Home-automation networks mature while the PC industry chases a new home LAN

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In five years, expect the state-of-the-art home to be well-connected. A broadband pipe will provide the home with digital video and high-speed Internet access; one or more PCs will connect with the living-room entertainment center; and one PC will sit at the center of a hybrid data, voice, video, and control network (Figure 1). The choices for implementing home-automation or control networks are stable and mature, but an inexpensive and foolproof LAN that can carry a variety of data types is still just a concept. But don't let this immaturity fool you. The biggest companies in the PC industry are fervently working on a new LAN for the home. The technology will roll out rapidly over the next 18 months, providing enticing opportunities for the entrepreneurs and designers that tap the right technologies and quickly bring products to market. Moreover, the technology will be equally applicable in some embedded systems with PC-industry volumes once again allowing designers to tap new technologies at low cost.

The future state-of-the-art home will be well-connected, and companies are fervently pursuing home network technologies that rely on power-line, phone-line, RF, and 1394 data links.

The requirements for control and data networks differ substantially. A home LAN will require fairly high data rates to allow Internet access throughout the home along with file and peripheral sharing. Data rates must further escalate if the LAN is used to carry video streams. Control networks require very low cost so that the technology can be integrated into low-cost nodes, such as light dimmers, thermostats even toasters or irons. Fortunately, most control applications don't require data rates above 10 kbps, and several companies have developed reliable schemes to transmit such data rates over a home's ac wiring. That ubiquitous power line also fulfills another major requirement of a control network: an easily accessible, essentially free physical layer or medium that can transport the control information.

Your choices in control-network technology come down to the Consumer Electronics Bus (CEBus) and LonWorks. In some cases, other networks, such as Fieldbus have been used in factory or industrial automation, and control applications. Only CEBus and LonWorks, however, meet the cost require-

Two types of networks are headed into the home. Control, or home-automation, network technology has finally matured enough to promise widespread deployment. Meanwhile, the PC industry is furiously pursuing new data LANs for the home. IC, card, and system vendors must choose the right LAN and meld it with the right control net-

ments of home-control networks. CEBus resulted from the traditional electronics-industry-standards process and has been published by ANSI and EIA as EIA-600. The CEBus Industry Council (CIC) is affiliated with EIA and now shepherds the standard.

Although Echelon created LonWorks, the technology is today arguably as open as or more open than CEBus. In fact, just this April, the EIA recognized the widespread usage of LonWorks and has published a new standard for home networking (EIA-709) based on the technology. LonWorks is much more widely supported today, achieving much of its success through factory- and building-control applications. Echelon asserts that there are close to 5 million installed LonWorks nodes. Meanwhile, CEBus proponents estimate the number of installed nodes at much fewer than 1 million. You can get copies of the specs for both standards from Global Engineering Documents (http://global.ihs.com). (See References 1, 2, and 3.)

In the past, most comparisons of CEBus and LonWorks have centered on each camp's assertion of superior physical layers. Today, both groups have reliable physical layers. You should choose one or the other based on the following criteria:

- Which technology, based on your own detailed analysis, will ultimately become ubiquitous or at least prevalent in your application.
- Which software architecture best meets the needs of your application.
- Which available physical layer or combination of physical layers can fulfill your application requirements.

You should also consider a combination of other factors, including cost, level of integration, installed base, and multivendor support.

Chasing a ubiquitous standard

Home automation and control are still waiting for a killer application, but proponents have never wavered in their belief that the technology will eventually pervade our lives. For this reason, choosing the eventual winning technology can be critical. At first, you might not think a single standard could be so critical. After all, when you as home owners want to automate lighting or heating and cooling, you can just make sure you buy interoperable products. Moreover, these products are just components, such as light controllers, dimmers, and outlets.

Think for a moment, however, about some examples provided by Grayson Evans, a long-time home-automation proponent and owner of The Training Department, a CEBus consulting company. Evans envisions an iron that automatically shuts off when you leave your house. If it turns out that the ironers of the world aren't thrilled with models that shut off after 10 or 20 minutes of inactivity. If you get interrupted by a phone call while ironing, you might return to a cold iron. An automated iron could shut off when you arm your home-security system, when you lock an automated door lock, or even when you remotely close your garage door from your car.

Evans also points out that some devices would naturally benefit from the capabilities in other devices. For example, you could have one master clock in an entire house. The clock could be super-accurate because it could be updated by precise time data broadcast via cable TV, satellite video streams, or even a low-cost Global Positioning System (GPS) receiver that deciphers only the time data that's constantly broadcast by GPS sattelites. This master clock would then broadcast the time via a power-line network. Appliances, such as microwave ovens, VCRs, and even clockradios, would always have the accurate time and receive automatic updates during the transitions between standard and daylight-saving time.

Evans' scenario may never come to fruition. It's clear that iron or toaster manufacturers won't add support for a control network unless there is a ubiquitous standard. Without a standard, consumers may automate lighting or heating and cooling, but they will not reach the full potential of

Designers who want to evaluate CEBus can buy either a power-line or an RF evaluation kit from Intellon.

@a glance

- CEBus and LonWorks control networks offer mature choices from home automation.
- Ultimately, only a ubiquitous standard for home control will lead to appliance vendors embedding a control network in every product.
- The Internet will drive a new flavor of LANs into the home and possibly spur the home-automation market as well.
- Early on, expect the phone wiring within homes to carry LAN data and later to see a new 1394 standard emerge that can deliver digital video throughout the home.

home automation.

Comparing software schemes

Despite the importance of a universal home-automation standard, you may not be able to pick a winner. You may need to choose a technology based on the software architectures. Both CEBus and LonWorks leverage a peer-to-peer architecture and rely on relatively simple network protocols implemented on microcontrollers.

Echelon developed the LonTalk protocol and made deals years ago with Motorola and Toshiba to develop Neuron ICs to host LonTalk. Both semiconductor vendors have developed several generations of Neurons that typically integrate two microcontrollers that handle the LonTalk protocol and leave a third microcontroller available for node tasks. Complex nodes can require an additional µP or microcontroller. Echelon reasoned that the Neuron approach virtually guaranteed 100% LonWorks compatibility, and every LonWorks node shipped to date includes a Neuron IC. The latest Neuron ICs cost around $6 (1000), with some versions selling for as little as $2 in very high volumes.

The CEBus spec, meanwhile, simply defined the protocol stack, allowing anyone to deploy the network on a microcontroller. You can buy development tools that allow you to deploy CEBus on an 8051 or 68xx microcontroller from companies such as Intellon, Domosys, and ACS. A complete development environment can cost around $2000, and you can use the tools to develop node functionality as well. The CIC also recognized the need for compatibility and has established a testing program that can verify that a product complies with the CEBus standard.

Now that LonWorks has become an EIA standard, Echelon also recognizes that some designers might want to host the LonTalk protocol on a µP of their choice. Anyone can do so now that the standard is published. Echelon is working with a partner and hopes to offer a reference implementation this year. You needn't worry about LonWorks compatibility, however, because the LonWorks community in 1994 beat CIC to the punch and established the LonMark Interoperability Association. The group has around 200 members, and its many functions include conformance testing.

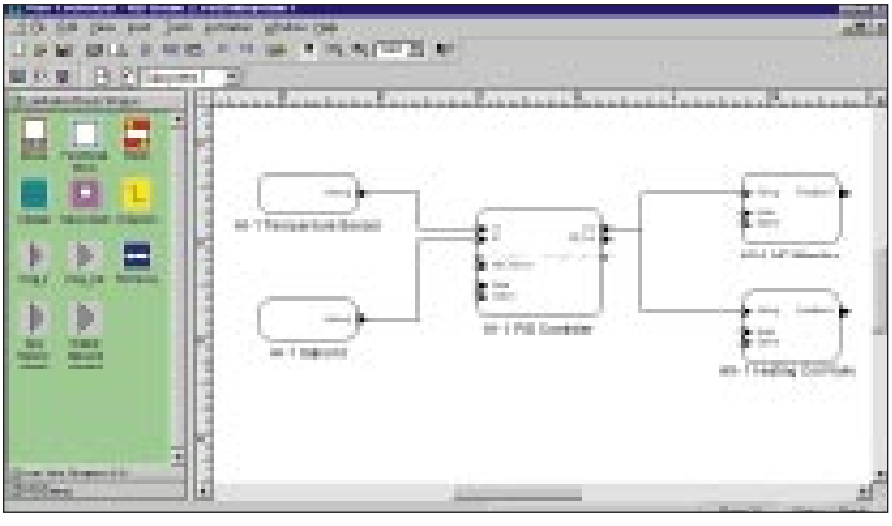
The LonMark group has been defining common contexts or data structures that allow products from different vendors to communicate. The CIC garnered even more recent publicity with its Home Plug & Play specification, although the LonMark effort predates it by several years. Both work similarly. For example, the CIC has defined several categories of products including security, lighting, heating/cooling, consumer electronics, convenience (ga-rage-door openers for example), user interfaces, and others. Within each category, CIC has also published contexts that guide node operation. Each context can include a number of objects or data items for input, output, or I/O. Objects can be binary, such as on or off, or more complex, such as inside temperature or inside humidity. More complex objects require an analog value. The contexts allow even unlike products to listen for and react to network broadcast of status contexts.

To develop a CEBus node, designers must extend the network protocol stack with the appropriate contexts. The node must also be capable of sending command strings based on the object-oriented Common Application Language (CAL) defined in the CEBus specs. Intellon, Domosys, and ACS offer tools that help you implement CAL. LonWorks lacks such a fully specified command language, but programming for LonWorks nodes is typically less complex than it is for CEBus nodes.

Network protocols and services

Differentiating LonWorks and CEBus software can become difficult. LonWorks offers a more robust protocol with more options for guaranteed delivery of control packets, low-latency delivery services, and support for much larger networks. However, some of the advantages may not affect home applications.

CEBus promises to be simpler to configure. The Home Plug & Play spec defines fairly complex node-design procedures that will allow a consumer to buy products from different vendors and install them with no master controller on the network. For example, you could buy a light-dimmer control module and connect it to the power line, and the module would essentially publish a status as a controller over the network. You could then connect a dimmer-capable light fixture that would request a compatible controller and bind to the unattached dimmer module. CIC is sure that this scheme will work as consumers incrementally add CEBus mod-



Echelon has adapted the widely popular Visio technical drawing package in its LonMaker product, allowing users to configure LonWorks control networks with a graphical drag-and-drop interface.

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ules, but for practical purposes, the home will need a master controller.

LonWorks networks can also work without a controller, but they do require a controller for initial configuration. LonWorks nodes feature more intelligence than CEBus nodes. For example, LonWorks nodes can respond to an inquiry from a controller with an address and a list of device capabilities. Essentially, LonWorks configuration relies on the LonWorks Network System, a multiple-client, multiple-server network operating system that s optimized for configuring control networks. In large networks, such as commercial-building networks, you can use multiple LonWorks controllers simultaneously on one network.

But don t misconstrue LonWorks as too complex for a home application. Echelon points out that building electricians regularly configure and maintain control networks with thousands of nodes. As an example of how simple LonWorks configuration can be, consider LonMaker software for Windows. LonMaker is a new, highly customized version of the popular Visio (www.visio.com) technical drawing program. LonMaker can use the inquiry capabilities of LonWorks to take an inventory of every node on the network and present each node as a Visio object. You can then graphically manipulate the LonWorks nodes on screen and connect or bind the desired sensors and actuators. Once configured, the LonWorks network will operate without the PC. LonMaker costs $895 and includes a full copy of the technical version of Visio.

The only potential disadvantage of LonWorks software is its tie to the LonWorks network. The CIC has succeeded in separating CAL and all of the control contexts from the CEBus physical layers. In fact, the CIC is promoting CAL as the language for control no matter how you choose to transport the commands.

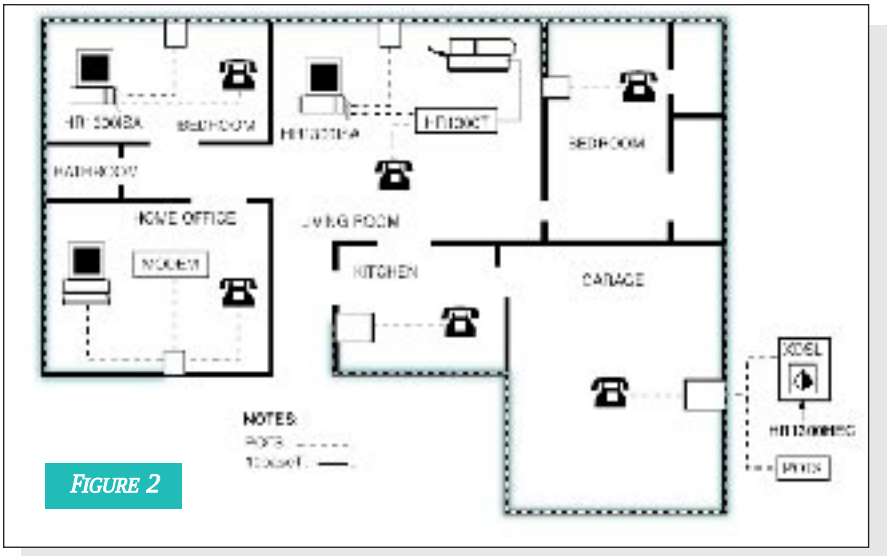


FIGURE 2

The most likely near-term media for home LANs appear to be the phone wires already installed in the walls of homes. Next month, Tut Systems will ship a 1.3-Mbps Ethernet-like LAN that shares the phone wiring with voice calls.

Control network physical layer

It s likely that the software environment will heavily influence your choice in control-LAN technology, but you may need to consider the physical layers available for CEBus and LonWorks. You could certainly compare the underlying physical-layer technologies, such as wideband versus narrowband transmission on power lines, but you will most likely find today s physical layers reliable. You will benefit most from a physical layer or combination of physical layers that meet your application requirements.

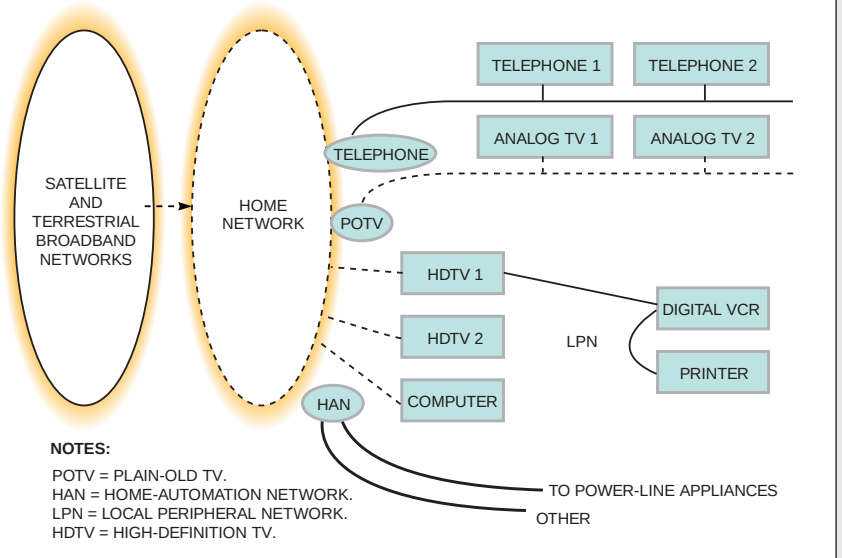
The CEBus standard defines five physical-layer choices for twisted-pair, power-line, coax, RF, and infrared media. The standard also includes a place holder for a fiber-optic medium that s not fully defined. All of the physical layers support 10-kbps data rates. To date, only power-line and RF products are widely available. Intellon offers the broadest group of products. Intellon ICs, including the P200, implement the basic network services and include a power-line transceiver. These ICs sell for as little as $2.50 (10,000) and require an external $1 (10,000) amplifier IC to connect to the power line. They also include a serial interface for communications to a microcontroller. Domosys, meanwhile, has ICs that integrate a microcontroller with the transceiver and sell for around $10 (1000). RF products are far more costly. Amnet Datacomm offers radio front ends for around $100 (1000) that work with Intellon ICs. Intellon also offers power-line and RF evaluation kits for $199 and $299, respectively.

Echelon s abundance of physical-layer choices could be an advantage or a disadvantage. For example, the company s three power-line physical layers work at 2, 5, and 10 kbps, and each use different transmission technologies. You may have an application that requires such a choice, but having only one choice may speed the search for a ubiquitous standard. Echelon claims the 5-kbps physical layer will be the likely choice for home networks; a transceiver costs less than $15, depending on volume. You can t directly compare CEBus and LonWorks transceiver costs, however. Echelon packages its products in a module that includes all the discrete passive components. With Intellon s ICs, you have to add the discrete components on a pc board. Echelon points out that several companies sell end products that use the 5-kbps physical layer and cost less than $30.

Echelon also offers many other physical-layer choices, including 1.25-Mbps twisted-pair schemes. The company has developed dozens of modules that combine Neuron ICs and transceivers, modules that bridge physical layers, and even

box-level bridges and routers. Echelon doesn't preclude other companies from making competing LonWorks transceivers. One company even developed a transceiver to run a LonWorks network over an electric fence. See Echelon's Web site for links to transceiver vendors that support specialty and standard physical layers. It's also interesting to note that the control network hatched within a company essentially has an open physical layer, but a vendor that wants to offer an EIA-hatched CEBus power-line transceiver must negotiate a license with Intellon.

FIGURE 3



The VESA Home Network committee envisions that homes will ultimately feature a backbone network based on 1394 with bridges to access and component networks.

Waiting for the killer app

While control-network technology has been maturing, consumers as well as appliance and consumer-electronics vendors have been waiting for a compelling application before adopting the technology. Many have speculated that power-demand management might spur the market. Power utilities could provide input to an automated household, allowing power-hungry appliances to operate when the overall demand for power is low. The power companies would discount power rates to such customers. Power companies have tested and sparsely implemented demand management and automatic meter reading, but these haven't proven to be the awaited killer application.

The PC industry believes that broadband Internet access and home-data LANs can spur the home-automation market. You would certainly want to bridge the control network and data LAN in a wired home. In fact, the Internet provides the persistent data link that home-automation proponents have long envisioned a part of home-automation and control applications. For example, a relative could arrive at your home while you're at work. When the visitor rings the doorbell, your control-network security camera could capture an image of the visitor, and the data LAN could transfer the image to your office via the Internet. Upon recognizing your visitor, you could send a command to the control network to open the front door. The same scenario could catch intruders breaking in or allow you to preheat your spa before leaving the office.

Ultimately, however, the PC industry wants to promote multiple-PC homes and even PC technology in the living room. This isn't just a marketers' pipe dream. Studies show that consumers buying a second PC account for an increased percentage of sales. Just as LANs proliferated in offices, consumers will want to share files and peripherals in the home. The proponents of home LANs ultimately view Internet access throughout the home as a killer application. You certainly would want Internet access at every PC, but you might also need access from Internet phones, fax machines, and set-top boxes.

A home LAN will have to carry a variety of traffic that only starts with typical IP-based data. You can envision audio and even video streams traversing a house via a home LAN. Two primary obstacles stand in the way of LANs in the home. First, homes aren't wired for LANs and therefore require expensive custom wiring before LAN installation. Even a low-cost LAN cannot make up for the high cost of custom wiring. Second, LAN software even a simple Windows LAN is too complicated for the average consumer.

The potential physical-layer or media choices for home LANs may surprise you. Industry groups are championing RF, power-line, and phone-line physical layers, attempting to avoid the need for retrofit wiring. Surprisingly, near-term technologies will deliver relatively high data rates over these channels. Other industry groups believe the need for a home LAN to carry digital video will require a new long-cable version of 1394. Perhaps, the home of the future will use a hybrid of LAN technologies.

Market leaders, such as Microsoft (www.microsoft.com) and Intel (www.intel.com) are now focusing on no-new-wires initiatives for home LANs. Each of the potential mediums has advantages and disadvantages. RF technologies offer the ultimate in flexibility, allowing support for untethered devices, such as handheld PCs or remote controls, but today's RF LANs don't come close to consumer cost requirements. Power-line access is practically ubiquitous, with outlets located at 8-ft intervals along walls

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throughout most houses. Most proven power-line communication schemes, however, operate at approximately 10 kbps rather than the approximately 1 Mbps of LANs. Phone wires offer the simplest technical challenge and therefore reasonable cost, but phone wires aren't available in every room in many houses. A phone outlet might be unusable just because it's on the wrong side of a room.

Intel's networking business group has decided to focus on power-line LANs. Dan Sweeney, manager of Intel's home-networking business unit, asserts that only power-line LANs meet the cost and accessibility requirements of home LANs and that consumer de-mand will place the maximum cost of a home LAN at $200 to connect the first two nodes. You can find several white papers and presentations on home networking at www.intel.com/home/network/index.htm. The material primarily describes the market and its requirements but may be the best and most easily accessible source for market data. Intel claims that home LAN could be a $1 billion market in five years. Intel does not provide details of its power-line technology, other than to say that 10-Mbps rates appear feasible and that it can meet the cost requirements of the consumer market. The company envisions widespread availability next year. Sweeney also insists that the result of Intel's work will be open and available for OEMs' use, although no other OEMs are publicly collaborating in the power-line effort.

Judging from other power-line communication technologies, Intel could face a tough challenge. The control network vendors haven't pushed power-line rates past 10 kbps, and several previous power-line LAN start-ups have folded. Adaptive Networks has had the most success developing faster power-line physical layers and offers ICs and power-line modems that can achieve 100 kbps. Such modems, however, cost more than $2000. Adaptive Networks also claims to be developing a lower cost home LAN and believes it can boost rates to 3 to 5 Mbps.

In the short term, you may be limited to home LANs that run over phone wiring. Microsoft and Tut Systems are championing this technology (Figure 2). Microsoft's endorsement of Tut's technology appears to be based on the technology's near-term viability. In July, Tut will begin shipping the HomeRun family of products. These products essentially use an Ethernet MAC (media-access controller) with a phone-line physical layer. The HomeRun physical layer becomes just another Ethernet physical-layer choice along with thin coax, 10BaseT, and Fast Ethernet. Initially, HomeRun products will support 1.3-Mbps rates over home phone wires, despite the prevalent free-form topology with numerous wiring stubs. The company asserts that HomeRun will work reliably, provided that less than 500 ft of wiring exists between any two nodes. The HomeRun transmission is frequency-isolated from the analog phone voice-band, so the wiring can simultaneously support voice and data. Tut claims its technology will also coexist with xDSL links into the home via phone wires.

Tut will offer HomeRun network-interface cards, ICs that integrate an Ethernet

FOR MORE INFORMATION...

For free information on the home networking products discussed in this article, circle the appropriate numbers on the postage-paid Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in EDN.

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Circle No. 333

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Intellon Corp
Ocala, FL
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www.intellon.com
Circle No. 339

Motorola
Austin, TX
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www.motorola.com/lonworks
Circle No. 340

Toshiba
Irvine, CA
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www.toshiba.com
Circle No. 341

The Training Department
Tucson, AZ
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MAC with a HomeRun physical layer, and stand-alone physical layers that work with other Ethernet MAC ICs. The network-interface cards sell for $140 not an unreasonable introductory price for a brand-new technology. The company claims that PC vendors will be able to ship HomeRun support in new PCs for less than $50 and ultimately see the price approaching $10. AMD began supporting Tut's technology in early May. The semiconductor vendor licensed HomeRun and will offer compatible ICs with all of its other Ethernet products.

Tut isn't the only company focused on phone wires. Start-up Epigram also plans to offer an Ethernet-like LAN with a phone-line physical layer. Epigram, however, believes that 10-Mbps rates are an absolute requirement for market success and plans to delay a product announcement until the company can economically reach that rate. Expect an announcement this year. Tut systems is also planning a 10-Mbps upgrade to HomeRun but indicates that a low-cost, shippable implementation might be two years away.

> Businesses are happy to pay $500 for a network-interface card that complies with the IEEE 802.11 wireless-LAN standard. The price doesn't meet consumer demands,

RF cost may hamper market

Meanwhile, RF LANs are shipping in volume in business applications. Network-interface cards that comply with the new IEEE 802.11 wireless-LAN standard typically cost around $500. Businesses are happy to pay that price to solve a difficult wiring problem or increase productivity. Restaurants are equipping servers with wireless-LAN units to take orders and transmit them to the kitchen. Unfortunately, the $500 price doesn't meet consumer demands.

The Home Radio Frequency Working Group (HRFWG, www.homerf.org), an industry coalition, is pursuing a low-cost RF LAN that can carry data and voice. The HRFWG consists of PC market leaders Compaq (www.compaq.com), Intel, and Microsoft, as well as leading companies from the networking and telecommunications markets. The group hopes to publish a specification this fall that defines a spread-spectrum RF physical layer, a MAC, and the Shared Wireless Access Protocol (SWAP). SWAP will allow companies to design interoperable products, such as

wireless-phone base stations with multiple handsets. The protocol will also be key to phone-call processing, such as unified messaging and call forwarding. At the same time, SWAP will allow Internet access from all linked nodes ranging from Internet phones to PCs.

The HRFWG borrowed from two established standards to create its MAC, physical layer, and SWAP specifications. The MAC and physical layer are essentially feature-reduced implementations of 802.11. The physical layer adopts the frequency-hopping spread-spectrum flavor that is one option in 802.11. The HRFWG will loosen oscillator and filter tolerances and support a range only equal to a typical home and yard. Meanwhile, the SWAP spec borrows heavily from the DECT (Digital European Cordless Telephone) standard for wireless-phone systems and local loops.

Proponents believe that by early next year the HRFWG work will yield a low-cost LAN capable of 1- and 2-Mbps rates. By then, the coalition predicts, IC vendors will offer compliant chip sets with a bill-of-materials cost of $20 the cost from antenna to digital bits.

Unfortunately, none of these home-LAN alternatives affords the data rates necessary to carry digital video streams. Yet, almost any view of a wired home of the future includes digital video delivered by satellite, cable, or digital versatile disk. Consumers will need a way to move those streams between living-room entertainment devices and also to other rooms with TVs or digital VCRs. Moreover, the modern PC enables video editing, so the PC needs to be connected as well.

The IEEE 1394 or Firewire standard solves the video-transport problem in the living room. The interface can carry data as fast as 400 Mbps with faster versions on the way. Unfortunately, 1394 supports only 5m-long cable between nodes, so the standard is unsuitable for use throughout the home. However, there is yet another industry group with ideas about a future home LAN. The Video Electronics Standards Association (VESA), which is responsible for some graphics-related PC standards, has formed the VESA Home Network Committee. It turns out that the manufacturers most concerned with a video-capable home LAN, such as consumer- electronics companies, were also active VESA members.

VESA s vision of the home LAN runs slightly contrary to the no-new-wires mantra repeated by Intel and Microsoft at recent developers events. It is obvious that a video-capable home LAN will require some new wiring. VESA considered several communication technologies, including Fast Ethernet, that could be routed over Category 5 twisted-pair wiring. The committee decided to develop a new

physical layer for 1394 that could support long cable runs and a star topology. The committee chose a new version of 1394 rather than Fast Ethernet because 1394 inherently supports isochronous services for video streams. Still, VESA home network nodes will be Internet Protocol (IP)-based.

In VESA's scenario, the new version of 1394 will serve as a backbone network for the home (Figure 3). The backbone will connect to broadband access networks via xDSL, terrestrial cable, or satellite. Inside the home, it will connect to what VESA terms component networks. These networks could include home automation and control networks, analog plain-old-telephone-system phones, traditional analog TVs, and next-generation digital TVs and VCRs. VESA doesn't preclude the power-line, RF, and phone-line LANs from connecting to the backbone as an auxiliary LAN.

Unfortunately, VESA's backbone is chronologically the farthest from reality and surely the most expensive approach to home LANs. Still, the committee hopes to have a spec available late this year. It is also working on a software spec for device control that lies on top of the IP network stack. The committee is considering borrowing CAL from the CEBus arena. CAL includes support for data channels and could easily serve as a software standard that allows VCRs, TVs, camcorders, and PCs to communicate. Some members of the committee would prefer to adopt a much less robust command set that Sony (www.sony.com) developed strictly for audio-visual devices. VESA may ultimately support both approaches. The consumer-electronics companies may come to realize that CAL provides far more capabilities and moves the home-automation industry along at the same time.

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Simplifying LAN software

Regardless of which LAN technologies make it to the home, it's clear the industry will need software that's much easier to configure than Windows 95 or even Windows 98. Microsoft has pledged to develop software layers that reside on an IP LAN that implement network plug-and-play. Currently, a user must enter data in more than 30 fields to configure a Windows LAN. Experienced users may find it trivial, but average consumers will find it impossible. Error messages use arcane terminology that can baffle even experienced users. The success of the home LAN may hinge on Microsoft's reducing the configuration of each node to a few steps with straightforward questions.

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