THE HOME PHONELINE NETWORKING ALLIANCE

SIMPLE, HIGH-SPEED ETHERNET TECHNOLOGY FOR THE HOME

A WHITE PAPER
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EXECUTIVE SUMMARY

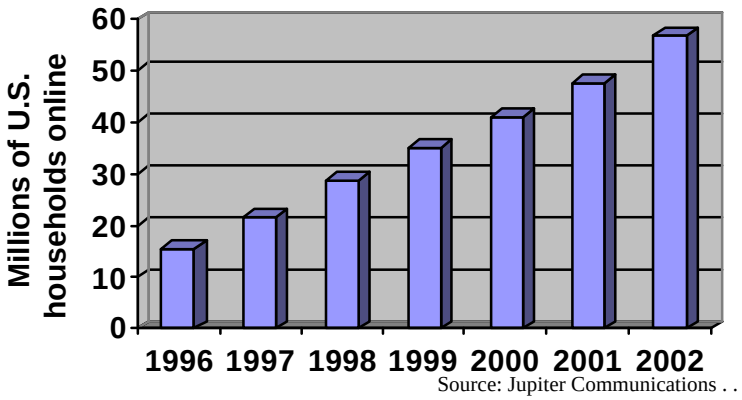
A new segment of the networking marketplace is poised for rapid growth: home networking. As with any networking technology, standards are important to ensure interoperability between various equipment manufacturers and reduce consumer concerns about obsolescence and compatibility. The Home Phoneline Networking Alliance (HomePNA) was formed to develop specifications for interoperable, home-networked devices using the already in place phone wiring. The paper introduces how and why the home networking marketplace is emerging and outlines the requirements for a consumer-friendly home network. The challenges of networking within the home are discussed and we describe how the current 1 Mbit/s technology overcomes these challenges and enables simple and robust home networks. Finally, the paper discusses emerging applications for the home network that drive the need for phoneline networks that operate at 10 Mbit/s and beyond.

OVERVIEW

The personal computer has become a powerful platform in the home for work, communication, education, and entertainment. Almost overnight, the Internet has exploded into an essential means of information access. Many new digital appliances are on the horizon that will exploit communication of voice and video across digital networks. Just as there is a critical need for high-speed connections to information and broadband entertainment sources *outside* the home, there is a growing need to rapidly move this digital data between devices *within* the home. Businesses accomplish this by deploying Local Area Networks (LANs); however, networks are not commonly deployed in the home due to the cost and complexity of installing the new wiring required by traditional LANs. The Home Phoneline Networking Alliance (HomePNA) specification will enable simple, high-speed, and cost-effective home networks using the consumer's existing phoneline.

The driving force behind the need for home connectivity products is the growth of on-line households (Figure 1) and the growing number of homes with two or more PCs. More than 47 percent of US households are likely to have Internet access devices by 2002, with some 20 percent of this subset owning multiple devices that need to share access to the Internet as well as each other.[1]

Figure 1: U.S. Online Households



Source: Jupiter Communications . .

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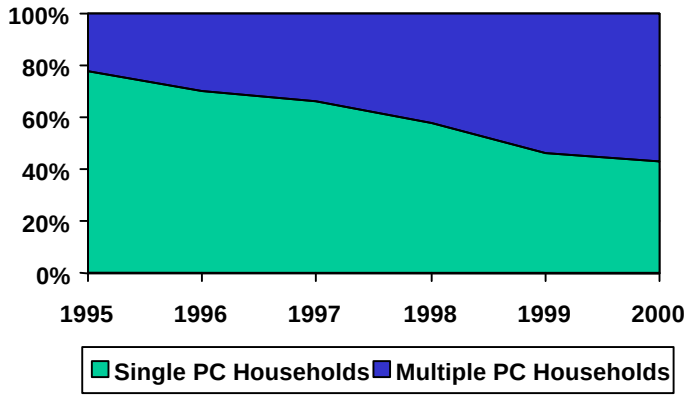
With the increased focus on computers in education and the boom in Internet connectivity, a large number of PCs being purchased today are additional PCs, as opposed to replacement units. Today, it is estimated that over 15 million of the nearly 100 million homes in the United States have two or more PCs. This number is growing 30 percent annually.[2] In fact, the number of multi-PC homes is growing faster than the number of single PC homes (Figure 2).

[1] Source: Jupiter Communications . . .
[2] Source: Jupiter Communications . . .

Figure 2: Drop in First Time PC Buyers, Multiple PC Households Growing



Source: Jupiter Communications . .

Already, close to one-third of US households (about 30 million according to Census statistics) have Internet access devices including PCs, set-top boxes, game consoles, and Internet screen-phones. By the year 2002, 15.3 million households will depend on their in-home networking connections to enable communications between multiple PCs and other electronic devices.[3] Growth in these multiple-PC households accessing the Internet creates a fertile market for equipment to network those multiple PCs. The following key applications drive demand for home networked devices:

- Internet Sharing

  Sharing simultaneous access to the Internet is a major driving factor for home networking. Today, when multiple home users want to enjoy Internet access without constraint, separate telephone lines and Internet accounts are required. Since this is costly, multiple users are typically restricted to using the Internet one individual at a time. Home networks can deliver significant savings and greater utility by enabling shared access to a single Internet connection. The need for this shared access will grow as today's 28.8K, 33.6K, and 56K analog connections are replaced by higher-speed "always-on" connections such as Universal ADSL, cable modem, or satellite. Standardizing on a high-speed local-area home network interface insulates installed home networked devices from changes in Internet access technologies.

- Peripheral Sharing

  Today, in a home with multiple PCs, each computer needs a duplicate set of peripherals, such as printers or scanners. With a home network, the limited budget can optimize for one higher-end shared peripheral rather than many low performance units. With a

[3] Source: Jupiter Communications . . .

network standard for the home, future peripherals can be designed to connect directly to the network, simplifying installation.

- File and Application Sharing

  Multiple users can easily share applications, move files, or back up data, saving time and money. Automatic software updates are enabled by a network connection.

Other applications enabled by the home network:

- Entertainment

  Easy-to-use home networks will also enable popular multi-player network games, either within the home or over the Internet.

- Home Automation

  A ubiquitous, easy-to-install home network will also foster home automation applications, such as environmental control and security systems.

- Voice and Video over IP

  New digital voice and video services are being introduced into the home. All these digital services—whether data, voice, or video—need to be accessible anywhere in the home by any device. All digital devices, including PCs, digital televisions, and digital telephones, will require a high-speed connection to the home network.

IN-HOME NETWORK REQUIREMENTS

Success in the consumer market requires that a home networking technology be inexpensive, easy to install, and easy to use. To be truly effective and embraced by consumers, a home networking solution must meet these criteria:

HOME NETWORK CRITERIA	HomePNA SOLUTION
No new wiring. Most existing homes are not wired for traditional networking equipment. Rewiring the home is too expensive and a hassle for most consumers.	Leverage existing infrastructure provided by phone wire inside the home. Every RJ-11 modular phone jack in the home can also become a port on the network as well as a phone extension.
Simple to install and use	The HomePNA's technology uses the same Windows® NDIS driver model used by existing Ethernet cards. True Plug-and-Play operation, supported in both Microsoft® Windows® 95 and Windows 98 operating systems, frees users from having to deal with any complex software settings.
Must be low cost to allow the mass market to enjoy the benefits of home networking	With new highly integrated silicon, Home Phoneline network interface cards (NICs) can be manufactured to sell below $100, or simply be integrated onto the PC, printer, or Internet appliance.
The range must be adequate to operate within a typical home.	With the first release, the HomePNA's technology operates at distances of at least 500 feet between nodes. Based on typical home wiring analysis, this represents a home of up to 10,000 square feet.
Support high speed data rates	The HomePNA's first specification adopts Tut's HomeRUN technology at 1 Mbit/s data rates. A backwards compatible next generation specification targeting data rates of 10 Mbit/s and beyond is being proposed by Epigram to the HomePNA.
The networking capability must grow with user applications without obsoleting existing devices.	The HomePNA's technology is scalable to higher speeds and functionality, while being backward compatible.
The network must be secure. The network data must remain private; it must not be accessible to neighbors or anyone outside the home.	Home phoneline wiring is not shared with neighboring residences so data privacy is assured.

In addition, home phoneline networking solutions will require the home-networked devices to share the phoneline with other existing devices and services. This places two additional key requirements on any home networking technology that uses the phoneline as the medium of communication:

PHONELINE NETWORK CRITERIA	HomePNA SOLUTION
The technology must be immune to interference on the phoneline. Within a home, there may be a number of phones, answering machines, and other devices that might cause electronic interference.	Frequency ranges used by the HomePNA products are carefully chosen to avoid interference from the various sources of interference found in the home.
Phoneline networking must not interrupt existing phone services, such as voice/fax, ISDN, or xDSL services.	The adopted technologies will not compromise or interrupt existing telephone, ISDN, or xDSL services in any way. Frequency division multiplexing (FDM) is used to simultaneously handle existing and emerging telephone services along with networked data traffic.

THE HOMEPNA SOLUTION: HOME NETWORKING OVER PHONE WIRES

The Home Phoneline Networking Alliance (HomePNA) was formed with the objective of quickly creating a *de facto* standard and widely available in-home networking solution, which leverages the existing phoneline. The HomePNA's goals are to endorse an initial available technology at 1Mbit/s that meets all of the above criteria and to rapidly deliver on a roadmap to higher performance and functionality that is backward compatible with the existing 1Mbit/s solution. This technology promises to bring the power of networking to home users for the first time in a way that is inexpensive and easy-to-use.

Creating a technology that can deliver high-speed networking over phoneline is not without its challenges. The 10 Mbit/s Ethernet technology found in the corporate office environment was specified from the outset to use CAT3/CAT5 twisted pair cabling specially designed for data transmission. Homes in North America have a wide range of existing wiring, not originally intended to transmit data. Implementing low-cost, high-speed data access over a home's existing, random-topology phoneline has offered network engineers a challenging puzzle that has gone unsolved for nearly a decade. Now the availability of low-cost, high-performance signal processing in silicon makes it possible to achieve robust, high-speed communications over the vast amount of in-place phone wiring.

Home phoneline networking presents the following challenges:

- Must tolerate completely random and unspecified wiring topologies. The telephone wiring structure within each home is unknown and even changes on a day to day basis. For example, a simple action like plugging in a telephone or fax machine will add a "branch" onto the phone-line wiring "tree."
- Must be designed to take into consideration the unknown but typically large degree of signal attenuation which 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. This effect is compounded by impedance mismatches and lack of termination (for example, a phone jack with nothing plugged in).
- Must be able to tolerate high and varying levels of signal noise. Appliances, heaters, air conditioners, consumer appliances, and telephones all add random and varying levels of signal noise onto the phone wires.
- Must be able to tolerate the dynamically changing transmission line characteristics. Telephones and other phoneline devices have a wide range of dynamically changing operating characteristics which, if the network is not properly designed, can interfere with data transmission. The simple act of a user picking up a telephone can dramatically change the data transmission characteristics of the phone wiring. Conversely, without care, data transmissions might interfere with the proper operation of telephones and fax machines.
- Must be able to coexist with telephone service and comply with FCC Part 68. Phoneline network solutions are constrained to use signals with low energy levels, which further complicates the task of establishing adequate signal-to-noise ratios.
- And, finally, must maximize data throughput given the above constraints and limitations.

Figure 3 below shows how a user might set up a network of devices within a home. Note the phoneline "network" is a random tree structure.

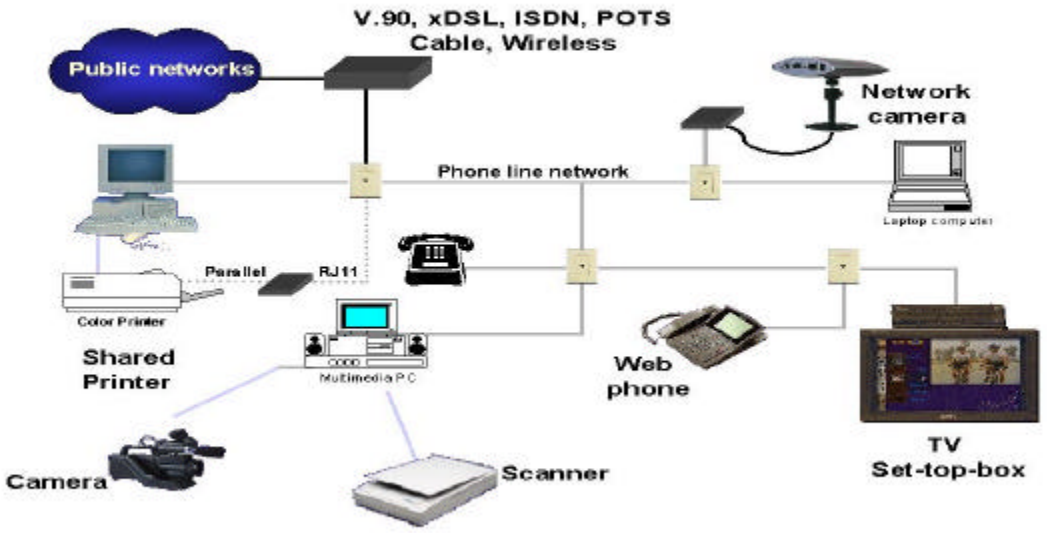


Figure 3: Possible Home Network Diagram

Home phoneline networking is complementary to other home networking media such as powerline networking and RF wireless. Phoneline home networks can act as a high-speed backbone for powerline networked devices, RF cordless devices, and devices clustered around USB or P1394. Phoneline networking is unique in that it uses the same connection as the most prevalent Internet access method today, the voice band modem, and its broadband successor, Universal ADSL.

SPECTRAL COMPATIBILITY

An added requirement for home phoneline networking is the simultaneous operation of normal telephone service and the home networking function over the same phoneline. One of the most common methods for simultaneously operating multiple services over a single pair of wires is Frequency Division Multiplexing (FDM). With FDM, each communications service is assigned a frequency spectrum that is different from all others. Through the use of frequency-selective filters, devices using one type of service can exchange information without interference from other services that communicate in another frequency band.

The summary below illustrates the frequency ranges used for each type of service on the line:

- Standard voice occupies the range from 20 Hz to 3.4 kHz in the U.S. (slightly higher internationally)
- xDSL services, like Universal ADSL, occupy the frequency range from 25 kHz to 1.1 MHz
- Phoneline networking can operate in a frequency range above 2 MHz.

Figure 4 below depicts the spectral compatibility of the various types of services:

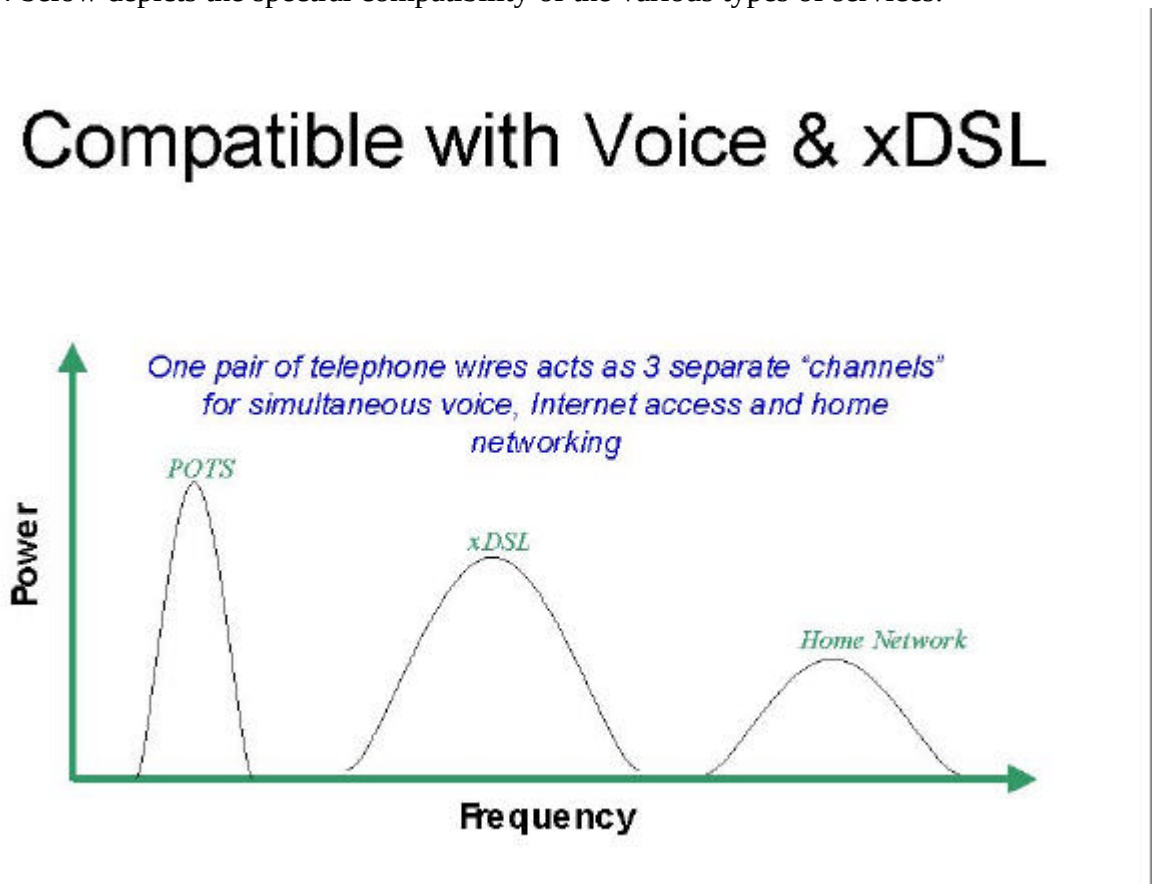


Figure 4: Compatibility between existing telephone services and home networking

This means a consumer can simultaneously be using the phone or sending a fax, using the home network, and accessing the Internet via an "always-on" Universal ADSL (UADSL) connection.

1 MBIT/S HOMEPNA SPECIFICATION: TUT TECHNOLOGY OVERVIEW

Like all phoneline networking technology candidates, the 1 Mbit/s technology specification from Tut Systems has been designed to ensure compatibility with other communications services within the home, such as voice, ISDN, and xDSL data services. Tut 1 Mbit/s technology occupies the passband frequency range between 5.5MHz and 9.5 MHz. Passband filters attenuate frequencies below 5.5MHz very rapidly, so there is no interference with other DSL services or traditional phones.

Tut 1 Mbit/s technology is implemented using straightforward IEEE 802.3 CSMA/CD (Carrier Sense Multiple Access/Collision Detect) methods for multiple access to a common communication's medium -- the foundation of Ethernet. In simple terms, it's a 1 Mbit/s Ethernet over phoneline. This is an important design criterion, since it allows the HomePNA network to

leverage the tremendous amount of Ethernet compatible software, applications, and existing hardware in the market today.

Transmitting data accurately over the random phoneline topology as detailed earlier is only part of the problem. To achieve high-speed data throughput, one must encode as much data as possible (instead of single pulse-bits) in each signal pulse. To accomplish this, multiple data bits are encoded into each pulse. Tut's unique and patented technology accomplishes this – delivering multiple bits in every pulse.

The core technology in the implementation is the Time Modulation Line Coding Method developed by Tut. This is the key to Tut's ability to transmit data on an arbitrary topology of un-terminated wires found in homes. Tut's patented line coding mechanism incorporates an adaptive circuit which, by design, has the ability to adapt to varying noise. Within each network interface, the receiver circuit adapts to varying noise levels that might appear on the line. In addition, the transmitting circuit can vary its level of output signal strength. Both transmit and receive circuits continually monitor line conditions and adjust their settings accordingly.

HOMEPNA ROADMAP: 10 MBIT/S AND HIGHER TECHNOLOGY

The PC is by far and away the most rapidly changing technology in our society. The pressure of new applications, combined with ever advancing silicon integration, has resulted in an incredible increase in PC performance and functionality. To keep up with the evolution of new PC applications, the HomePNA's roadmap for Home Networking recognizes the need for speed, while retaining backward compatibility with earlier specifications. The HomePNA intends to rapidly extend its initial 1 Mbit/sec technology, targeting an interoperable 10 Mbit/sec technology based on upcoming field tests of working implementations.

Application trends that lead to the need for 10 Mbit/sec and faster home networking are:

Application	**Impact on Home Network**
Higher speed Access services	xDSL from 1-8 Mbit/sec, cable modem bursts up to 30 Mbit/sec, multimegabit data services over satellite and DTV broadcast
Multi-user Games, PC-hosted TV games	Games evolve quickly to exploit technology, requiring more network bandwidth.
Digital Video Networking	Interconnection of digital TVs, digital broadcast receivers, PCs, and other video appliances. MPEG1/DBS video 1.5 Mbit/sec, DVD video 3-8 Mbit/sec, ultimately 19 Mbit/sec for HDTV. Connecting the PC to the TV will open an entire new space of applications.
Sub-$500 PCs, Remote Windows Terminals, Information Tablets	Increasing PC-PC traffic
Voice-over-IP Telephony, Videoconferencing, Internet Radio, Video Security, and Monitoring	Quality-of-Service support for multimedia streams

10 MBIT/S HOME PHONELINE SPECIFICATION: THE HOMEPNA'S NEXT GENERATION TECHNOLOGY

The achievable capacity over most existing premises' phone wiring can extend upwards to 100 Mbit/sec, using selective portions of the 2-30 MHz frequency band. Employing a spectrally efficient modulation technique that encodes up to 8 bits of data per symbol, founding member and technology contributor Epigram is proposing a next generation 10 Mbit/s and faster speed technology to the HomePNA.

The patent-pending Epigram technology defines a low-cost, scalable Home Ethernet network running at 10 Mbit/sec today, with the ability to increase to speeds approaching 100 Mbit/sec in the future – while maintaining backward compatibility across previous generations of HomePNA compatible equipment, including the HomePNA's 1 Mbit/sec specification.

Home Ethernet is dynamically rate adaptive, instantaneously adjusting to the changing electrical characteristics of the phoneline communication channel. Multiple generations of Home Ethernet can be accommodated simultaneously on the same phoneline. Home Ethernet also targets home network applications that require performance options for error control and multimedia Quality-of-Service. This highly flexible adaptivity makes high data rates robust in the face of "no-new-wires" impairments and scalable to present and future needs of real time multimedia applications in the home.

Home Ethernet can be integrated within a wide range of price-performance points and form factors, such as multi-mode modems, fully integrated Home Ethernet controller ICs, and core logic on system-on-chip VLSI. The HomePNA's vision is that products equipped with next generation HomePNA technology would include PCs, ADSL modems, cable modems, home gateways, digital TVs and set-top boxes, digital IP phones, digital IP radios, and other network appliances.

SUMMARY

Over the last two decades, we have seen the microprocessor incorporated as an essential component into almost every electronic device. Over the next decade, the "Network" will become an essential component alongside the microprocessor. Embedding the microprocessor didn't mean every electronic device was then used as a computer, and embedding the Network is not about turning everything into a Web browser – instead it is about enabling a wide range of smart products and compelling applications that will be enhanced by being able to access an unlimited amount of information.

The Phoneline Network technology put forward by the HomePNA is better suited for enabling ubiquitous networking than other solutions. The simplicity of use, coupled with the pervasiveness of existing home phone wiring, enables an immediate market for products with "Networking Inside." The HomePNA's Phoneline Networking solution is a robust, easy to use technology that can be cost-effectively integrated into every PC. This technology transforms the

voice dialtone that comes out of hundreds of millions of phone jacks into a powerful digital dialtone, capable of interconnecting every electronic device in the home with every network service in the world.

HOMEPNA WORKING PLAN

The HomePNA is being founded by a core group of companies to promote Phoneline Home Networking technologies. The HomePNA is open to all Adopters who wish to join in the effort to advance Home Networking.

The HomePNA is not a standards making body, but will work to accelerate standards in home networking by adopting specifications based on working implementations, by field testing the adopted technologies, by submitting specifications to the appropriate standards bodies, by establishing a Certification and Interoperability testing process, and by coordinating a Marketing and Education effort around Home Networking.

The first HomePNA Specification will be adopted soon after this announcement, and further Specifications will be advanced as implementations are brought to the field for testing. Products using equipment built to the HomePNA's Specifications are expected in the market by the end of this year (1998).

Please visit our web site at http://www.HomePNA.org for more information.