Home Networking: Extending Cable's Reach

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Abstract

Home networking offers the promise of distributing high-speed Internet access and entertainment media throughout the home. By pushing the Internet experience out to where non-technical users are, and by making the in-home cable system the anchor of a pervasive communications and entertainment experience, it can increase penetration and reduce churn.

Scientific-Atlanta has experimented with three different wireless standards and a variety of devices in order to understand how home networking can become a reality. Our experiments have highlighted several short-term obstacles that must be overcome as home networking becomes a routine and lucrative addition to an MSO's product offering.

Survey of Applications and Physical Media

What's It Good for?

Home networking is rapidly emerging as a key technology, a rapidly growing market, and a prime opportunity for forward-thinking companies. There are (at least) four distinct roles for home networks—routing video, routing voice (presumably over IP), routing data, and basic home automation functions. This is important because they have completely different bandwidth needs and realtime / quality of service constraints, as shown in the table below.

This chart indicates that several different uses for home networking exist, with widely disparate service requirements. A comprehensive home networking solution must take these factors into account. For example, power line networking may be widely adopted for home automation functions (such as climate control, appliance access, and home security) and phone line networking for data transfer.

Application	Bandwidth needed	QoS Guarantees?	Two-way?
Video: HDTV	19 Mbps	Yes	No
Video: DVD	3 - 9 Mbps	Yes	No
Video: MPEG-2	2 - 5 Mbps	Yes	No
Video: Videoconf.	30 kbps - 1.5 Mbps	Yes	Yes
Data: File Sharing	200 kbps – 10 Mbps	No	Yes
Data: Printing	60 kbps – 1 Mbps	No	No
Data: Web Surfing	80 – 250 kbps	No	No
Interactive Gaming	10-100 kbps	Yes	Yes
Audio: "Hi-Fi"	100 – 200 kbps	Yes	No
Audio: Voice	5 - 64 kbps	Yes	Yes
Home Automation	100's of bps	No	No

Table 1: Some Applications for Home Networking

One interesting point of this comparison is the "1 Mbps gap". Essentially all applications except video work well, or at least are usable, below 1 Mpbs. Broadcast-quality video, on the other hand, demands more than 1 Mbps. This highlights the importance of understanding what services subscribers will want from home networking as operators plan for the subscriber products and the infrastructure required to support home networking.

How Can I Connect?

There are seven ways to convey voice, video, and/or data inside a home. One, ultrasonic, will not be considered here. The remaining six are important and should be considered in an overall home networking strategy.

The six media are radio, infrared, phone line, power line, cable coax, and wired networking, as illustrated below in Figure 1.

Some of these media encounter serious limitations immediately. For example, wired networking (Ethernet and Firewire) require extensive rewiring (in the case of Ethernet) or only work over short distances (in the case of Firewire). Infrared is limited as a practical matter to line-of-sight and is really only possible inside a single room.

Cable coax can form a home networking backbone, and well-established standards exist for it, but it is limited by the number of outlets inside a house. Its role in home networking will grow in the future, but since it is so well-understood by this audience it will not be considered further.

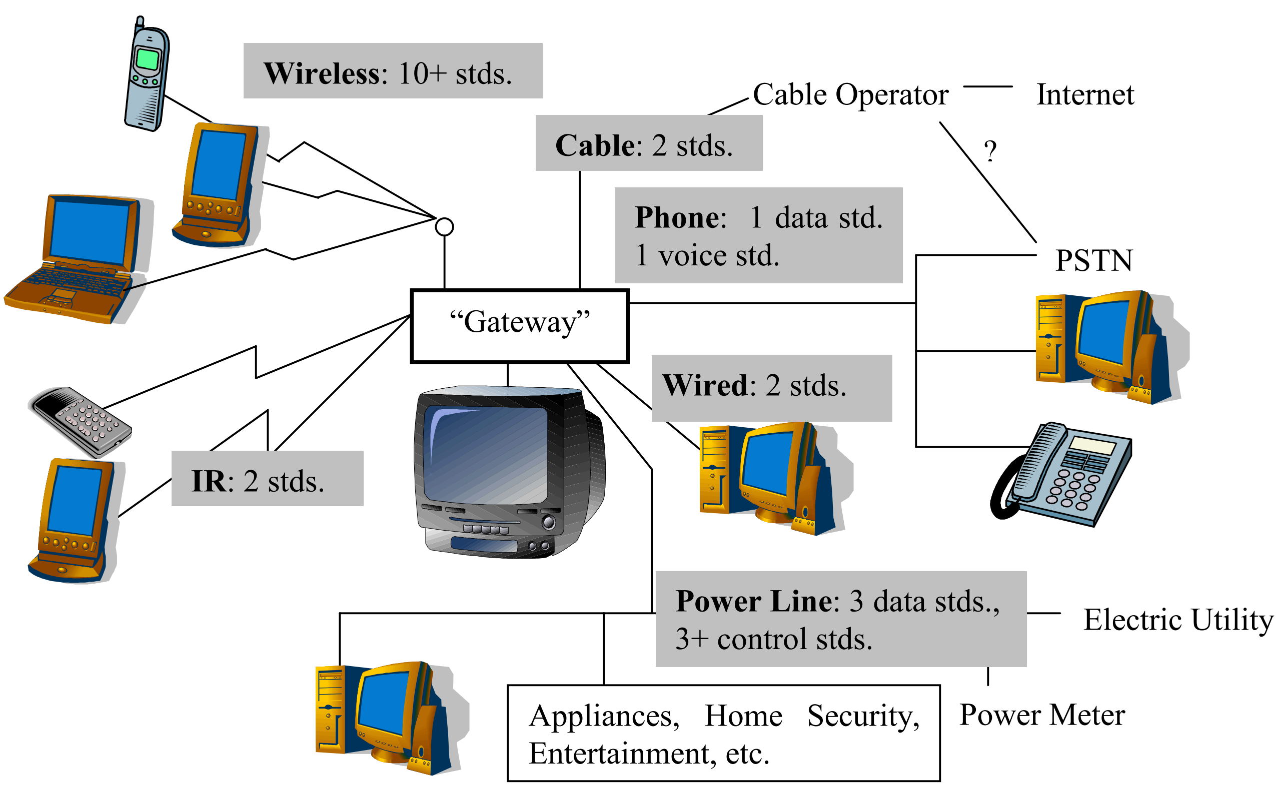

Figure 1: Home Networking Physical Media

There remain, then, three additional physical media to consider in developing a home networking strategy -- RF, phone line, and power line.

RF networking (or "wireless networking", which is a bit of a misnomer since IR is also wireless) is emerging as a powerful and flexible way to connect devices inside a home. It uses no new wiring and offers portability and ubiquity advantages over wired networking. However, it is not as foolproof as wired networking, and the market has been hindered by profound standards confusion.

There are three standards available today, Bluetooth, IEEE 802.11b (hereafter referred to as "802.11b"), and HomeRF, that are market leaders. Their capabilities will be discussed below.

Some of these wireless standards have interference problems with each other, although this is becoming less of an issue. Two of the major standards, Bluetooth and 802.11b, are being harmonized under IEEE 802.15.2, which may help solve some interference issues. Another source of reconciliation is a move towards 5 GHz networking, and many consider the way of the future to be 5 GHz 802.11a and 2.4 GHz Bluetooth.

Phone line networking takes full advantage of the inherent signal quality of twisted pair. It can routinely deliver tens of megabits per second (Mbps) around typical homes, making it a serious candidate for essentially all home networking applications. More importantly, there is a single, uniform, universally adopted standard – HomePNA. However, phone taps are limited, especially in Europe, and it always seems like set-top boxes are never near RJ-11 jacks.

Power line networking has the advantage of a truly ubiquitous network interface, and so is as convenient as wireless (unless you need portability). There is still confusion over the standards, and it is not even clear that all of the standards will work in the field. Proposed data rates are as high as 14 Mbps, but the usable bandwidth must be divided by the number of homes that share a transformer's secondary winding. (In the US this is typically 5-10 homes.) One concludes, then, that powerline is a serious candidate for applications requiring 1 Mbps or less.

Commonly discussed multi-Mbps powerline standards include HomePlug and Adaptive Networks' solution. Both are in prototyping and field-trial stages.

Our Experiments

Scientific-Atlanta assembled a series of experiments in the area of wireless (RF) home networking in order to demonstrate capabilities and to learn first-hand the requirements for a complete product offering.

First, we connected an Intel AnyPoint HomeRF-based access point through an Explorer set-top box's USB port. This enabled the delivery of 1.6 Mpbs of TCP/IP to a remote portable client. The portable client, in this case a laptop, was able to browse the web and watch low bitrate movie trailers. These trailers typically use around 300 kbps and are CIF or QCIF resolution screens. The sustained throughput of HomeRF is actually about 550 kbps; 1.6 Mpbs is the physical layer symbol rate and neglects effects such as error correction and packet header overhead.

The system was decidedly popular at a cable trade show. One non-technical user even commented that while he currently lived outside of one of Scientific-Atlanta's customer's coverage areas, he would move into their service area if they launched wireless web access!

Second, we connected a set-top to a Bluetooth-enabled web tablet made by Ericsson. Bluetooth was routed into the set-top through an external attachment for demonstration purposes. The web tablet was able to display a program guide, and selections made on the web pad changed the set-top's channel. This demonstrates the ability of wireless peripherals to operate two-way and to function as a remote control. Note that the Ericsson product was also able to browse the web, although Bluetooth provides a relatively lower 721 kbps bitrate. This sort of remote control application is exactly the type of short-range, low-bitrate application that the designers of Bluetooth had in mind.

Third, with help from Intersil, we put an 802.11b access point inside an Explorer 8000 set-top. We encoded the set-top's tuner output using 1.5 Mbps MPEG-2 and transmitted it via the access point to a remote laptop. The remote laptop simultaneously displayed a live web browser, a functioning MP-3 player, a live video screen, and a working remote control. The remote control tuned the set-top, activated the program guide, and can even work with interactive set-top applications like pizza on demand. A screen capture of the demo is shown below in Figure 2.

The three demonstrations were actually laid out side-by-side at the trade show (against the advice of engineers) and actually interoperated fairly well. The three displays had to be kept near their respective access points, and carrying one display next to another access point did disrupt the traffic, but it did highlight that non-interfering operation may not be as difficult as some fear.

Figure 2: Screen Capture of Scientific-Atlanta / Intersil 802.11b Demonstration

Capabilities of Existing Systems: How They Can Help MSO's

These demonstrations highlight four key advantages of home networking.

First, basic web access can be pushed out to where non-technical users are. This is an extremely important paradigm shift. Think about technophobes like my wife. They hate using the Internet because the computer is off in a back room and, if they rely on dial-up, there is a lengthy and annoying process to get connected. Wireless networking through a DOCSIS channel changes all that because wireless is available anywhere and DOCSIS is always-on. This is one strength of DOCSIS-based home networking that may increase penetration rates of digital cable.

Second, subscribers purchase the peripherals that hang off of the home wireless network, such as extra PC and PDA network adapters and wireless appliances like MP3 players. Once they have purchased the peripherals, they will be strongly motivated to keep their existing service. Thus home networking is a powerful churn-reduction tool.

Third, deploying the infrastructure enables lucrative services. For example, the MP3 player we showed in the Intersil 802.11b demonstration foreshadows possible new subscription services.

Fourth, home networking is on the verge of being able to deliver broadcast-quality video in the home. The existence of the cable industry is proof that video offers tangible revenue streams, and this is emerging as a new way to distribute video content.

Limitations of Existing Systems: Lessons Learned

These demonstrations raised several key issues related to the "productization" of home networking.

Fire Hose or Soda Straw?

The first issue that comes up is bandwidth. As seen in the first table, subscribers' bandwidth needs are highly application-dependent. Some networking standards are not suitable for all applications.

For example, phone line is currently the only technology with ample bandwidth for video, and 802.11b is the only open standard in the wireless world that has barely enough bandwidth for video. (There is one proprietary system, ShareWave WhiteCap, which increases the usable bandwidth available for video delivery).

The answer to the question "how much is enough?" is simply "it depends on what you want to do with it." In the video-centric world of cable, however, home networking is really only barely able to deliver video right now.

The IEEE 802.11a standard is on the horizon; most expect it to be generally available by the end of 2001. It features a substantial increase in bandwidth that, coupled with the quality of service (QoS) features added by IEEE 802.11e, may well enable practical multi-channel wireless video delivery in the home.

Hey, I'm Trying to Talk!

The 802.11b demo highlighted the need for quality of service in delivering video. The 1.5 Mpbs MPEG-2 was selected simply to leave enough bandwidth margin for web browsing and MP-3 in the absence of QoS. (We have to be honest here – 1.5 Mbps is not broadcast quality, which is why this was a demo and not a real product.)

Note that "quality of service" in the context of broadcast-quality video implies not only reservation of bandwidth but also guarantees and bounds on packet jitter. Web browsing over the corporate LAN, which boosts the peak bandwidth of a web page download, can disrupt the demo's video panel, for example, because it does not leave enough free bandwidth for video. Likewise, attempting to display a movie trailer in the demo web browser panel completely wipes out the demo video panel.

By the way, in the case of 802.11b this is being handled two ways. First, the IEEE 802.11e standard is being constructed to reserve bandwidth on an 802.11b channel. Second, proprietary standards such as ShareWave WhiteCap are also available.

Perform Steps 1-37 in Painstaking Detail

Finally, we learned through the process of nailing up trade show demonstrations that installing, maintaining, and administering home networks are going to be hard. Do set-tops have to run DHCP? What about DNS and NAT? Do they run Firewalls and, if so, how much more expensive is it to run firewall (because of increased memory and processor demands)? What happens when there is interference on the currently selected 802.11b channel? Who decides there needs to be a channel-change? How does the operator know the state of the 802.11b access point, and how does the operator change the settings? Thankfully these and a myriad of other small but important details are being taken up in the CableLabs' CableHome home networking forum.

Where We Need to Go: Conclusions and Future Work

By exploring various technologies and various product form factors, it became clear that home networking is nearing fruition, but not quite ready yet. Various standards-making efforts, including those supporting systematic support of home networking (CableHome) and those adding quality of service to Ethernet-based protocols (IEEE 802.11e) can close the gap. Practical home networking will soon be in a position to be a valuable addition to MSO product offerings.

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