Home Networking

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Abstract

This report discusses keypoints and overviews in related home networking literature. After introduction, five specific technologies (LAN, Phoneline, Powerline, Wireless and IrDA) are reviewed. Services and other issues are also discussed. Finally there is an overview of current market players.

See also: Cable Data Networks | Residential Broadband: High-Speed Access to Home (Class Lecture by Prof. Jain) | High Speed Access From Home References | Books on Residential Broadband, xDSL and Cable Modems
Other Reports on Recent Advances in Networking
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1. INTRODUCTION

As more and more households become computerized and have mutliple computers, home networking has become a hot topic for both R&D and manufacturing community. Basically, home networking will involve the networking technologies, including protocol, connection and media technologies, for home computing devices. At present, it is mainly focused on the interconnection of home PCs and how to connect them to outside world - the Internet.

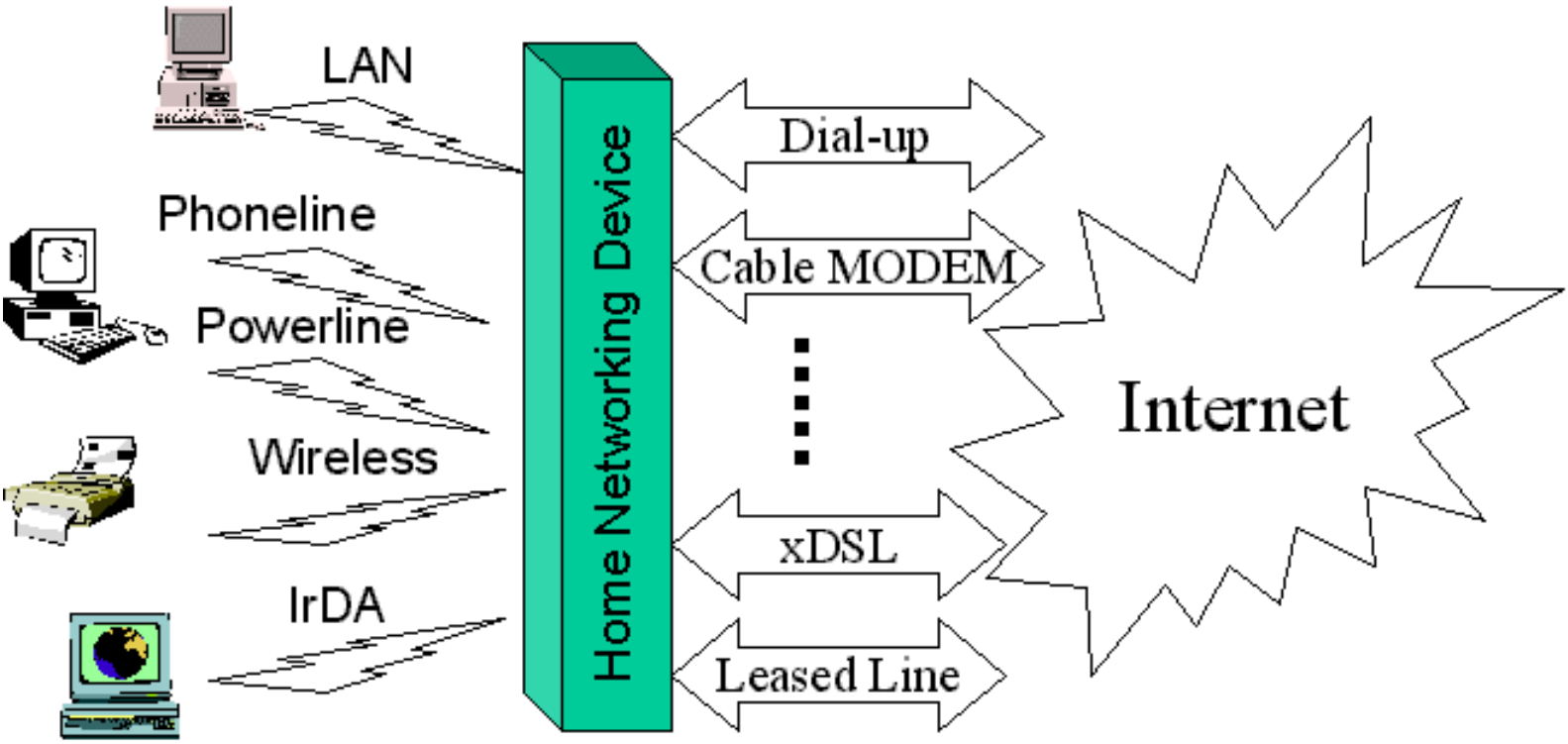

Figure 1 The Home Networking Scenario

There is a lot of literature on this hot topic. Here we will have a brief overview of keypoints summearized from these web pages, reports, news analyses and technical papers. First, we will go over the market and technology potential, then we will list the keypoints further in five possible networking technologies, traditional LAN, phoneline networking, powerline networking, wireless networking(including RF and wireless LAN) and infra-red digital access(IrDA). Then there is a discussion on the service and requirement issues for home networking. Finally an overview of current market players is given.

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2. MARKET AND TECHNOLOGY POTENTIALS

The year 1999 had been boasted as a year of home networking. In news analysis [1], the author found out the current market share of home PC is big, especially the multiple PC households. The industry estimates that the number of homes with more than one PC is at about 20 million. Also, the market to connect digital home applicances, together with home PCs, would be prominent in the analysts' view. How to connect them to share the computing resources, and how to connect them to share the Internet connection or ever further to the telecommunication? That is what for the market for home networking products and technologies. In the Intel and Dell's white papers [2] and [3], they also

list some figures and charts to show what would be the future market share and expected customer groups.

A home network can consist of multiple PCs and peripherals linking together by certain networking wires/wireless channels. It can be used for shared Internet access, peripheral sharing, and file and application sharing. Future visions of the home network also include consumer electronics devices such as televisions, VCRs, and CD players, as well as traditional home appliances such as a refrigerators, microwave ovens, washers and dryers, heating and air conditioning thermostats, home security systems, and home automation controls. Home automation and security functions can be implemented by linking consumer electronics, appliances, and system controls. For example, the television, VCR, stereo, and lights could be linked together and controlled from a PC or from several PCs connected to the network to form a surveillance system and can be expanded to an alarm system.

Currently, the near applications of home networking could be,

- Shared Simultaneous Internet Access - every home with a telephone line and serveral PCs could access the Internet at the same time through a single Internet account, one modem and one phone line.
- Printer/disk Sharing - PCs in any room could access the best printer/disk located anywhere in the house. Or they can share storage space on disks/CD-Roms located in other PCs or familiy server.
- File Sharing - everyone could share files from any PC in the home.
- Multiplayer Video Gaming - family members could participate in games designed for two or more players from two or more PCs in the house at the same time.

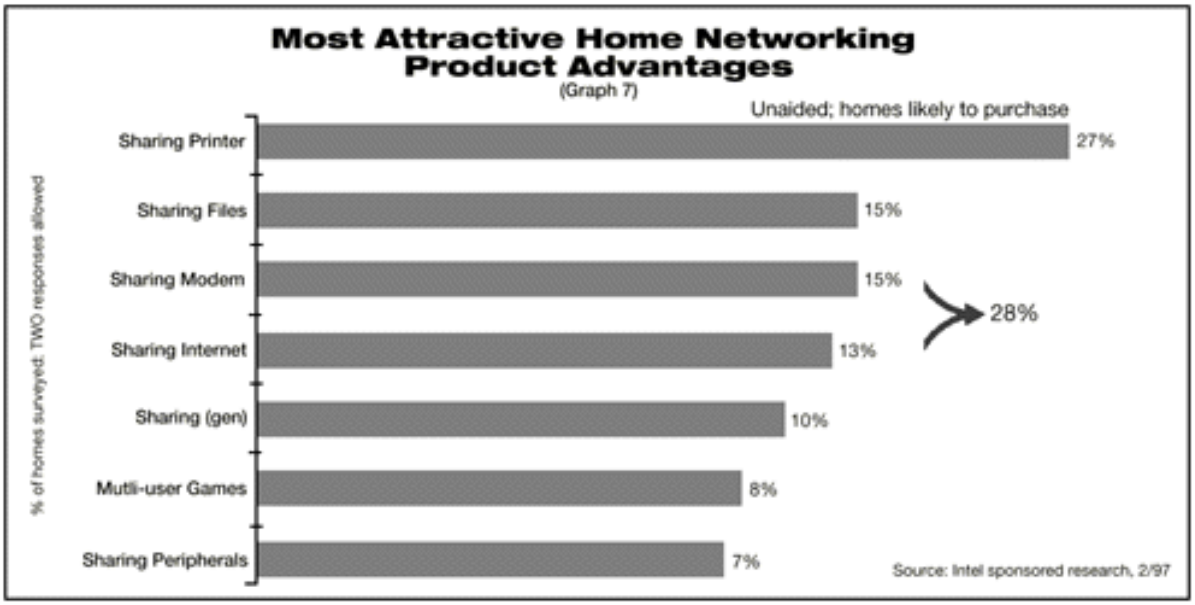

Figure 2 Home Networking Applications(Source: Intel's Anypoint Webpage)

In some industrial research articles [4], [5] and [6], the behavior of current home PC users and how they use their home PCs to connect to Internet are investigated. They also point out some potential problems in the future home networking market, like the cost-effectiveness, the possible security and data integrity holes. With the technologies' progress, the problem of scalability and interoperatibility is also very important.

Interoperability, Privacy, Regulation and Oligopoly, Reliability and Ubiquitous Marketing could all become the future obstacles in the way of makeing home networking the backbones of home computing. Meanwhile, the development of home-aware community information infrastructure is also very important. The history of the telephony has showed the early trends could easily mislead analysts and industry representatvies. So the detailed market and technologies potential should be clearly addressed before the future failure or loss.

Carnagie Mellon University has conducted a pioneerig research project called HomeNet [7], they have a trial residential Internet environment with different kinds of users, including both adults and teenagers. Now the project is

supervised by telerama.com, an ISP in Pittsburgh area. In that project, systematic data collection and user pattern analysis have been conducted. Also they made some demographical analysis for all future Internet usage in the typical American families. Their study reveals some interesting facts, like the teenagers are always the central to Internet use at home and motivate their parents invest and surf on the Internet. The race, gender and education do have some impact of the usage pattern. These study and facts would provide good background for future home networking development. Detailed report could be found in [7].

They also introduce a future vista of technology development directions. From the existed infrastructure like phoneline or powerline to wirless solutions like IrDA or Radio Freqency, there are some possible cost-effective solutions. Many pioneering vendors have done reasearch and development with some products. Also, some industrial organization or forums are formed or engaged to establish the standards, service and interoperability environment for these technologies. Typical organizations are Home Phone Networking Alliance, Home RF working group (www.homerf.org) and Home Applications Programming Interface(Home API) (www.homeapi.org) .

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3. Connectivity Technologies

In a typical today's home, there are some available power and telephony infrastructures. So the practical networking solutions will first try to utilize them. Based on current infrastructure, we can have traditional LAN, Phoneline and Powerline as the transmission media. If we go with the wireless solutions, we can have Wireless RF connectivity or Infra-red connectivity. On top of them, research and standardization communities also have tried to establish many transportation protocols, application level interfaces, and interoperability standards. Here we will present a short summary.

3.1 Traditional LAN

Traditional LAN refers to the LAN standards developed by IEEE 802 committees. The most important are Ethernet. Currently, with the price of Ethernet adapters/hubs falling, it becomes a good method to connect home PCs. There are many standards and discussion on this topic. But from technological prospects, they are matured.

As a well-established and extremely stable networking solution, Ethernet has long been used by businesses to link employees, systems, and network devices and forms a Local Area Network (LAN). Now, Ethernet is becoming popular in the home environment. The primary advantage of Ethernet is its reliability and reasonably high speed. At 10 to 100 megabits per second (Mbps), Ethernet is sufficient for most data networking needs. And the price of Ethernet devices is relatively reasonable. However, some issues have stagged its wide acceptance into home networking market. The first is separate wiring using Category 5 unshielded twist pair (Cat 5, UTP) which requires extra cost. And this networking technology is somewhat too complicated for a home networking. In near future, while Ethernet is still a very important connectivity solution in corporate networking, its market share in home networking is not significant.

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3.2 Phoneline

With the phoneline in a household, we can connect PCs and other devices using the digital modulation technology which is shared with the development of MODEM. Most available products are now running at 1Mbps which is regulated by Home Phoneline Networking Alliance (HomePNA), but some companies are now exploring 10Mbps

phoneline technologies (www.epigram.com). Lucent Technologies also has developed another 10Mb/s techonology. [8] Based on their proposals, the HomePNA group is now trying to establish the standard for the second generation phoneline technology according to the news press [9].

The existing twisted pair plain old telephony system (POTS) wiring in the home is probably the first home connectivity solution coming to our mind. Home Phoneline Networking Alliance (HomePNA) is the leader of development and standization efforts in this field. It is an industrial consortium of 11 companies working toward a single, unified telephone line networking standard. The HomePNA standardization effort is well ahead of the AC power-line and wireless/RF efforts. The first version of the specification has been submitted to standards bodies like IEEE and ITU-T for future acceptance. And the first generation of products based on this standard is also available, including internal PCI-based HomePNA adapter cards that connect to an external RJ11 jack. External HomePNA adapters that connect to the PC via a Universal Serial Bus (USB) or parallel port are also available soon.

The HomePNA 1.0 specification is generally based on the HomeRun technology developed by Tut Systems (www.tutsystem.com). It supports data rates of 1 Mbps over the existing in-home telephone wiring. Without extra wiring, it enables every RJ11 telephone jack to serve as LAN port. No hubs, routers, splitters, filters, or terminations are required for a network. HomeRun supports up to 25 nodes, with a maximum of 500 feet between devices. HomeRun operates concurrently with voice and fax service. Currently HomePNA is also developing a 10 Mbps specification which is said to be fully backward-compatible and interoperable with current 1-Mbps devices. It is based on Lucent and Epigram's proposals.

In whole, HomePNA technology offers a technically easy and affordable transition for home networking. It is based on Ethernet and uses well-known modulation techniques. As the HomePNA specification includes higher speeds and as it expands its interoperability by supporting wireless protocols such as Bluetooth, HomePNA may be poised to become a de facto home-networking standard. Some other key enablers will be HomePNA's ease of use, as well as operating system and independent software vendor (ISV) support. Microsoft supports HomePNA in its Windows 98, Second Edition and Windows 2000 Professional will include native support for HomePNA.

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3.3 Powerline

Using the current AC power delivery infrastructure for information exchange proved to be a pretty refreshing solution since it will not require additional investment on cabling. Both telecom companies and control companies have shown interest in it. Nortel's branch Norweb tried to transmit Internet and data traffic over the powerline networks [10]. The DPL 1000 uses the Digital PowerLine technology in order to deliver data traffice with more that 1 MBPS speed. Nortel is planning to integrate it into its Magellen ATM platform. The utility industry is now begining to take this kind of technology in their way to provide residensual data access service.

Home automation vendors like X10 (www.x10.com) and control networking companies like Echelon (www.echeolon.com), Intelogis (www.intelogis.com) are trying to utilize their powerline control networking technologies to the home networking market. In their technical white papers [11], [12], [13] and [14], they give the prospects of powerline networking. With their properitary protocols like LonWorks or PLUG-IN, and the control chips from major IC vendors, the powerline networking are now an affordable solution for home pc users.

3.3.1 X10 Home Automation

X10 Technology offers a solution with its 20 years old powerline technology which was initially developed to integrate with low cost lighting and applicance control devices. X-10 powerline technology transmits binary data using AM technique. Now X10 is trying to innovate it into higher speed with regard to establish the communication between home PCs and controled home applicances.

As a power-line carrier protocol, X10 allows compatible devices to communicate over home power supply electrical wiring. X10 enables control over lights and virtually any other electrical device from anywhere in the house with no additional wiring. A controller/transmitter is plugged into a standard electrical outlet, or is installed as a replacement to a current switch. Then each appliance that you want to control is plugged into an X10 module which is connected to a standarad electrical outlet. Then the controller/transmitter could use the electrical wiring as the transmission media to communicate with those modules.

X-10 powerline technology employes an Amplitude Modulation (AM) technique to transmit binary data. In order to differentiate the data symbols, the carrier uses the zero-voltage crossing point of the 60 Hz AC sine wave on the cycle's positive or negative transition. Synchronized receivers accept the carrier at each zero-crossing point. X-10 uses two zero crossings to transmit a binary digit so as to reduce errors. So every bit requires a full 60 hertz cycle and thus the X-10 transmission rate is limited to only 60 bits per second (bps). Usually a complete X-10 command consists of two packets with a 3 cycle gap between each packet. Each packet contains two identical messages of 11 bits (or 11 cycles) each. Therefore, a complete X-10 command consumes 47 cycles that yields a transmission time of about .8 seconds. This technology is a bit slow to connect home PCs, but would be a potential technology for later connectivity between home electrical applicances.

3.3.2 Intellon CEBus

Based on CEBus standard, Intellon produces products which can be used to provide control capabilities to home networks. The products consist of two fundamental components - a transceiver and a micro controller. The transceiver implements spread spectrum technology and the controller to run the protocol. The CEBus standard is an open standard that provides separate physical layer specifications for communication on power lines and other media.

Data packets are transmitted by the transceiver at about 10 Kilobits per second (Kbps), using spread spectrum technology. The CEBus protocol uses a peer-to-peer communications model so that any node on the network has access to the media at any time. Similar to Ethernet, it uses a Carrier Sense Multiple Access/Collision Detection and Resolution (CSMA/CDCR) protocol to avoid data collisions,. Basically, this Media Access Control (MAC) protocol requires a network node to wait until the line is clear, which means that no other packet is being transmitted before it can send a packet.

In the upper layer, CEBus includes a common application language (CAL) that allows devices to exchange commands and status requests. It defines a common command syntax and vocabulary to do this. CAL defines various electronic device functional sub-units called contexts. And each context is further divided into objects, which represent various control functions of the context. Objects are furtherly defined by a set of instance variablesthat specify the operation of the function of the object. By utilizing the CAL specification, Intellon ensures their products can communicate with other CAL compliant devices.

Intellon offers products ranging from chip sets to board solutions, depending on the level of integration the manufacturer wants to perform on their own. But the cost issues have made Intellon chips less affordable and thus they are not widely used as X10 devices.

3.3.3 Echelon LONWorks

Echelon, like Intellon, provides a peer-to-peer communication protocol, implementing Carrier Sense Multiple Access (CSMA) techniques. It make efforts to provide a whole set of control networking technology, with its Neuron chip, LonTalk protocol and LONWorks Network Service. Echelon offers a 10 Kbps power line chip based on spread spectrum technology. Echelon also offers a sophisticated proprietary MAC protocol embedded in their Neuron chip, providing the peer-to-peer networking layer. The LONWorks has just been passed ANSI/EIA standards proecess and now can be known as ANSI/EIA 701.9-A-1999.

In LONWORKS, control networking technology goes beyond simply being a communication protocol. It provides a complete platform on which to build control systems. The LonTalk protocol, an open and international standard designed specifically for the needs of control, is at the heart of LONWORKS networks. Neuron Chip in LONWorks family includes an implementation of the LonTalk protocol along with other built-in features to provide a complete system-on-a-chip solution for control devices. Inside this chip, LonTalk protocol support many communication media including, twisted pair, power line, fiber optics, coaxial cable, radio frequency, and infrared. Good news is that Echelon's proprietary protocol strategy changed recently when they opened up their Neuron protocol, allowing it to interface with third-party power line transceivers.

Above these, LONWORKS Network Services (LNS) architecture is a powerful network operating system, which provides an object-oriented method to connect networked control devices. It provides a unified API system for developing tools for installing, configuring, and maintaining, monitoring and controlling LONWORKS control networks. LNS clients can run on any platform (PC, MAC, UNIX, embedded, etc.). And LNS Server supports both LONTALK and TCP/IP protocols at the transport layer.

3.3.4 Intelogis PLUG-IN

Intelogis PLUG-IN is another control networking protocol from Intelogis. It is closely related to the Open System Interconnection (OSI) model. Of the OSI model's seven layers, all but two, the presentation and session layers, are defined in the PLUG-IN protocol stack. The PLUG-IN protocols associated with each of these five OSI layers are as follows:

- Application Layer - PLUG-IN Intelogis Common Application Layer (iCAL) Protocol.
- Network Layer - PLUG-IN Power Line Exchange (PLX) Protocol
- Transport - PLUG-IN PLX Protocol
- Data-Link - PLUG-IN PLX Protocol
- Physical Layer - PLUG-IN Digital Power Line (DPL)

PLUG-IN uses the CEBus Generic Common Application Language as its Application Layer protocol but Intelogis uses a client/server topology instead of the peer-to-peer model. Using a client/server topology allows more of the intelligence of each PLUG-IN node' s application to be placed in a centralized Application Server. In the lower layer, PLX protocol defines rules of operation for the Data Link, Network, and Transport layers, however, the main function of PLX is to define the media access control (MAC) portion of the data link layer. It uses a MAC protocol consisting of two separate access mechanisms – datagram sensing multiple access (DSMA), and Centralized Token Passing (CTP).

At the physical layer, DPL protocol uses a modulation methodology called Frequency Shift Keying (FSK) to send digital signals over the power line. FSK modulation sends digital signals over the power line by using two or more separate frequencies that are in a fairly narrow band. PLUG-IN DPL single channel solution boasts line speeds of up to 350 Kilobits (Kbps) per second (Mbps). Using multiple channels and carrier signals, the future versions of PLUG-IN DPL will be capable of speeds up to 1 Mbps and beyond. Furthermore, the PLUG-IN FSK modulation scheme delivers bit error rates in the range of 10 -9 with 80 dB of dynamic range.

3.3.5 Powerline Technologies Conclusion

Beyond avoiding new wire installation, powerline networking technology provides network access points (electrical outlets) which is much availale throughout a house. It also provides reasonable data rates of 1 Mbps and above. However, power-line networking is still in its childhood. Data integrity across power-line networks is still a big issue, particularly in homes with older wiring. Data security between houses and apartments is not sufficiently protected in the current standards. Future efforts are needed to make powerline networking a capable competitor for phoneline networking.

There are also other home automation technologies like Adaptive Networks, VESA and HAVi, etc. But most of them are targeted at low-speed automation controls.

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3.4 Wireless

Another natural solution for a home without data networking wiring would be wireless connection. Currently, in Radio Frequency bands, there has been a lot of research work in telecommunication and networking industry. The IEEE 802.11 Wireless LAN is the first standard for WLAN from IEEE. It operates at 900MHz and 2.4GHz ISM frequency bands. Either Frequency Hopping Spread Spectrum (FHSS) or Direct Sequence Spread Spectrum(DSSS) RF transmission standards could be used. And it can sustain a 1Mbps to 2Mbps data rate. [15],[16],[17] For DSSS, the data rate could be up to 11Mbps. Once equipped, they are suitable for a home office network. However, the current cost per port of installing an 802.11 network is prohibitively expensive for the typical home-networking customer. Two primary groups are working to develop affordable wireless home-networking standards: Bluetooth and the HomeRF Working Group.

3.4.1 IEEE 802.11 Wireless LAN

IEEE 802.11 is limited in scope to the Physical (PHY) layer and Medium Access Control (MAC) sublayer, with MAC origins to IEEE802.3 Ethernet standard. WLANs can be used either to replace wired LANs, or as an extension of the wired LAN infrastructure. Figure 3 shows the basic topology of an 802.11 network. A Basic Service Set (BSS) consists of two or more wireless nodes, or stations (STAs), which have recognized each other and have established communications. In most instances, the BSS contains an Access Point (AP). The main function of an AP is to form a bridge between wireless and wired LANs. The AP is analogous to a basestation used in cellular phone networks.

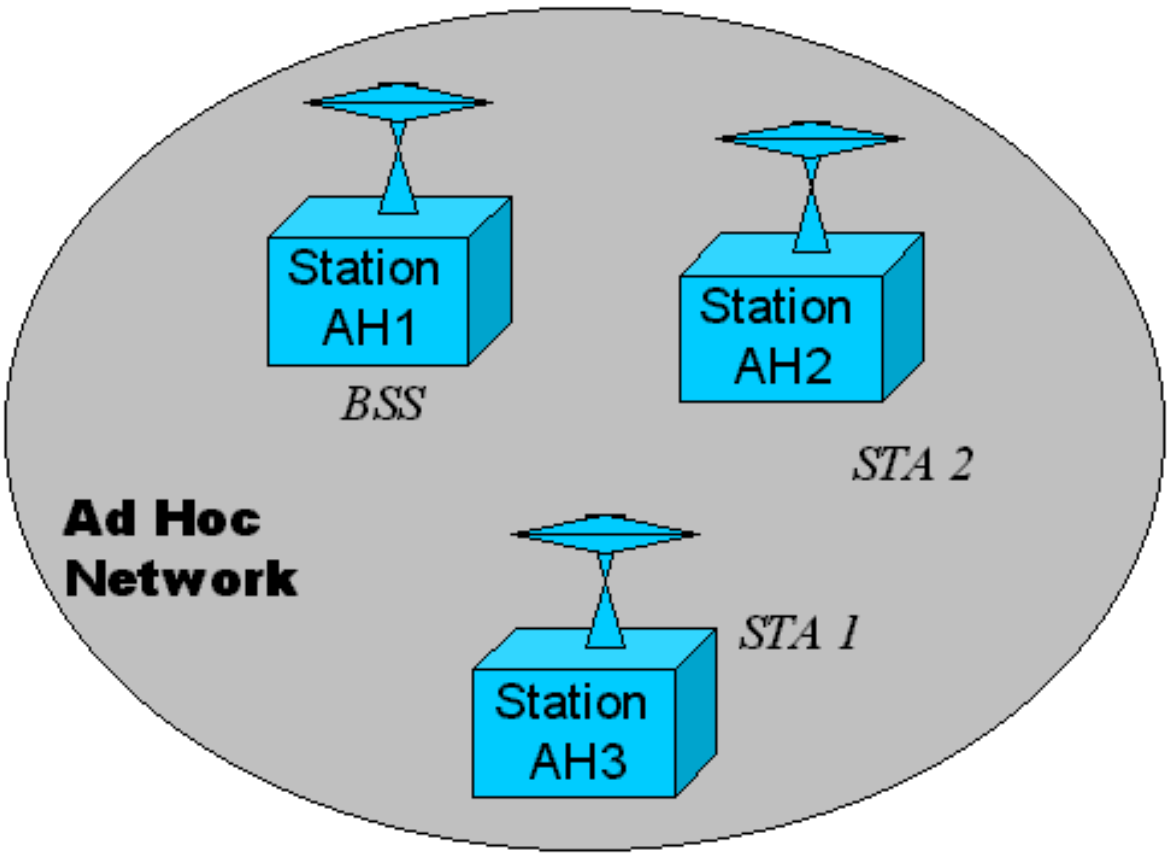

Figure 3 Sample IEEE 802.11 topology

IEEE 802.11 provides for two variations of the PHY. These include two RF technologies namely Direct Sequence Spread Spectrum (DSSS), and Frequency Hopped Spread Spectrum (FHSS). The DSSS and FHSS PHY options were designed specifically to conform to FCC regulations for operation in the 2.4 GHz ISM band, which has worldwide allocation for unlicensed operation.

Region	Allocated Spectrum
US	2.4000 - 2.4835 GHz
Europe	2.4000 - 2.4835 GHz
Japan	2.471 - 2.497 GHz
France	2.4465 - 2.4835 GHz
Spain	2.445 - 2.475 GHz

Table 1 Global Spectrum Allocation at 2.4 GHz

Both FHSS and DSSS PHYs currently support 1 and 2 Mbps. And all 11 Mbps radios are DSSS. Operating principles of DSSS radios are described in the following paragraphs. DSSS systems use technology similar to GPS satellites and some types of cell phones. Each information bit is combined via an XOR function with a longer Pseudo-random Numerical (PN) sequence as shown in Figure 3. The result is a high speed digital stream which is then modulated onto a carrier frequency using Differential Phase Shift Keying (DPSK).

For more information of IEEE 802.11 works, please refer to related standards and [15], [16], [17].

3.4.2 Bluetooth

Bluetooth (www.bluetooth.com) is the code name adopted by a consortium of wireless equipment manufacturers. This consortium is working toward a low-cost, global standard for wireless communication of data and voice.

The Bluetooth technology is based on a short-range radio link built into small application-specific integrated circuits (ASICs). It can support both stationary and mobile communications and use frequency hopping (up to 1,600 hops per second) to reduce noise impact. Bluetooth supports data transmissions between devices of up to 721 Kbps and up to three voice channels. Operating in the unlicensed and globally available industrial, scientific, and medical (ISM) band at 2.45 gigahertz (GHz), it uses spread spectrum to connect devices as much as 30 feet apart. Bluetooth technology can enable a user to replace the various cables between devices with a universal short-range radio link. And they could interoperate with similarly equipped devices such as printers, fax machines, desktop computers and peripherals, and a host of other digital devices. Futhermore, Bluetooth technology can provide a connection between the ad hoc network and existing data networks.

As claimed, Bluetooth technology is designed for wireless personal area networks (WPANs), which are networks of personal electronic devices in close proximity to each other. Bluetooth technology is expected to become a major player in the wireless data communications market because of simplicity and its support from large companies. And Bluetooth members are encouraging vendors to incorporate the technology into their products by waiving intellectual property royalty fees.

3.4.3 HomeRF and SWAP Protocol

The HomeRF Working Group (www.homerf.org) was established in March 1998. It is a subset of the International Telecommunication Union (ITU) and specially works on the development of a standard for inexpensive RF voice and data communication. Currently, the HomeRF Working Group specification provides for wireless Ethernet transmission at data rates of 1.2 Mbps for as far as 40 meters. Furthermore, it includes four personal communication

services (PCS)-quality voice channels for cordless telephones. An interoperable low-range/low-power mode is provided this specification for digital devices such as PDAs.

The HomeRF Working Group also is developing the Shared Wireless Access Protocol (SWAP), which operates in the 2.4-GHz range of the spectrum and employs frequency hopping at 50 hops per second. SWAP is also expected to support as many as 127 devices per network at up to 50 meters apart.

SWAP system is designed to carry both voice and data traffic and to interoperate with the Public Switched Telephone Network (PSTN) and the Internet; it operates in the 2400MHz band and uses a digital frequency hopping spread spectrum radio. It is derived from extensions of existing cordless telephone (Digital Enhanced Cordless Telephone or DECT) and wireless LAN technology to enable a new class of home cordless services. In SWAP, a TDMA (Time Division Multiple Access) service is supported to provide delivery of interactive voice and other time-critical services, and a CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) service for delivery of high speed packet data.

The main features of SWAP are,

- Frequency hopping network: 50 hops/second
- Frequency range: 2400MHz ISM band
- Transmission power: 100mW
- Data Rate: 1 Mbps using 2FSK modulation 2 Mbps using 4FSK modulation
- Range: Covers typical home and yard
- Supported stations: Up to 127 devices per network
- Voice connections: Up to 6 full duplex conversations
- Data security: Blowfish encryption algorithm (over 1 trillion codes)
- Data compression: LZRW3-A algorithm
- 48-bit Network ID: Enables concurrent operation of multiple co-located networks.

For Network Topology, 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, only data communication is supported and all stations are equal and control of the network is distributed between the stations. But 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. The SWAP system also can use the Connection Point to support power management for prolonged battery life by scheduling device wakeup and polling. The network can accommodate a maximum of 127 nodes. These nodes can be a mixture of these 4 basic types:

- Connection Point that supports voice and data services.
- Voice Terminal that only uses the TDMA service to communicate with a base station.
- Data Node that uses the CSMA/CA service to communicate with a base station and other data nodes.
- Voice and Data Node which can use both types of services

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3.5 IrDA

Infra-read Data Association (IrDA) (www.irda.org) was originally designed as a standard for interoperatable universal two way cordless infrared light transmission data ports. [19] But now with envolution, it could also be a means to transport data over a short sight-of-vision distance. The possible data rates are 9600 - 115.2kb/s for Async serial-IR, 1.152Mbs/s for Sync Serial-IR and 4Mb/s for Sync 4PPM.

Now IrDA has a set of protocols covering all layers of data transportation, it also has some network management,

security and interoperability designs.[20], [21], [22] Also, now IrDA is a standard on the Palm devices so its role in home networking would be essential in the future. IrDA protocols have IrDA DATA for data delivery and IrDA CONTROL for the controling aspect.

3.5.1 IrDA DATA

The protocol stacks of IrDA DATA is as follows,

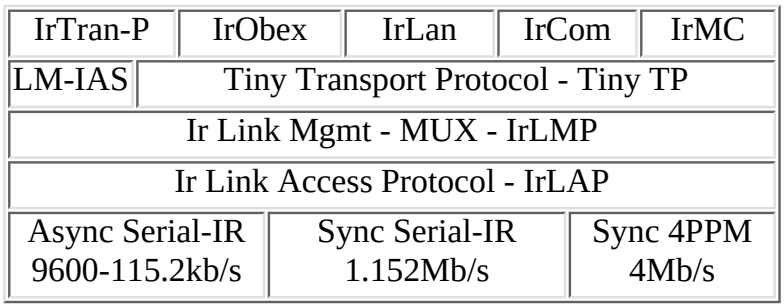

Figure 4 IrDA DATA – Hardware/Protocol Stacks

"IrDA DATA" defines a standard for an interoperable universal two way cordless infrared light transmission data port. Adapters now include the traditional upgrades to serial and parallel ports, plus Universal Serial Bus (USB) and Ethernet/Token Ring LAN point to point access.

IrDA Data Protocols consist of a mandatory set of protocols and a set of optional protocols. The mandatory protocols are listed below.

- PHY (Physical Signaling Layer)
- IrLAP (Link Access Protocol)
- IrLMP (Link Management Protocol and Information Access Service (IAS))

And for each of these protocols, an outline of their characteristics is given in below,

1) Physical IrDA Data Signaling,
   - Range: Continuous operation from contact to at least 1 meter (typically 2 meters can be reached). A low power version relaxes the range objective for operation from contact through at least 20 cm between low power devices and 30 cm between low power and standard power devices. This implementation affords 10 times less power consumption. These parameters are termed the required maximum ranges by certain classes of IrDA featured devices and sets the end user expectation for discovery, recognition and performance.
   - Bi-directional communication is the basis of all specifications
   - Data transmission from 9600 b/s with primary speed/cost steps of 115 kb/s and maximum speed up to 4 Mb/s
   - Data packets are protected using a CRC (CRC-16 for speeds up to 1.152Mb/s and CRC-32 at 4 Mb/s).

2) IrDA Link Access Protocol (IrLAP)
   - Provides a device-to-device connection for the reliable, ordered transfer of data.
   - Device discover procedures.
   - Handles hidden nodes.

3) IrDA Link Management Protocol (IrLMP)
   - Provides multiplexing of the IrLAP layer. Multiple channels above an IrLAP connection.
   - Provides protocol and service discovery via the Information Access Service (IAS).

The optional IrDA Data Protocols are,

- Tiny TP - provides flow control on IrLMP connections with an optional Segmentation and Reassembly service.
- IrCOMM - provides COM (serial and parallel) port emulation for legacy COM applications, printing and modem devices.
- IrOBEX - provides object exchange services similar to HTTP.
- IrDA Lite - provides methods of reducing the size of IrDA code while maintaining compatibility with full implementations.
- IrTran-P - provides image exchange protocol used in Digital Image capture devices/cameras.
- IrMC - specifications on how mobile telephony and communication devices can exchange information. This includes phonebook, calendar, and message data.
- IrLAN - Describes a protocol used to support IR wireless access to local area networks.

3.5.2 IrDA CONTROL

IrDA Control is an infrared communication standard that allows cordless peripherals to interact with many types of intelligent host devices. Host devices include PC's, home appliances, game machines and television/web set top boxes. IrDA Control is well suited to deal with devices that leverage the USB HID class of device controls and home appliances, while traditional remote controls will sophisticated implementation guideline for bi-directional remote control with MAC enumeration and binding and with LLC transactions.

IrDA Control Protocols consist of a mandatory set of protocols.

- PHY (Physical layer)
- MAC (Media Access Control)
- LLC (Logical Link Control)

For these protocols, their characteristics can be described as below,

1) IrDA Control Physical Signaling

- Distance and range equivalent current uni-directional infrared remote control units (minimum 5 meter range).
- Bi-directional communication is the basis of all specs.
- Data transmission at 75 kb/s at the top end
- The data is coded using a 16-Pulse Sequence multiplied by a 1.5 MHz subcarrier which is allocated for high speed remote control in IEC 1603-1 although this base band scheme has harmonics which can intrude upon other IEC bands.
- Data packets are protected with a CRC (CRC-8 for short packets and CRC-16 for long packets). The physical layer is optimized for low power usage and can be implemented with low-cost hardware.

2) IrDA Control MAC

- Enables a host device to communicate with multiple peripheral devices (1:n) and up to 8 peripherals simultaneously.
- Ensures fast response time (13.8 ms basic polling rate) and low latency.

  For Asymmetric MAC

- Provides for dynamic assignment and re-use of peripheral addresses.
- Scheduling of media access is actually embeded in the HID LLC.

3) IrDA Control LLC:

- Provides reliability features that provides data sequencing and retransmission when errors are detected.
- Works with an HID-IrDA Control Bridge to enable the link control functions of USB-HID.

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4. SERVICE AND OTHER ASPECTS

In an IETF draft [23], some requirements for Networks In The Small(NITS) are discussed. As in the home networking scenario, newly introduced computer need some sepecific processes to be introduced into the "home area network". But not all protocol procedures defined in other networking scenarios could be applicable here. Things like scalability, automatic configuration need some new modification. This draft also discusses some open issues so far.

In general, the following requirements need to be paid attention to during the design of NITS including home networks, "

1. Hosts MUST be capable of dynamic configuration of host configuration, whether DHCP servers or relays are present or not.
2. Hosts MUST be capable of being configured by DHCP so that they can be reconfigured if a NITS network is (re)attached to a larger network.
3. Clients MUST be capable of obtaining service configuration information (principally the location of services) through the use of a service discovery protocol.
4. Services MUST be discoverable by means of a service discovery protocol.
5. Hosts SHOULD be able to resolve domain names even in the absense of a DNS server.
6. Protocols specified for use in NITS networks which include an applicability statement which states that they are not appropriate for use in larger networks MUST NOT be used in larger networks. There MUST be a way for hosts to detect when it is inappropriate for the protocol to be used.
7. Global multicast addresses SHOULD NOT be used in NITS protocols. Administratively scoped multicast addresses SHOULD be used in NITS protocols." [23]

In this Internet Draft, some opening issues like service discovery and advertisement, scalability, security issues, automatic configration, etc. are also discussed. But protocol specification and standardization need future effort.

In order to faciliate the developing of software applications over home network, HomeAPI is now setting up to simplify and reduce the efforts in both migration and interoperation. [24] The unified API would be an efficient way to establish a uniform communication across the home network. Combining the latest home networking technology and object model together, it will bring a new generation of sevice definition and application development. It uses a property-based OLE automation object model and extensible home device models to support run-time autonomous operation. The key features of HomeAPI are,"

- Enables applications to enumerate, control and receive state change events from home devices.
- Exposes devices such as protocol-independent OLE Automation objects using "properties" to model device controls.
- Defines standard control properties for common home devices. New device types can be defined and additional properties can be easily added to support custom features and devices.
- Supports a variety of home networks and underlying protocols. New or proprietary protocols can be added easily.
- Includes a run-time component to support intelligent home features.

- Enables applications to discover and incorporate user interface components for home devices.
- Integrates well with popular development tools and is accessible from a variety of programming languages, including C++, Java, Visual Basic, Visual Basic development system Scripting Edition and Java Script." [24]

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5. MARKET OVERVIEW

For the technologies discussed above, there are many products available. Especially for traditional LAN technologies, there are many matured products from major vendors. However, the market is still in its early development era. Phoneline products are now becoming matured. Most peripherals vendors have phoneline networking products. Lucent, Intel and Diamond are the market leaders so far. Other startups, like Tut System, Epigram (now part of Broadcom), etc. are quickly catching up.

Nortel's DPL-1000 is targeted at telecommunication service companies like ISP. X-10 is now a de facto standard for home automation, so it is now trying to push into home networking sector. Lucent puts much attention to WaveLAN and RF products. Traditonal control networking companies are quickly tranfering their products into home networking market. Echelon and Intelogis are now presenting into this market. Wireless vendors like Sharewave, Enikia and SOHOWare are starting to sell Home RF based products. The IrDA market is still primarily in the peripheral interconnection stage, hopefully there will be some products for home networking in near future.

The Universal Plug and Play, USB technologies are also essential technologies to support home networking.[30]

Overall, home networking market is still in its early age. Considerate user education and solution development needs some time. [31]~[40]

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6. SUMMARY

Home networking, as the new low-end branch of networking technology, is now under its critical development era. There are a number of technologies, protocols, manufacturers and standardization bodies are making efforts on this new branch. In this report, we briefly go over the market and technology aspects of current available home networking technologies, including traditional LAN, phoneline, powerline, wireless and IrDA technologies. A considerately deep introduction of these protocols and solutions is given. The new control networking migration to home networking is also covered with several key control networking technolgies discussed. Also we've discussed something about the services and security issues. Home networking is claimed to be the focus of the coming five years for most networking vendors. Big companies, as well as new start-ups, are now shipping their new products based on HomePNA, HomeRF, HomeAPI and IEEE/ITU-T standards.

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7. LISTS OF ACRONYMS

AM - Amplitude Modulation
API - Application Programming Interface
CAL - Common Application Language
CSMA - Carrier Sense Multiple Access
DPSK - Differential Phase Shift Keying
DSSS - Direct Sequence Spread Spectrum
FHSS - Frquency Hopping Spread Spectrum
FSK - Frequency Shift Keying
HomePNA - Home Phone Networking Alliance
HomeRF - Home Radio Frequency Working Groupd
IrDA - Infra-red Data Association
ISM - Industrial, Scientific and Medical
MAC - Media Access Control
NITS - Networks In The Small
OLE - Object Linking and Embedment
PHY - Physical
POTS - Plain Old Telephony System
PSTN - Public Switched Telephone Network
RF - Radio Frequency
SWAP - Shared Wireless Access Protocol
TDMA - Time Division Multiple Access
UTP - Unshielded Twisted Pair
USB - Universal Serial Bus
WLAN - Wireless Local Area Network

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