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# An Introduction to Home Networking

Author: Amit Dhir, Krishna Rangasayee

## Summary

Once connected, consumers find innumerable uses for their home networks. Sharing in-home appliances to provide faster Internet access has proven to be the main motivator for consumers installing a new home network. Telecommuters, knowledge workers, students, and families are some of the groups of people that are at the forefront of the home networking revolution.

The ultimate goal of a home network is to provide access to information, such as voice, audio, data, and entertainment between different digital devices around the house. Home networking allows users to communicate and interact anywhere at anytime. This new and emerging technology will bring the Internet to the hands of the consumers, to every appliance in the house, and help interconnect people across the globe. It allows access to homes via the Internet when one is away, enabling security and energy management. Home networking is really a three part equation offering entertainment, information, and automation services that are distributed between appliances in the home.

## Introduction

The integration of computer and smarter chips into next generation, everyday consumer devices is one of the major factors that is driving the home networking market. The home network enables the distribution of data, voice, and video between different consumer devices. Our cars have had intelligent consumer devices for years—now our children's toys, our kitchen appliances, and our living room entertainment systems have computing power that rivals previous generation desktop computers. This white paper provides a brief overview of how convergence of technologies and digitization of appliances are fueling the demand for home networks.

Opinions vary over the exact definition of what constitutes home networking. Xilinx has created its own definition of home networking. Our definition, coupled with motivating factors and profiles of people who are adopting home networks, is also covered in this white paper. We will present data on the expected size of this new market and list the architectural components of these types of networks. This white paper concludes with a brief overview of digital homes and how Xilinx products enable this new and rapidly evolving computing paradigm.

## Convergence and Digitization

We are transitioning from an industrial-based analog economy to an information-based digital economy. The momentum for this transition is been fueled by a number of converging factors.

- **Converging media:** Digitization of data, voice, video, and communications is driving consumer product convergence. Convergence is happening in everyone's backyard with incredible computing power being embedded within everyday consumer appliances. The digital revolution, be it from vinyl players changing to MP3 players or from analog TV to digital TV, is occurring very rapidly. Data, video, and voice can now be transmitted over the same backbone due to the digital revolution.
- **Internet based lifestyles:** As quickly as the Internet came into our lives it has become omnipresent. Families are becoming more aware of how the Internet can be used in their homes, and companies are also increasingly using it as a commercial channel. The Internet serves as the technology platform that enables an entirely new generation of consumer applications, including voice and video communications, e-commerce solutions, personalized news services, home security and automation, utilities resource management, and entertainment title distribution. The availability of such a wide variety of applications is changing the way people relate to the Internet itself.

"Internet Lifestyles" is a new way of thinking that has resulted in the formation of an organization called the Internet Home Alliance. The principle behind this new organization is that consumers want to enjoy the benefits of the Internet lifestyle without worrying about the technology that enables it to work. The Alliance is bringing new levels of comfort, convenience, and security by creating the necessary infrastructure. Installation and support from various companies provide integrated services, eliminating the need for multiple points of consumer contact.

- **Deregulation:** There is a heavy deregulation of global infrastructure industries such as telecommunications, utilities, and cable. These companies are developing new ways of improving their business by using the Internet and increasing revenues through additional services to the home.
- **Digitization of consumer products:** For some time now, there has been a trend towards the digitization of consumer products. A product that is digital is one which is synonymous with higher quality, greater accuracy, higher reliability, faster speed, lower power, and lower cost. Simply stated, anything that is digital is better. The digitization of consumer products has not only led to the improvement of existing products, but it has also lead to the creation of a whole new class of products that never before existed. PVRs (Personal Video Recorders) are revolutionizing the way we watch TV, satellite modems are bringing faster Internet access to the home, and MP3 players have revolutionized portable digital music.

## The Connected World Improves Productivity

Humans, by nature, have an innate urge to stay connected, share information and news, and collectively enhance our understanding of the world. The term connected society has become more appropriate with the Internet era. The Internet by far has had the fastest adoption rate of any communication medium. In a brief span of five years since its inception, more than 50 million people were connected on the Web. And today, we have more than 400 million people worldwide connected and sharing information through the Internet!

This communication media connects people and helps enhance productivity. After the transatlantic cable was laid in the 19$^{th}$ century, it helped reduce the communication gap significantly and made communication relatively cheaper. The introduction of the telephone in the mass-market was a major improvement in connecting people and offered a better and more affordable alternative. However, it still cost over $15 a minute and took two seconds to connect. The Internet today has allowed us to communicate in less than 30 milliseconds (ms) and for free! Whether it is through data, voice, or video, the Internet has brought people closer together and helped make corporations and businesses more efficient.

The 1980s were the era of PCs and they contributed to improving the productivity of corporations. The late 1990s has been the Internet/communications era and has taken productivity to unprecedented levels. The Internet era has brought together a tremendous revolution in the way we communicate, share information, perform business, and eventually the manner in which we live our lives.

This opportunity to be connected has helped improve productivity extensively. The process of a banking transaction in person costs a bank a $1.07 to process, while the same transaction costs just a penny when completed online over the Internet. This translates to reduced time, lower cost, lower investment in labor, and convenience to the consumer. FedEx has indicated in reports that the company would need 20,000 customer service employees to replace its online service. E-mails have become an established, non-intrusive way of communicating with people. In 2000, over 6.9 trillion e-mails were exchanged. Never have we communicated so much with each other in the history of mankind. These examples, illustrating productivity acceleration, imply that there is a need to increase bandwidth to accommodate demands.

The productivity acceleration we see today can be sustained only by increasing the bandwidth requirements of the networking infrastructure. John Sidgmore, COO of MCI WorldCom, quoted that "Bandwidth demand increases by 1000 percent every year." There is an insatiable demand for bandwidth that networking solution providers are scrambling to satisfy, leading to tremendous advances in connectivity and productivity.

With the increase in the bandwidth requirements, every aspect of networking is evolving—whether it is the backbone (wide area networks [WAN]), metropolitan area networks (MAN), the local area networks (LAN), or the small office-home office (SOHO). Networks of all sizes are being upgraded with faster technologies to achieve better performance.

The WAN backbone is migrating from 10 Gbps (OC-192) to 320 Gbps using technologies such as carrier-class routing and dense wave division multiplexing (DWDM). Metropolitan area networks are upgrading from 100 Mbps to 2.5 Gbps (OC-48) speeds using Synchronous Optical NETwork (SONET) and metropolitan DWDM technologies. The LAN technologies are employing Asynchronous Transfer Mode (ATM) and Gigabit Ethernet to achieve performance of 1 Gbps. SOHOs are upgrading from analog dial-up modems to cable and DSL modems to achieve rates of over 1.5 Mbps.

The demand for increased bandwidth is forcing a fundamental change in the networking infrastructure and this change is extremely rapid. The only thing constant about this phenomenon is change. Today's networks are demanding higher performance, scalability, upgradeability, increased security, product differentiation, and lower cost of ownership. Leading networking solution providers are scrambling to service the needs of this constantly changing marketplace. Xilinx solutions are the "story behind the story" and critical to the success of the networking solution providers. Xilinx provides silicon, software, Intellectual Property (IP), and services that add tremendous value to networking customers. These features provide solutions to help our customers manage chaos.

The dynamics affecting the networking industry are playing out in the homes and as well as the SOHOs. Consumers are demanding faster access to the Internet and to network appliances. There is an invasion of information appliances such as set-top boxes, MP3 players, digital TV, etc., in the home today. There is increased digital content such as online shopping, MP3 files, digitized photographs, and video-on-demand. A combination of these factors are bringing the digital revolution into the homes of the consumers.

## Digital Revolution Fuels Growth in the Consumer Electronics Sector

According to a recent report by the Consumer Electronics Association (CEA), sales of consumer electronics goods from manufacturers to dealers will surpass $95.6 billion in 2001. The total for 2001 will set a new annual sales record and represent a six percent increase over the 2000 total, making 2001 the ninth consecutive year of growth for the industry. The spectacular growth in sales of consumer electronics this year is due in large part to the wide variety of products made possible by digital technology.

One of the categories most affected by the digital revolution has been in-home appliances. This sector includes technologies that allow consumers to work anywhere and at anytime. According to the new CEA estimates, the home information category will grow by 3.3 percent in 2001, with total sales of more than $39 billion.

The other category most greatly affected by the digital revolution has been mobile electronics. Digital technology has vastly improved the ease with which consumers can access information and entertainment as well as stay in touch with friends and family. Sales of mobile electronics are projected to reach $10.5 billion in 2001, an eight percent increase over 2000. CEA also predicts strong growth in the video appliance category in 2001, with products such as digital televisions, camcorders, set-top boxes, personal video recorders, and DVD players leading the charge.

## What is Home Networking?

From a purely technical perspective, a home network connects a number of devices or appliances within a small geographical area (home, SOHO). A home network improves communication and allows the sharing of expensive resources among members of a family. A home network consists of a number of components, which may be divided into two basic categories: hardware and software. It has evolved from its roots in automation and security and has come to include the distribution of audio, video, and data content around the home. Home networking is also the interconnection and interoperation of different home electronic appliances, entertainment devices, PC hardware, and telecommunication devices. In general,

home networking is all about the convergence of voice, video, and data, and their associated appliances in the home.

## Motivations to Network a Household

For the vast majority of people, the prestige of being up to date with their nearest neighbor is not enough to motivate the installation of new home networking technologies. So, what are the motivating factors that encourage people to network different classes of household appliances and computers together?

- **Leverage existing investments**: First and foremost, people want to leverage their investments in expensive appliances such as computers, set-top boxes, personal video recorders, digital cameras, and cable modems. Hence, sharing hardware resources is the number one motivating factor for consumers investing in new home networking interconnection technologies.
- **Shared Internet access**: The second most popular motivating factor fueling the deployment of home networks is shared Internet access. Home networks, in conjunction with devices called media gateways, allow different members of a family to simultaneously use a single, fast Internet access, thus saving money.
- **Interconnecting subsystems**: Other motivating factors include the ability of a home networking infrastructure to interconnect different types of subsystems together. For example, home security systems are also defined as a network, but instead of interconnecting devices like printers and PCs, in-home security networks connect different types of sensors to a central controller. Integrating this type of network with an existing PC-based home network helps people expand the functionality of their security system and better manage different subsystems.
- **Rise of multi-PC households**: The rapid growth of multi-PC homes indicates that the number of nodes in a PC network will continue to skyrocket as home networking appliances are introduced. Also, sharing PC peripherals (such as printers and scanners) between multiple PCs provides cost savings.
- **Evolving in-home applications**: File sizes of typical personal computer applications are growing rapidly with each generation of standard software applications. For example, the file size of a Powerpoint demonstration with the same content has doubled over the last few years. Graphics and digital photography over e-mail are now commonplace. Also, distributing video, MP3 files, and other digital content between information appliances is gaining importance.

Figure 1 shows the appliances that are driving home networking.

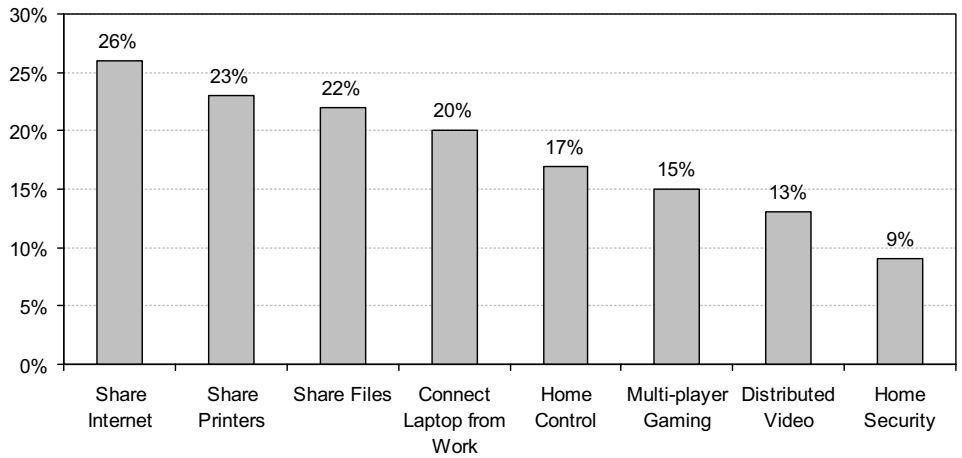


*Figure 1:* **Applications Driving Home Networking**

## Consumers Demand Corporate User Requirements for the Home

The end users of a home network demand a different set of requirements than traditional corporate network environments. These requirements include:

- **Ease of use, low complexity:** Unlike a corporate network, there is no network system administrator or MIS department in the home. As a result, home networking must be easy to use and simple to install. A home network must be “invisible,” providing seamless operation with little or no user intervention or maintenance.
- **Reliability:** Similar to corporate networks, home networks must be reliable. The network needs to resolve interference from other home networking devices as well as common household appliances, such as microwave ovens and cordless phones.
- **Scalability**: As consumers begin to buy home networking products, scalability must be considered, even with their first purchase. Scalability results in a lower lifetime cost to the consumer. Buying a network device is not a single product purchase; it establishes the foundation for an entire home network. Consumers who make informed decisions would avoid purchasing technology that will soon be obsolete. A home network needs to maintain interoperability and accommodate future applications to protect the consumer's initial investment.
- **Standards compliance:** Industry standards are crucial for enabling mainstream consumer adoption of home networking products. This has proven a powerful factor in fueling the proliferation of corporate networks.
- **Support for high-bandwidth multimedia content**: Most applications and data types that traverse a corporate network have relatively low bandwidth requirements. In contrast, home networks will have to support all types of bandwidth intensive digital content. Existing and emerging digital devices such as televisions, DVD players, digital video recorders, digital audio/MP3 players, DBS systems, flat-panel displays, digital set-top boxes, and PCs create the need to support multimedia content in the home. The ability to support multimedia is the “killer app” that will drive the mass adoption of home networks.
- **Cost**: Consumers, unlike corporations, will never pay high prices for home networks, information appliances, or broadband access. New business models will evolve to grow home networks.

### Profiles of People Adopting Home Networking Technologies

Despite the fact that millions of people around the world will become home networked in the next five years, members of this new and evolving group may be further classified into the following profiles.

- **Home office workers**: According to a study by the International Data Corporation (IDC), nearly 50 million households in the United States alone will include rooms that are dedicated home offices.
- **Telecommuters**: Market technology consultants at Dataquest-GartnerGroup predict that over one-third of the workforce in the U.S. will engage in part-time telecommuting. This trend is mirrored throughout the world with workers using dial-up and broadband connections to remotely connect into corporate networks.
- **Self-employed knowledge workers**: Software engineers, Web designers, free-lancers, graphic artists, and other self-employed professionals work from home and enjoy the flexibility that home networks offer.
- **Students**: Information technology, the Internet, and education are inextricably linked to each other. Students are, almost by their very description, interested in and study the Internet and in-home networking technologies.
- **Families**: Home networking offers many enticing benefits for members of a family. Children, for instance, use home networking technologies to access different types of learning resources on the Internet while parents use the same network to access information (such as weather, stocks, etc.) and monitor their children.

## Market Overview

The home networking market is changing very rapidly. Figure 2 presents an overview of the types of companies and organizations involved in managing this change and developing the global home networking industry.

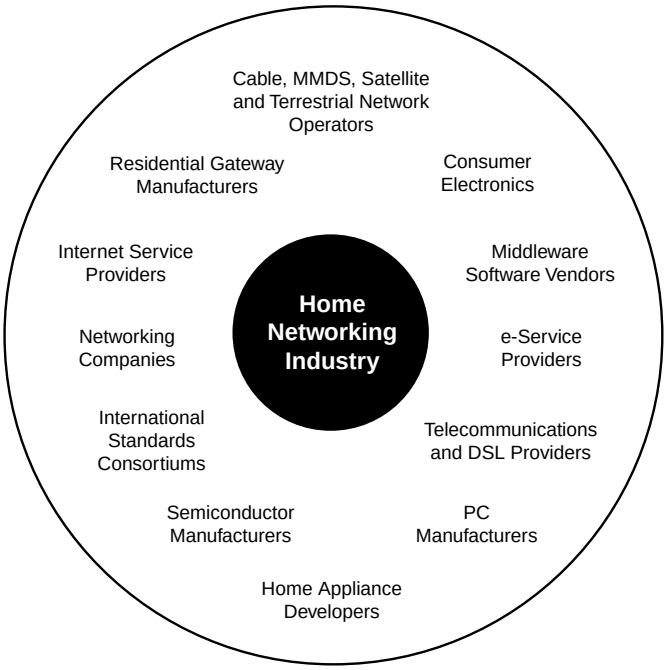


*Figure 2:* **Home Networking Industry Overview**

## Architecture of Home Networking Systems

Home networking is in fact a four-part equation defined by broadband access, residential gateways, home networking technologies, and information appliances (see Figure 3). The middleware software is also a key component of the home networking market.

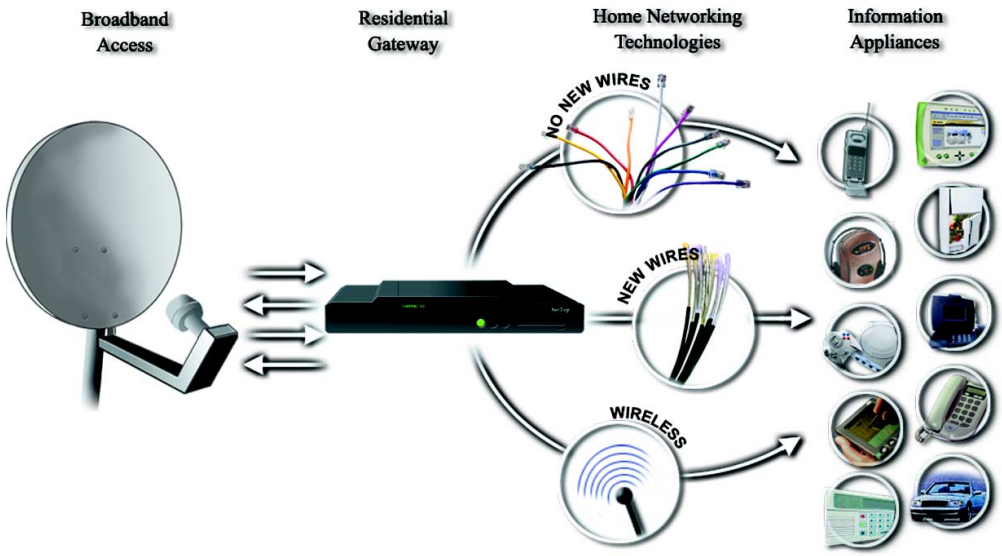


*Figure 3:* **Architecture of a Home Network**

### Broadband Access

Digital broadband access to the home has revolutionized communication by providing a very fast, two-way communication channel. Internet access and the ability to transmit real-time

audio and video anywhere at anytime is a revolutionary concept helping drive broadband access to the home. Rapid technological advances have immensely extended the list of possible broadband platforms that consumers can use to access the Internet. Solutions available include xDSL, cable, powerline, satellite, and wireless platforms.

### Media Gateways (Residential Gateways)

The media gateway (MG), also known as a residential gateway, is the interface device that connects the broadband access technologies to the in-home network, effectively bringing a bidirectional communications channel to every networked device in the home. Since it serves as the centralized access point between the home and the outside world, the media gateway represents an important strategic technology. Additionally, the MG serves as the convergence point that bridges the different broadband and LAN technologies. Another important function of the MG is to serve as an access platform through which service providers can remotely deploy services to the home via the Internet.

### Home Networking Technologies (Information Appliance Network)

The Information Appliance Network (IAN) consists of high-speed in-home data networking technologies that distribute Internet access to ubiquitous access points and appliances. The IAN provides interconnectivity for all home appliances. A wide variety of technologies exist for interconnecting devices within the home, but no single technology meets all of the requirements for the diversity of applications that will be created. While traditional Ethernet systems offer a robust and proven solution, most consumers do not have the time, interest, or knowledge to rewire their homes.

Fortunately, the emergence of “no new wiring” technologies offers possibilities for solving the mass-market home networking issue. New technologies include wireless, phoneline, and powerline solutions. Since each solution presents distinct benefits and drawbacks, many organizations are beginning to suggest that all of these technologies will co-exist in a multi-layered home network architecture. Types of home networking technologies are:

- **No New Wires:** Phonelines, powerlines
- **New Wires:** Ethernet, optic fiber, USB/USB 2.0, IEEE 1394
- W**ireless:** HomeRF, Bluetooth, wireless LANs (IEEE 802.11, HiperLAN2)

### Information Appliances

These intelligent devices have the ability to communicate and interoperate using the IAN. In cases where the IAN is connected to a broadband access, these devices will be able to connect to the Internet. Networking these digital appliances will bring improved convenience and flexibility for the consumer. The functional requirements of digital appliances are:

- **Ubiquity:** Prevalence of network access points
- **Reliability:** Operational consistency in the face of environmental fluctuation such as noise interference
- **Cost:** Affordable for mass market
- **Speed:** Support high-speed distribution of media rich content
- **Quality of Service (QoS):** Must support scalable QoS levels for application requirements of individual devices
- S**ecurity:** User authentication, encryption, and remote access protection
- **Remote management:** Ability for external network management (queries, configuration, upgrades)
- **Ease-of-use:** Operational complexity must be similar to existing technologies, such as TVs and telephones

These information appliances include: PCs, printers, scanners, Web pads, MP3 players, kitchen pads, digital VCR, gaming consoles, set-top boxes, DVD players, digital TVs, IP phones, utility meters, security cameras, etc.

### Middleware

Universal Plug and Play (UPnP), Home Audio Video Interoperability (HAVi), Jini, and Video Electronics Standards Association (VESA) are competitors in what is called the middleware market. Middleware operates between the operating system and a home networking application. It allows home networking users to run applications that are independent of the underlying hardware platform.

## Market Analysis Data

With the advent of high-definition television, computers, Internet access, and rich entertainment systems, consumers are spending more time than ever in their homes. People spending more time at home is fueling the demand for convenience and flexibility, which in turn leads to a demand for home networking technologies.

Home networking is projected to be an extremely fast growing sector in next couple of years. In fact the market research company, Cahners In-Stat, estimates a growth rate of 500 percent over the next four years (see Figure 4). As shown in Figure 5, Cahners In-Stat predicts that worldwide the home networking and residential gateway market will exceed $5 billion by 2004.

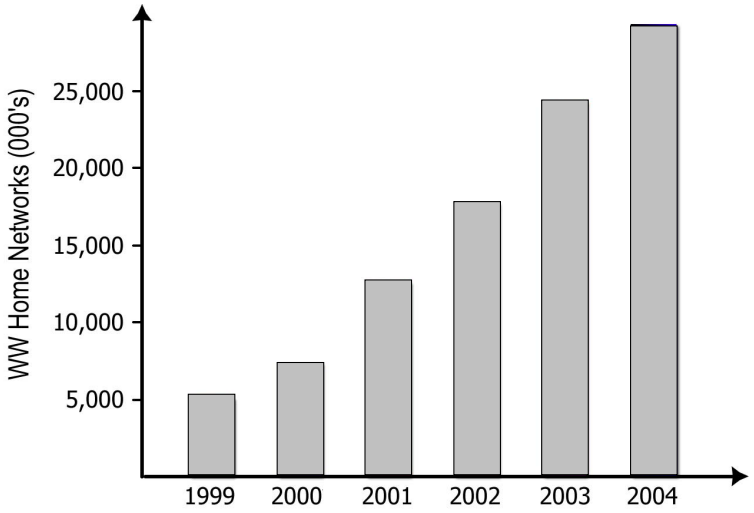


*Figure 4:* **Worldwide Deployments of Home Networks (Source: Cahners In-Stat Group)**

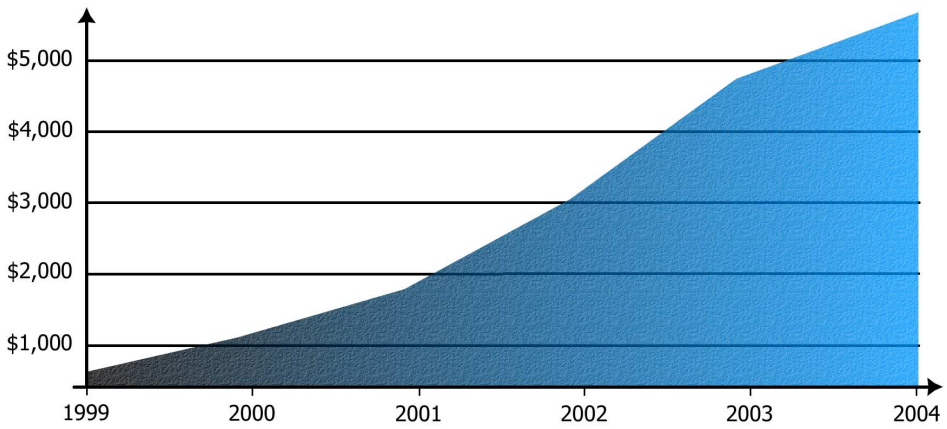


*Figure 5:* **Worldwide Home Network and Residential Gateway Forecast (Source: Cahners In-Stat)**

## Emergence of Digital Homes

The concept of a digital home has taken a long-time in becoming a reality. For the past few years, most homes used only a single PC for accessing the Internet, sharing files, and accessing a printer. With the expansion of Internet applications, such as web browsing, e-mail, and web messaging, more homes are moving towards using multiple PCs and other types of networked appliances. The demand for bandwidth is bringing broadband connectivity to the "last mile" of the house. However, homes today have a myriad of disparate electronic ecosystems, including:

- PC centric ecosystems that comprise of modems, scanners, digital cameras, and printers connected to a localized network
- Multimedia centric ecosystems that comprise of set-top boxes, digital televisions, digital video recorders, speakers, stereos, and DVD players
- Wireless centric ecosystems that comprise of personal digital assistants (PDAs) and mobile phonesets

In the near future, homes will have a single broadband connection bringing information to and from the house. The ecosystems within the home will be connected enabling Internet access to a multitude of digital devices. Xilinx believes that the evolution to a fully-integrated digital home will take place in three separate stages (Figure 6).

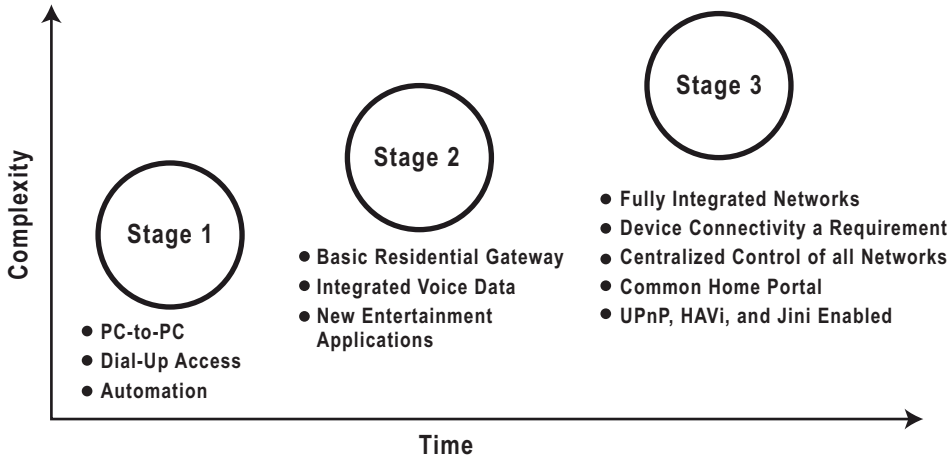


*Figure 6:* **Migration to Digital Homes**

Stage one is already prevalent in millions of households around the world. This normally includes a simple computer-to-computer connection, a dial-up connection to the Internet, and some type of home automation system.

Migration to stage two of a digital household has commenced in some corners of the world. This evolution has included the installation of a basic media gateway (a digital set-top box or a broadband centric modem) and the use of new entertainment applications. At the moment, stage three is a vision for the future where consumers will be able to connect and communicate at anytime from anywhere.

Several organizations and companies around the world are developing technological standards and products to encourage consumers to upgrade their households to a fully integrated digital home. This final stage of evolution will include a tighter integration of data, video, and voice services. Home networking software and middleware will play a primary role in connecting various types of digital appliances together, regardless of their brands and manufacturers.

## Xilinx—Enabling Home Networking Products

For years, Xilinx has enabled networking equipment in wide area networks, metropolitan area networks, local area networks, and broadband access devices. This has brought the Internet connectivity to countries, cities, corporations, and now in the hands of consumers. Xilinx products have also enabled the consumer digital revolution with solutions in set-top boxes, DSL modems, and digital TV. The programmable logic solutions enable faster time-to-market and longer time-in-market in this quickly evolving industry.

The networking infrastructure and home networking industries are experiencing similar dynamics, except that cost is a critical factor for home networking products. Xilinx product solutions help address the issues in developing home networking products by providing time-to-market (and thus shortening design cycles), flexibility for evolving standards and product differentiation, higher performance cost sensitivity, and field upgradeability.

While Xilinx field Programmable Gata Arrays (FPGAs) have historically been relegated to less cost sensitive applications, the price of FPGAs have reduced significantly. With the introduction of the new Spartan™-II product family, Xilinx is able to offer a device with 100,000 system gates today for under $10. The same FPGA cost $1,000 five years ago. The Spartan-II product family provides higher density, higher performance, and is feature rich for cost-sensitive applications. This enables Xilinx FPGAs to be used in new applications such as home networking.

There is also chaos in the home networking market. Connecting consumer devices within the house brings three choices to network the home depending on the consumers needs.

Most consumers would prefer to use the existing wires within their homes. Powerlines and phonelines are the dominant “no new wires” home networking technologies. The advantage of “no new wires” is that the consumer does not have to rewire the home, and new Internet appliances can be connected immediately. Taking advantage of the existing wires such as phonelines and powerlines, however, limits the ability to deliver high-speed video and other high-bandwidth applications.

For delivering high-speed data and video packets, new wire technologies such as Ethernet (IEEE 802.3), IEEE 1394, Optical Fiber, or USB 2.0 are required.

However, all of these technologies require additional special wiring around the house. Wireless technologies such as Bluetooth, HomeRF, IEEE 802.11, and HiperLAN2 can be used in areas where we can not take advantage of the existing wires or cost can not be justified for additional wiring. Wireless allows mobility, but bandwidth remains an issue. Bluetooth is a very popular personal area network technology that has been gaining momentum with huge industry backing. IEEE 802.11a and HiperLAN2 are focussing on telecommuters, SOHO, and hospitals to make there biggest impact. HomeRF remains focussed on transmission of voice and data to the home.

There are many different home networking technologies and standards. To further complicate issues, each technology has different specification versions, and the standards continue evolving to add more functionality, bug fixes, and adaptation of new standards. This creates an environment that guarantees unanticipated problems such as bugs and incompatibilities.

This chaos also translates to a steep learning curve. It virtually and eventually mandates a “ready, fire, aim” development model. Products should be planned for the longest life cycles for multiple geographical markets and should get to market as fast as possible (now). Products also need to be manufactured to accommodate rapid integration and enhancement.

Application specific integrated circuits (ASICs) and application specific standard products (ASSPs) cannot meet the consumer market requirements. Short product life cycles do not make manufacturing of ASICs a cost effective proposition. Changing standards, multiple standards, and rapidly evolving features make programmable logic (FPGAs) the natural fit for the consumer world. The price points offered by Spartan-II FPGAs from Xilinx are perfect for this cost-sensitive and quickly evolving market.

Apart from providing solutions to enable home networking products, Xilinx also provides a dedicated portal (eSP™) which includes comprehensive information and solutions to help accelerate design of digital consumer products that are based upon emerging standards and protocols.

## Revision History

The following table shows the revision history for this document.

| Date | Version | Revision |
|---|---|---|
| 03/21/01 | 1.0 | Initial Xilinx release. |