions about call management in real time.
- **traditional wireline POTS networking**—All telephone lines serving a home terminate on the controller. They are then distributed to wireless handsets or to wireless RJ-11 phone jacks with built-in transceivers to which standard telephones, fax machines, or modem-equipped PCs can be connected.

The non-PC-based switching center (the controller in *Figure 8*) is software derived so that new networking requirements in the home can be met without wholesale changes. Future developments for home networking are outlined in the next module.

## 4. The Future

The American home is the center of a convergence of competing technologies, architectures, and suppliers, each with a unique set of advantages and solutions. Systems are being researched, developed, and deployed to manage, monitor, and control the following list of functions:

- data and voice communication needs internal and external to the home
- electronic entertainment devices
- service appliances that prepare food
- service appliances that maintain the home appearance
- systems and devices that maintain the in-home environment
- devices that keep the home secure from intrusion or damage from internal and external man-made or natural events

Successful home-network system providers must develop capabilities that are upward compatible. A central controller (the brain, microprocessor, switcher, or data storage device) to capture home-network events and react in conditioned or learned responses is essential to future product innovation.

The home-network transport medium of the future will be wireless, as is dictated by the homeowner's need for flexibility, the moving continuum of product

development, and the high cost and sheer inconvenience of wire-based installations.

In addition, consumers will require a system that manages everything within the home, including voice, data, and appliances. Wireless technology will provide necessary convenience, simplicity, and long-term cost savings.

## 5. Home-Networking Standards and Specifications

Standards, whether established by standards bodies or leading system suppliers as de facto standards, will play an increasing role in system development.

Many different formats for standards and specifications are emerging in home networking, including the following:

- **IEEE 802.11 wireless LAN**—The IEEE 802.11 standard defines the protocol for two types of networks: ad hoc and client/server networks. An ad hoc network is a simple network in which communications are established between multiple stations in a given coverage area without the use of an access point or server. The standard specifies the etiquette that each station must observe so that all stations have fair access to the wireless media. It provides methods for arbitrating requests to use the media to ensure that throughput is maximized for all users in the base service set. The client/server network uses an access point that controls the allocation of transmit time for all stations and allows mobile stations to roam from cell to cell. The access point is used to handle traffic from the mobile radio to the wired or wireless backbone of the client/server network. This arrangement allows for point coordination of all of the stations in the basic service area and ensures proper handling of the data traffic. The access point routes data between wireless stations or to and from the network server (<http://www.wlana.com>).
- **a 2.4 GHz band using a relaxed IEEE 802.11 standard and digital European cordless telephone standard**
- **Bluetooth**—Bluetooth radio technology provides a universal bridge to existing data networks, a peripheral interface, and a mechanism to form small private ad hoc groupings of connected devices away from fixed network infrastructures. Designed to operate in a noisy RF environment, the Bluetooth radio uses a fast-acknowledgment and frequency-hopping scheme to make the link robust. Bluetooth radio modules avoid interference from other signals by hopping to a new

frequency after transmitting or receiving a packet (<http://www.bluetooth.com>).

- **SWAP 1.0**—The SWAP system can operate either as an ad hoc network or as a managed network under the control of a connection point. In an ad hoc network, where only data communication is supported, all stations are equal, and control of the network is distributed between the stations. For time-critical communications such as interactive voice, a connection point is required to coordinate the system. The connection point, which provides the gateway to the PSTN, can be connected to a PC via a standard interface such as universal serial bus (USB) that will enable enhanced voice and data services. The SWAP also can use the connection point to support power management for prolonged battery life by scheduling device wakeup and polling (<http://www.homerf.com>).
- **X10**—This is a communications protocol for remote control of electrical devices and communications over standard household AC powerline wiring (off, on, and dim functions).
- **IEEE 1394**—This is a serial interface for short-range, low-data-rate, infrared communications between entertainment and computer devices.
- **Home Phonline Networking Association (HomePNA)**—Home phonline–networking technologies must tolerate completely random and unspecified wiring topologies. They must also be designed to take into consideration the unknown but typically large degree of signal attenuation that occurs within the random tree network topology. A transmitted pulse is attenuated and scattered on the wires as it bounces around inside the wiring. The longer the pulse travels through the wire mesh inside the house, the more it attenuates and dissipates. Home phonline–networking technologies require high and varying levels of signal noise and must tolerate dynamically changing transmission line characteristics, while coexisting with telephone service and complying with Federal Communications Commission (FCC) Part 68. Lastly, they must maximize data throughput given the above constraints and limitations (<http://www.homepna.org>).
- **HWN SSERQ/AAWG**—Superspread equilateral reservation queueing (SSERQ) protocol is optimized for wireless transport of voice, data, and multimedia services. Its packet-reservation scheme provides the high QoS and access priority required for voice and multimedia services. Wideband, common-channel signaling permits rapid setup and takedown of virtual private circuits for high-speed intranet traffic and Internet access. SSERQ supports IEEE–802.11 infrastructure-

mode (client/server) networking via the air-to-air (air-squared) wireless gateway, which provides translation, supervision, and transport between 802.11 and SSERQ networks (<http://www.homewireless.com>).

## Self-Test

1. What are the forces driving the growth of home networking?
  - a. the growth of second telephone lines in homes
  - b. the need for modems to access the Internet
  - c. the explosive growth of the Internet
  - d. the growth of PCs
  - e. all of the above
2. Which of the following represent the key functions of the combined elements in a typical home network?
  - a. processing
  - b. managing
  - c. transporting
  - d. storing
  - e. all of the above
3. What is the key to home networking success in the mass marketplace?
  - a. packaging and point of service (POS) promotions
  - b. style of equipment and color
  - c. no wires and no wired jacks
  - d. simplicity and reliability
4. Which of the following does not fit the definition of a wired home-network transport element?
  - a. coaxial cable system

- b. twisted-pair category 3- and 5-based systems
  - c. AC powerline-based system
  - d. RF transmission-based system
5. Which wireless home-networking systems are most effective?
- a. wireless and wired systems
  - b. voice- and data-integrated home networks
  - c. PC-centric wireless LAN networks
  - d. voice-based networks
6. Which of the following statements best describe the development of home
- a. There are no common standards. Several interest groups are publishing de-facto standards to meet their own self-interests.
  - b. The IEEE 802.11 standard provides a common and well-accepted standard around which all manufacturers develop.
  - c. If a standard is published and several manufacturers produce accordingly, then all devices will interoperate.
  - d. Home-networking standards are well developed and accepted.
7. Wired home-networking transport elements are flexible for users and, for developers, inexpensive and easy to implement.
- a. true
  - b. false
8. Most home-based coaxial cable systems in the installed base are bi-directional transport systems.
- a. true
  - b. false
9. What is the function of the network controller discussed in this tutorial?
- a. the network server for multiple PCs
  - b. a digital switch for voice traffic to PSTN



- c. a digital switch for voice traffic internal to the home
  - d. a gateway to the Internet for all PCs in the home
  - e. a multiline gateway for all incoming enhanced voice services
  - f. all of the above
10. All but which of the following are characteristics of DTM as a content-server network?
- a. Significant progress is being made to turn twisted pair into a robust home-networking transport element.
  - b. Wired systems require a substantial amount of preplanning for a home network.
  - c. To be truly wired, you must be wireless.
  - d. AC powerline systems are widely used for voice and data communications.

## Correct Answers

1. What are the forces driving the growth of home networking?
- a. the growth of second telephone lines in homes
  - b. the need for modems to access the Internet
  - c. the explosive growth of the Internet
  - d. the growth of PCs
  - e. all of the above**
2. Which of the following represent the key functions of the combined elements in a typical home network?
- a. processing
  - b. managing
  - c. transporting
  - d. storing

**e. all of the above**

3. What is the key to home networking success in the mass marketplace?
  - a. packaging and point of service (POS) promotions
  - b. style of equipment and color
  - c. no wires and no wired jacks
  - d. simplicity and reliability**
  
4. Which of the following does not fit the definition of a wired home-network transport element?
  - a. coaxial cable system
  - b. twisted-pair category 3- and 5-based systems
  - c. AC powerline-based system
  - d. RF transmission-based system**
  
5. Which wireless home-networking systems are most effective?
  - a. wireless and wired systems
  - b. voice- and data-integrated home networks**
  - c. PC-centric wireless LAN networks
  - d. voice-based networks
  
6. Which of the following statements best describe the development of home networking?
  - a. There are no common standards. Several interest groups are publishing de-facto standards to meet their own self-interests.**
  - b. The IEEE 802.11 standard provides a common and well-accepted standard around which all manufacturers develop.
  - c. If a standard is published and several manufacturers produce accordingly, then all devices will interoperate.
  - d. Home-networking standards are well developed and accepted.

7. Wired home-networking transport elements are flexible for users and, for developers, inexpensive and easy to implement.
- a. true
  - b. false**
8. Most home-based coaxial cable systems in the installed base are bi-directional transport systems.
- a. true**
  - b. false
9. What is the function of the network controller discussed in this tutorial?
- a. the network server for multiple PCs
  - b. a digital switch for voice traffic to PSTN
  - c. a digital switch for voice traffic internal to the home
  - d. a gateway to the Internet for all PCs in the home
  - e. a multiline gateway for all incoming enhanced voice services
  - f. all of the above**
10. All but which of the following are characteristics of DTM as a content-server network?
- a. Significant progress is being made to turn twisted pair into a robust home-networking transport element.**
  - b. Wired systems require a substantial amount of preplanning for a home network.
  - c. To be truly wired, you must be wireless.
  - d. AC powerline systems are widely used for voice and data communications.

## Glossary

### CAT5

#### Category 5

**CATV**

community antenna television or cable television

**CPU**

central processing unit

**DSSS**

direct sequence spread spectrum

**FCC**

Federal Communications Commission

**FHSS**

frequency hopping spread spectrum

**HLAN**

home local-area network

**IEEE**

Institute of Electrical and Electronic Engineers

**ISP**

Internet service provider

**IT**

information technology

**LAN**

local-area network

**PC**

personal computer

**POP**

point of presence

**POS**

point of service

**POTS**

plain old telephone service

**RF**

radio frequency

**SWAP**

shared wireless access protocol

**TCP/IP**

transmission control protocol/Internet protocol

**USB**

universal serial bus

**VCR**

video cassette recorder