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# Wireless Home Networks — DECT, Bluetooth, HomeRF, and Wireless LANs

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## Summary

A wireless home network is an intriguing alternative to phoneline and powerline wiring systems. Wireless home networks provide all the functionality of wireline networks without the physical constraints of the wire itself. They generally revolve around either IR or radio transmissions within your home. Radio transmissions comprise of two distinct technologies—narrowband and spread-spectrum radio. Most wireless home networking products are based upon the spread-spectrum technologies. To date, the high cost and impracticality of adding new wires have inhibited the wide spread adoption of home networking technologies. Wired technologies also do not allow users to roam about with portable devices. In addition, multiple, incompatible communication standards have limited acceptance of wireless networks in the home.

## Introduction

While several "no new wires" and "new wires" options exist to network the home, there are people who want to wander around their homes while having continual access to the home network. The new demand for a greater degree of mobility and flexibility has an obvious solution—wireless interconnection technologies.

Market research analysts are predicting that wireless network technologies will eventually become more widespread than the various wired solutions. A large technology consulting company Strategy Analytics, has forecasted that 19 percent of the households in the U.S. and 15 percent of European households are expected to have wireless home networks by the year 2005.

Wireless communications present the ideal solution for the home network, but these solutions have a variety of technical and deployment obstacles. This white paper explores the consumer applications and basic principles associated with deploying a home network using current wireless technologies. This paper also presents you with a detailed description of DECT, HomeRF, Bluetooth, and Wireless LAN technologies.

## Introducing Wireless Home Networking

Wireless home networking solutions satisfy the following four specific demands:

1. No new wiring infrastructures
2. The solutions must also be simple to install and easy to use
3. Interoperability with other networks such as phoneline-based home networks is also essential
4. Solutions need to be economical and home security cannot be compromised

Deploying a wireless network in a household brings a set of advantages and disadvantages. On the plus side of wireless home networking technologies, wireless solutions provide consumers with the ability to access data from anywhere at anytime. Cost is the main disadvantage of deploying a wireless home networking solution. Distances are also of concern for consumers who own large households. Wireless also brings an added worry about security. Eavesdropping on a wireless network is much easier because there is no physical connection.

## Basic Principles

Most home networks are linked over a physical medium. However, physical media can be:

- Expensive
- Inflexible
- Error- or failure-prone

Inflexibility is often a significant problem that can be easily overcome by wireless communication. Wireless solutions are ideal platforms for extending the concept of home networking into the area of mobile devices around the home. Consequently, wireless technology is portrayed as a new system that complements phoneline and powerline networking solutions. It is likely that wireless technology will not emerge as a home network backbone solution, but will instead serve to interconnect the class of devices that need mobile communications into a sub-network.

These mobility sub-networks will interface with other sub-networks and with the Internet by connecting to the home network backbone. Wireless home networks transmit and receive data over the air, minimizing the need for expensive wiring systems. With a wireless-based home network, you can access and share expensive entertainment devices without installing new cables through walls and ceilings.

At the core of wireless communication is a device called a transmitter and one called a receiver. The user interacts with the transmitter—for example, one of the children inputs a Web address into their PC. This input is then converted by the transmitter to Electromagnetic (EM) waves and sent to the receiver (which could be built into the set-top box) and then processes these electromagnetic waves for connecting to the Internet. For two-way communication, each user requires a transmitter and a receiver.

Many of the home networking device manufacturers build the transmitter and receiver into a single unit called a transceiver. The operation and functionality of a wireless and wired home network remain the same. However, there are distinctions in the technologies used to achieve the same objectives.

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## Wireless Technologies

There are two main core technologies used in the design of wireless home networking products.

1. Infrared (IR)
2. Radio Frequency (RF)

### Infrared

Most of us are familiar with every day devices that use IR technology, such as remote controls for TVs, VCRs, and CD players. IR transmission is categorized as a line-of-sight wireless technology. This means that workstations and digital appliances must be in a direct line to the transmitter in order to operate. An infrared-based network suits environments where all the digital appliances that require network connectivity are in the same room and can be installed rather quickly.

There is, however, new IR technologies being developed that can operate out of the line-of-site, so expect to see these products in the very near future.

### Radio Frequency

The other main category of wireless technology is radio frequency. RF technology is a more flexible technology allowing consumers to link appliances that are distributed throughout the house. RF can be categorized as narrow band or spread spectrum. Narrow band technology requires a clear channel uninterrupted by other digital appliances.

Since each transmitter/receiver appliance transmits using its own frequency, it is unlikely to interfere with other RF appliances connected to the home network. However, if the wireless appliance gets moved to another part of the house then it is possible that interference may

occur. This limitation makes the use of this technology unsuitable for a number of home networking applications.

Spread spectrum technology (SST) is one of the most widely used technologies in wireless home networks. SST was developed during World War II to provide greater security for military communications. As it entails spreading the signal over a number of frequencies, spread spectrum technology makes it more difficult to intercept.

There are a couple of techniques used to deploy SST, a system called frequency hopping spread spectrum (FHSS) is the most popular technique for operating wireless home networks. FHSS transmissions constantly “hop” over entire bands of frequencies in a particular sequence. To a remote receiver not synchronized with the hopping sequence, these signals appear as random noise. A receiver can only process electromagnetic waves by tuning to the relevant transmission frequency. The FHSS receiver hops from one frequency to another in tandem with the transmitter. At any given time, there may be a number of transceivers hopping along the same band of frequencies. Each transceiver uses a different hopping sequence that is carefully chosen to minimize interference on the home network.

Because wireless technology has roots in military applications, security has long been a design criterion for wireless devices. Security provisions are normally integrated with wireless home networking devices, making them more secure than most wire-line based in-house networks. Complex *encryption* techniques make it near impossible for hackers to gain access to traffic on your wireless network.

## Demystifying Wireless Home Networking Technologies

A number of industry initiatives are underway to develop interoperable wireless in-home appliances. The following sections describe the most popular of these technologies.

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## DECT

### About DECT

Digital Enhanced Cordless Telecommunications (DECT) is a flexible digital radio access standard for cordless communications in residential, corporate, and public environments. The first commercial DECT-based cordless phone systems were introduced in 1993, and by the end of 1996, accumulated worldwide sales of DECT systems amounted to over five million lines.

By the year 2000, it is expected that worldwide sales of DECT equipment will be more than 30 million lines a year. The DECT standard was initially conceived in the mid-1980s as a pan-European standard for domestic cordless phones. DECT is a digital radio access standard for single- and multiple-cell cordless communications. It is based on a multi-carrier time division multiple access (TDMA) technology.

This is the same technology used in the main digital cellular standards, but the central difference is that cellular systems were developed for wide-area coverage, whereas the DECT standard was optimized for local coverage, with high densities of users. It is supported and promoted by the DECT forum. This forum has representatives in all the major geographical regions around the world.

### DECT Technology Overview

DECT provides for voice and multimedia traffic, and contains many forward-looking technical features that allow DECT-based cordless systems to play a central role in important new communications developments such as Internet access and the Internet working with other fixed and wireless services such as ISDN and Global System for Mobile Communications (GSM). The DECT standard makes use of several advanced digital radio techniques to achieve efficient use of the radio spectrum.

The combination of digital radio technology and dynamic channel selection with additional encryption techniques, authentication, and identification procedures makes DECT radio transmissions extremely secure against unauthorized radio eavesdropping by third parties.

Speech quality in a DECT system is very high, thanks to the digital radio techniques applied. Data applications are becoming more and more important in home networks.

Today, DECT products provide data links with up to 552 Kbps. New modulation schemes will rapidly allow the rate to grow up to 2 Mbps for accessing the wireless medium. Similar to HomeRF, DECT in-home digital appliances also use a CSMA/CA algorithm as the media access scheme. Through the utilization of the same basic technology for residential cordless phones (mass-market) up to complex multi-cell systems, DECT has an attractive and competitive cost position.

### Applications for the DECT Standard

The three applications for the DECT standard that have reached widespread commercial deployment are home cordless phones, business cordless systems, and as a radio alternative to wired subscriber accesses in public fixed telecom networks, known as Wireless Local Loop (WLL). In a home networking environment, a typical DECT system consists of a phone handset and a base unit that contains the radio base station. The DECT standard permits cordless data communication so that a home network that uses the DECT system could be used to simultaneously support both cordless data and cordless voice services.

### Xilinx DECT Solutions

Figure 1 shows the DECT Cordless phone system. In a DECT phone system—handset and base station, Xilinx Spartan™-II FPGAs provide the following functionality:

- ADPCM (Adaptive Differential Pulse Code Modulation)
- Memory control
- System control
- System interface
- Interface to multiple home networking technologies

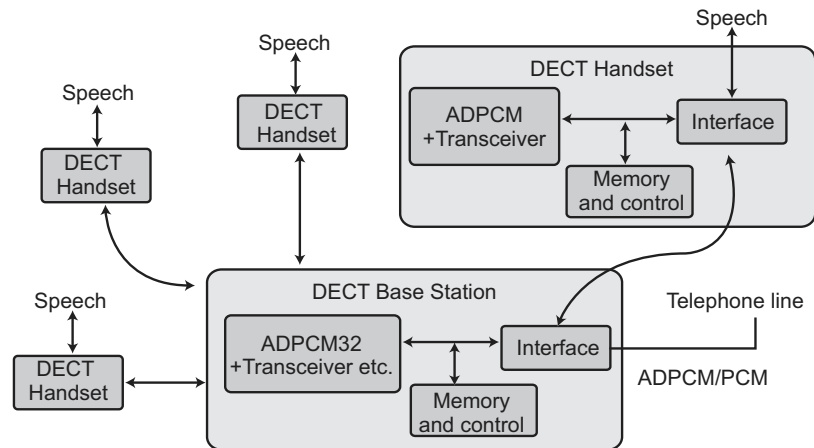


Figure 1: DECT Cordless Phone System

## HomeRF

### Introduction to HomeRF

Two major factors are presenting a real opportunity for networking data devices within the home. The first is the massive growth of people going online and accessing the Internet. The second factor is the emergence of sub-\$800 powerful home PCs. With these low-cost devices the barrier to getting on the Internet and discovering the functionality of PCs is low enough to reach the vast majority of middle-income households. However, consumers soon find that the PC/Internet combination, though very compelling, lacks some key attributes in terms of mobility and convenience of location compared with many of their traditional information and entertainment options.

With these issues in mind, several major stakeholders in the IT industry formed the HomeRF Working Group in early 1997. There are 85+ members, with major contributors including Compaq, Ericsson, HP, IBM, Intel, Microsoft, Motorola, Philips, Proxim, Symbionics. The key goal of the group is to enable interoperable wireless voice and data networking within the home at consumer price points.

Since its formation, the group has developed a specification for wireless communications in the home called Shared Wireless Access Protocol-Cordless Access (or “SWAP-CA”). Three sub-committees exist within the HomeRF Working Group. The HRFWG-Japan sub-committee was created to assist in defining SWAP and ensure that it complies with local regulations. The group has also formed committees to plan future versions of SWAP that address wireless multimedia and a lower cost alternative.

In addition to ratifying the standard, 13 companies have also committed to building products based on SWAP. Products that adhere to the SWAP standard will carry voice and data traffic between various portable appliances within the home using wireless system. Additionally, these products will interoperate with the public telephone network and the Internet.

## Building Blocks of a HomeRF-Based Home Network

The following components make up a HomeRF based network:

### SWAP-CA Protocol

SWAP has been developed and optimized to meet unique consumer needs at home and small offices-home offices. In designing SWAP-CA, the HomeRF Technical Committee chose to reuse proven RF networking technology for data and voice communications and added simplifications appropriate for home usage. With this approach, SWAP-CA inherited native support for Internet access via TCP/IP networking, and for voice telephony via the Public Switched Telephone Network (PSTN), and voice over IP.

Additionally, because of this design approach, the HomeRF Working Group made rapid progress in finalizing the specification and bringing it to market in a timely manner. From a technical perspective, the SWAP-CA protocol is designed to operate on the 2.4 GHz Industrial, Scientific, and Medical (ISM) band. The 2.4 GHz band is an unlicensed frequency band that is available worldwide, ensuring that SWAP-CA devices are operational globally.

### Different Classes of Digital Appliances

Four types of digital appliances can operate in a HomeRF home network:

1. **A connection point (CP):** The connection point can either be a separate device, connected to the main (home) PC, typically via the USB connection, or can be an integral part of the PC. It can also have a direct connection to the PSTN.
2. **Isochronous nodes (I-nodes),** which are voice-centric digital appliances such as cordless phones and walkie-talkies. I-nodes leverages existing DECT technology for voice.
3. **Asynchronous nodes (A-nodes),** which are data-centric appliances such as Web tablets and personal digital assistants.
4. **Combined Asynchronous-Isochronous nodes (AI-nodes):** HomeRF is capable of accommodating a maximum of 127 nodes connected to a home network.

### Software Framework

Due to the wide scale availability of the Microsoft's Windows operating system and its use as a de facto standard operating system for Home PCs, the HomeRF working group has sought to streamline operation of SWAP-CA based digital appliances using these operating systems. Hardware manufacturers who build A-node based HomeRF products are required to write a driver based on the Network Device Interface Specification (NDIS). Hardware manufacturers

who build I-node HomeRF products are required to write a driver based on the Telephone Application Programming Interface (TAPI).

**Note:** Microsoft and Intel introduced TAPI in 1993 as the result of joint development. It is used by to connect a PC running the Windows operating systems with telephone services.

HomeRF also utilizes a technology called DirectX to enable SWAP-CA enabled adapters to communicate with each other in real time. DirectX is a set of APIs that were developed by Microsoft allowing multimedia applications to take advantage of advanced hardware features.

## How HomeRF Works

The HomeRF network is designed to operate in two basic modes: the network can be configured either as a managed home network, or as a peer-to-peer ad hoc home network. In the managed network configuration, the home network is explicitly under the control of the CP, which is its gateway to other devices, the Internet, and the PSTN. Furthermore, it provides simultaneous support for both real-time audio traffic, such as interactive voice, and non-real time data traffic, such as traditional TCP connections.

In the ad-hoc network mode, the network provides traditional data networking support only and does not need the CP for proper operation. When a SWAP-CA digital appliance is turned on, it immediately enters into a network discovery phase in which it tries to determine if another appliance or connection point is present in its frequency range and if a home network already exists for it to join. The appliance accomplishes its discovery phase by scanning every channel that is operational on the home network. RF signals are not restricted to well-defined boundaries, consequently, unlike a wired network, an RF wireless network is difficult to secure. The transmission medium is open to anyone within range of the transmitter.

As a result of these concerns, HomeRF uses a well-established shared-key encryption algorithm for data privacy and authentication. The voice transmission is based on the low cost DECT model. It includes a Time Division Multiple Access (TDMA) service for delivery of voice traffic and a CSMA/CA service for delivery of multimedia data.

## Practical Uses of HomeRF Technologies

The HomeRF standards interoperable mechanism for connecting to the home PC allowing consumers to implement a number of innovative applications in their homes, including:

- **PC-enhanced cordless telephony:** Today there are no standards-based digital cordless telephones for consumer use in the U.S. where interoperability of multiple vendors is enabled. HomeRF defines a new standard for interoperable digital cordless telephones both in the U.S. and worldwide. Furthermore, the SWAP specification includes a standard method for connecting the cordless telephone to home PC software applications. Thus, many new enhanced features are possible. For example, caller ID information could be sent to a PC application to look up the caller's name and then route the call to an individual handset (rather than a number) and display the caller's name on any given handset. For outbound calls, the PC could interpret a spoken destination name (i.e., "Call Mom") through voice recognition and then based on date/time determine the likely number for the person and route the call using the lowest cost approach (which might be IP telephony). The handset could be used to pick up voice mail selective to the user from the Home PC call center.
- **Mobile display appliances:** This could take many forms but fundamentally consists of a color display (like that of a notebook computer) with some limited input device (such as a pen) and a SWAP-CA radio network connection. Such a device could be either an extension of the home PC (like an X-terminal) or simply a web-browsing extension of an Internet gateway.
- **Resource sharing:** The third of many potential applications is resource sharing between multiple PCs in the same home. The resource to be shared could be a high-quality printer, a back-up storage device, a file server, or an Internet connection. Another possibility for this is multi-player gaming.

### Future of HomeRF

The HomeRF organization is discussing a variety of future derivatives for the initial SWAP-CA specification. One possible derivative is simply to increase the data rate within the existing the 2.4 GHz band while retaining full backward compatibility with the initial specification. The group is presently considering options in this regard that would scale SWAP-CA to 10 Mbps in the 2.4 GHz band.

In addition, HomeRF is also developing two major new market requirements documents. The first is SWAP-MM (for multimedia), which is looking at true video applications within the home enabled by wireless networking. The other direction HomeRF is considering is an ultra-low cost version called SWAP-lite that could be developed to be interoperable with future SWAP-CA devices while achieving much lower price and power consumption points. Keyboards, mice, joysticks, remote controls, toys, etc. are the products that might use SWAP-lite. Clearly such a system will overlap in capability with infrared technology, which competes heavily in terms of price and performance.

### Xilinx Solutions Enable HomeRF Based Products

Figure 2 shows the HomeRF module which is a simple solution defined by the HomeRF Working Group that attaches on the front end of any information appliance to have wireless data and voice communication at home. Increasingly, consumer devices and gateways are becoming HomeRF enabled. Spartan-II FPGAs provide the following solutions in the HomeRF module:

- Radio control interface
- PCI and other system interface
- USB and USB 2.0 device controller
- Hardware accelerators
- Speech processor
- Interface to multiple home networking and broadband access technologies

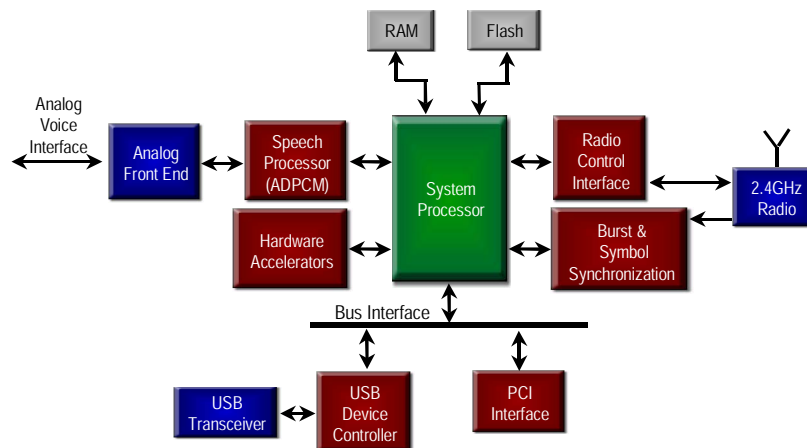


Figure 2: HomeRF Module

## Bluetooth

### Introduction to Bluetooth

Bluetooth is another industry group developing a competing specification for a low-cost, short-range radio link between mobile computers, cameras, and other portable in-home devices.

The Bluetooth technology is the result of a co-operation between leaders in the telecommunication and computer industries. It enables home networking users to connect a wide range of computing and telecommunications devices easily and simply eliminating the need to purchase proprietary or additional cabling to connect individual devices. It delivers

opportunities for rapid ad hoc connections, and the possibility of automatic, unconscious, connections between devices.

Because Bluetooth can be used for a variety of purposes, it will also potentially replace multiple cable connections via a single radio link. Bluetooth is being promoted and adopted by a group of companies called the Bluetooth Special Interest Group (SIG). This includes promoter companies 3Com, Ericsson, IBM, Intel, Lucent, Microsoft, Motorola, Nokia, Toshiba, and over 2000 adopter companies.

## Bluetooth Technology Overview

The technology is an open specification for wireless communication of data and voice. It is based on a low-cost, short-range radio link built into a 9 x 9mm microchip, facilitating protected ad hoc connections for stationary and mobile communication environments.

Bluetooth technology allows for the replacement of the many proprietary cables that connect one device to another with one universal short-range radio link. For instance, Bluetooth radio technology built into both the cellular telephone and the laptop would replace the cumbersome cables used today to connect a laptop to a cellular telephone. Printers, PDAs, desktops, fax machines, keyboards, joysticks, and virtually any other digital device can be part of the Bluetooth system.

Bluetooth radio technology provides a universal bridge to existing data networks, a peripheral interface, and a mechanism to form small private ad hoc groupings of connected devices away from fixed network infrastructures. Designed to operate in a noisy radio frequency environment such as a home, the Bluetooth radio uses a fast acknowledgement and frequency-hopping scheme to make the link robust.

**Note:** Bluetooth is so resilient to noise that some companies have started to attach Bluetooth chips to the interference sources.

Bluetooth radio modules avoid interference from other signals by hopping to a new frequency after transmitting or receiving a packet. Compared with other systems operating in the same frequency band, the Bluetooth radio typically hops faster and uses shorter packets. This makes the Bluetooth radio more robust than other systems. Similar to HomeRF, Bluetooth radios also operate in the unlicensed ISM band at 2.4 GHz.

**Note:** While the ISM band is freely available for anyone to use, there are rules for devices designed to operate in it.

Bluetooth has a maximum data capacity of only 1 Mbps, which translates to a throughput of only 780 Kbps once the protocol overhead is taken into account.

From a security perspective, Bluetooth provides user protection and information privacy mechanisms at the lower layers of its protocol stack. Authentication is based on a challenge-response algorithm. Authentication is a key component of any Bluetooth home networking system, allowing you to develop a domain of trust between personal Bluetooth devices, such as allowing only your personal notebook to communicate through your cellular telephone.

## Building Blocks of a Bluetooth Solution

The role of each component in a Bluetooth based home network is briefly outlined in the following categories.

### Personal Area Networks

Bluetooth was originally conceived to replace the myriad of cables that are synonymous with a PC-based home network. However, as the Bluetooth evolved it became clear that it would also enable a totally new networking paradigm, Personal Area Networks (PANs). With PAN technology, a home networking user will be able to organize a collection of personal electronic products ( PDA, cell phone, laptop, desktop, MP3 player, etc.) to automatically work together. Over time, PANs will revolutionize the user experience of consumer electronics.

### Piconets

The Bluetooth system supports both point-to-point and point-to-multi-point connections. A collection of digital appliances that are connected to a home network via Bluetooth technology is called a *piconet*. A piconet starts with two connected appliances, such as a digital set-top box and cellular phone, and may grow to eight connected devices. All users participating on the same piconet are synchronized to this hopping sequence. The range of Bluetooth and hence the size of the piconet is only ten meters. There is, however, a plan to extend this to 100 meters. This extension in range will however increase the power and interference levels for appliances connected to the piconet.

### Scatternets

Several piconets can be established and linked together ad hoc, where each piconet is identified by a different frequency hopping sequence. The resulting structure is called a scatternet (see [Figure 3](#)).

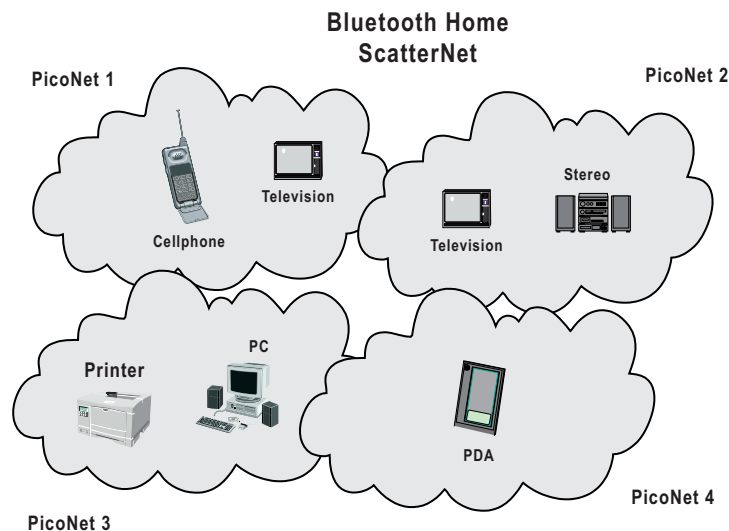


Figure 3: A Bluetooth Scatternet

### Software Framework

Every Bluetooth system is comprised of a host-based application and a Bluetooth module (see [Figure 4](#)).

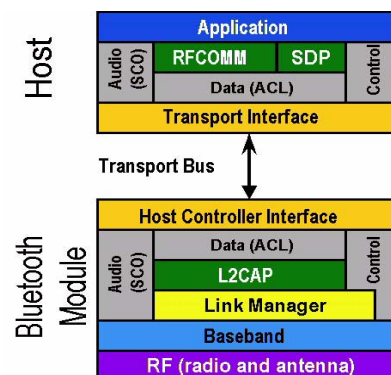


Figure 4: Bluetooth Software Protocol Stack

The Bluetooth protocol stack can be logically divided into four different layers according to their purpose in a wireless home networking environment. Each layer performs a specific, well-documented, function in much the same manner as an Ethernet stack. This well-defined

architecture makes system design much easier and has enabled many implementation variations to emerge. The four layers comprise the following:

1. **Bluetooth core protocols:** The main purpose of these protocols is to enable communication links between Bluetooth devices.
2. **Cable replacement protocol:** The cable replacement protocol used by Bluetooth is called RFCOMM and is used to emulate RS-232 control and data transfer.
3. **Telephony control protocol:** This Bluetooth protocol defines the rules for making speech and data calls across a home network.
4. **Adopted protocols:** This layer comprises of application-orientated protocols such as PPP, TCP/IP, HTTP, FTP, Wireless Application Protocol (WAP), etc.

## Practical Uses of Bluetooth Technologies Within Our Homes

### General PC Applications

The Bluetooth Specification defines interfaces where the radio modules may be integrated into notebook personal computers or attached using a PC-card or USB port. Notebook PC usage models include:

- Remote networking using a Bluetooth cellular phone
- Speakerphone applications using a Bluetooth cellular phone
- Personal card exchange between Bluetooth notebooks, handheld, and phones.
- Calendar synchronization between Bluetooth notebooks, handheld, and phones
- File transfers (file types include, but not limited to .xls, .ppt, .wav, .jpg, and .doc formats)

Bluetooth technology is platform independent and not tied to any specific operating system. Implementations of the Bluetooth specification for several commercial operating systems are in development. For notebook computers, the implementation of the Bluetooth specification in Microsoft Windows98 and Windows 2000 using Windows Driver Model (WDM) and NDIS drivers is being contemplated.

### Telephone Applications

The Bluetooth specification defines interfaces where the radio modules may be integrated directly into cellular handsets or attached using an add-on device. Phone usage models include (are not constrained to):

- Wireless hands-free operation using a Bluetooth headset
- Cable-free remote networking with a Bluetooth notebook or handheld computer
- Business card exchange with other Bluetooth phones, notebook, or handheld computers
- Automatic address book synchronization with trusted Bluetooth notebooks or handheld computers

The Bluetooth compliance document requires digital cellular phones to support some subset of the Bluetooth specification. The Bluetooth contingents within the telephony promoter companies are working with their fellow constituents involved in the Wireless Application Protocol (WAP) forum to investigate how the two technologies can benefit from each other.

### Other Applications

Usage models and implementation examples centered on other contemplated Bluetooth devices include:

- Headsets
- Handheld and wearable devices
- Human Interface Device (HID) compliant peripherals
- Data and voice access points
- Digital set-top boxes

- Integrated digital televisions

### Xilinx Solutions Enable Bluetooth Based Products

Enabling a system for Bluetooth requires an RF-chip and a baseband controller. Several variations of Bluetooth modules exist with single RF and baseband controller chips and separated variations.

In Bluetooth products, Xilinx Spartan-II FPGAs and CoolRunner CPLDs provide solutions in traditional component integration (i.e., system interface) role and fully integrated Bluetooth system logic (less the analog radio). Xilinx Virtex devices have been a pervasive vehicle for Bluetooth prototype design.

It should not be surprising, however, that the immediate opportunities tend toward the more traditional component integration and block logic roles as these are our strengths. However, Bluetooth will be such a pervasive technology that we expect fully integrated Bluetooth FPGA solutions to be of interest for many applications. The key will be the availability of appropriate core IP technology which will be the gating factor in pursuing these opportunities.

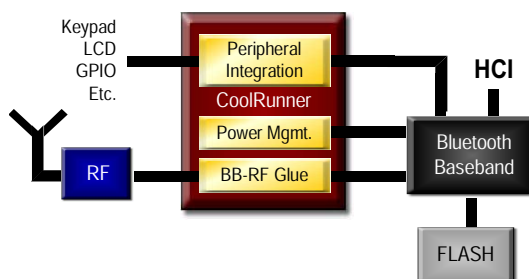
Today, Xilinx Spartan-II FPGAs and CoolRunner CPLDs provide component integration, power management, HCI bridging, and system integration functionality.

**Figure 5** shows the Bluetooth RF and Baseband controller, i.e., the Bluetooth module required for Bluetooth enabling the system.

In **Figure 6**, we show an example of how CoolRunner CPLDs participate in a Bluetooth design. The Bluetooth baseband to RF interface is not standardized, but it must be noted that most suppliers of these components have compatible chipsets. However, if a customer is considering different baseband and RF suppliers, a Xilinx FPGA and/or CPLD is required.



*Figure 5: Bluetooth RF and Baseband Controller*



*Figure 6: CoolRunner Peripheral Integration, Power Management, and Component Integration*

The benefits to the customer are the opportunity to open the radio component up to competition (and thus lower cost) and second sourcing (reducing availability risks). **Figure 7** shows a fully

integrated Bluetooth device with a single embedded baseband/RF link. CoolRunner CPLDs also provide power management and peripheral integration capabilities.

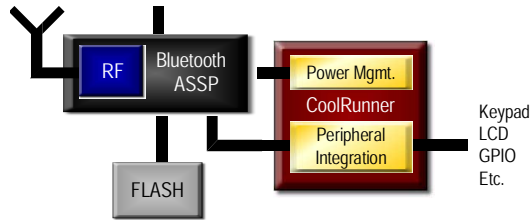


Figure 7: CoolRunner Power Management and Peripheral Integration

These interfaces include PCMCIA for laptop cards, PCI for a desktop plug in card, Compact PCI for industrial applications, IEEE 1394 for consumer electronics, Car Area Networking (CAN) for automotive use, etc. It should also be noted that the UARTs to date have been developmental artifacts as they are too slow (classic 115 Kbps vs. Bluetooth’s 1 Mbps). However, high-performance UARTs are emerging in some new devices to save cost and these should be ideal for bridging through FPGAs.

An application of the HCI bridge will be Application Acceleration. There is likely to be many cases where the customer desires additional functionality in their solution, such as voice encryption or enhanced forward error correction. To implement these efficiently will require hardware acceleration and the Spartan-II FPGA is an ideal device for it. Figure 8 shows the same functionality only with a fully integrated Bluetooth device. In Figure 9, the Spartan-II FPGA can also interface between the RF and baseband chipsets.

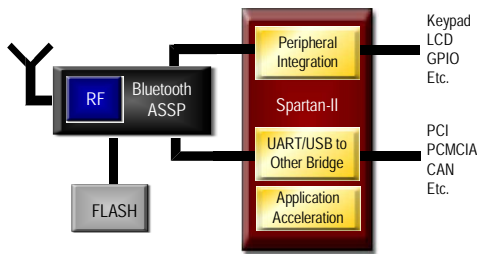


Figure 8: Spartan-II Application Acceleration, HCI Bridging, and Peripheral Integration

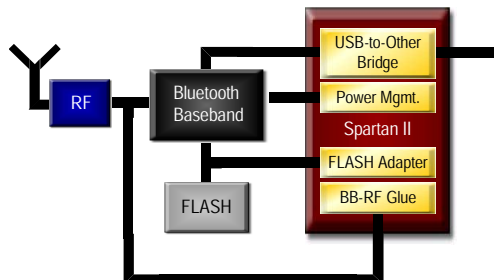


Figure 9: Spartan-II Component Integration, Power Management, and HCI Bridging

Bluetooth is going to find its way into an extraordinary number of products and applications, and virtually all of them will have need to integrate a variety of different parts. Examples include:

- Cordless base station or pay phone access point
  - Typically need a keypad, LED(s), battery charging logic, LCD, etc.
- Access points

- Bluetooth enabling a set-top box, DSL modem, cable modem, or Ethernet bridge where Xilinx is already used
- Scientific and industrial equipment
  - Bluetooth enabling a complex system already using Xilinx solutions
- Any application looking to extend or enhance Bluetooth's capability
  - Proprietary encryption for maximum security
  - Improved FEC for maximum transmission reliability

Whatever the application, with the increased features, high densities and low cost Spartan-II FPGAs and CoolRunner CPLDs will continue to provide critical functionality in Bluetooth enable devices.

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## Wireless LANs

### Introduction to Wireless LAN Technologies

Wireless local area networks (WLANs) are a rapidly emerging market. WLANs combine data connectivity with user mobility and provide a connectivity alternative for a broad range of consumers and business customers. They have a strong popularity in vertical markets such as telecommuting, SOHOs, health-care, retail, manufacturing, warehousing, and academia, where productivity gains are realized by using hand-held terminals and notebook PCs to transmit real-time information to centralized hosts for processing.

A WLAN is comparable to a cordless telephone, where the user can move about and still be able to use the telephone. Business Research Group, a leading market researcher, predicts that revenues from WLAN products will exceed \$2 billion in the year 2000, and show a steady growth of unit shipments and revenue. Demand for computing and telephony mobile devices will be one of the most influential market drivers, along with end users demanding higher data rates and ease-of-use to sustain growing Internet and data applications.

However, several issues remain unsolved for the industry. Although vendors have made great strides in achieving interoperability, a common wireless standard is far from reality (today, there are seven standards). Interference from competing 2.4 GHz technologies (like Bluetooth and HomeRF) threatens the already crowded band. In addition, uncertainties exist with several technologies migrating to the evolving 5 GHz frequency band.

### Why Use a Wireless LAN?

The Wireless LAN is perfect for rooms in a home that are hard to cable and locations where it is not economical for homeowners to implement new wire based technologies. Hence, cost savings is one of the primary drivers behind WLANs, however, there are many more advantages to be gained, including:

- Improved flexibility
- Extend the reach of communication between family members
- Support transmissions over hundreds of meters

### Wireless LAN Technology Overview

WLANs focus on the physical (PHY) layer and the data-link layer with the medium access control (MAC) and logical link control (LLC) sub-layers of the OSI model. The physical layer defines the electrical, mechanical, and procedural specifications, which provides the transmission of bits over a communication medium or channel. WLAN PHY layer technologies used are narrowband radio, infrared, OFDM (orthogonal frequency division multiplexing) and spread spectrum (frequency hopping spread spectrum), and direct sequence spread spectrum (DSSS). The MAC layer, which is part of the data link layer, ensures error control and synchronization between the physically connected devices communicating over a channel. It is also responsible for determining priority and allocation to access the channel.

## Types of WLAN Systems

Some of the popular WLAN technologies are IEEE 802.11a, IEEE 802.11b, and HiperLAN2.

### IEEE 802.11

The development of any new technology is part theory and part practice. A key issue in telecommunications is the adoption of technical standards that govern the interoperability of equipment to provide a stable environment for deployment of products and services. This does not mean that all vendor equipment will work in the exact same way. A standard sets a norm or performance expectation on the function of the technology—not its implementation. The standard that governs the wireless local area networks industry is the 802.11 family of standards that are part of the group that governs Ethernet data communications.

This standard is evolving and adapting to meet the needs of industry, as new technology is developed to allow new product design. IEEE 802.11 addresses the 2.4 and 5 GHz WLAN market. The IEEE 802.11b extension employs a modulation scheme called complementary code keying (CCK) and operates in the 2.4 GHz band. It is designed to enable data rates of 1 Mbps to 11 Mbps for DSSS systems and interoperability with both DSSS and FHSS networks operating at 1 Mbps or 2 Mbps. The MAC uses the popular CSMA/CA technique. IEEE 802.11a, a recently formalized extension to 802.11, will prove attractive to vendors looking for speed and compatibility with existing standards. IEEE 802.11a employs the OFDM modulation scheme in the 5 GHz band, with a maximum optional speed of 40 Mbps and a range of 150 meters.

### HiperLAN2

HiperLAN2 is the fastest growing wireless technology with a proposed data rate of 54 Mbps and a range of above 150 meters. This technology is best suited for multimedia applications. HiperLAN is popular in Europe due to the frequency allocation. HiperLAN2 is an OFDM-based, variable bit rate PHY layer technology operating at 5 GHz. It has FEC error control, with dynamic sub-channel modulation allowing data transmission at higher rates with a strong Signal to Noise Ratio (SNR) at lower throughputs in adverse conditions. It has a generic architecture and supports Ethernet, 1394, ATM, PPP, and 3G. The HiperLAN2 data-link layer/MAC provides QoS via dynamic fixed time slots. The time slotted structure allows simultaneous communication in both downlink and up-link in the same period. It is also a connection-oriented technology that allows negotiation of QoS parameters like bandwidth, bit error rate, latency, jitter and delay requirements and this assures that other terminals will not interfere with subsequent transmissions.

WLAN products include network interface cards (or NICs/PC adapters), access points (end-user-to-LAN and LAN-to-LAN) and technology bridges for communications. NICs provide an interface between the end-user device (desktop PC, portable PC, or handheld computing device) and the airwaves via an antenna on the access point. Access points act as transmitters/receivers between wired and wireless networks. They connect to the wired network via standard Ethernet cable (token ring is available, but less common) and use airwaves to transmit information to and from “connected” wireless end users. Technology bridges exist at the periphery of each product and are the most susceptible to constant change and evolution. These products need a flexible, re-programmable, and low-cost platform to accommodate for time-to-market pressures, specification changes, lack of clear direction, and

short product lifecycles. Table 1 shows a comparison between the different WLAN technologies.

Table 1: Comparing the Different Wireless LAN Technologies

Characteristic	IEEE 802.11b	IEEE 802.11a	HiperLAN2
Spectrum	2.4 GHz	5 GHz	5 GHz
Maximum physical rate (approx.)	11 Mbps	40 Mbps	54 Mbps
Maximum data rate, layer 3 (approx.)	5 Mbps	28 Mbps	32 Mbps
Medium access control/Media sharing	CSMA/CA		Central resource control/TDMA/TDD
Connectivity	Connection-less	Connection-less	Connection-oriented
Multicast	Yes	Yes	Yes
QoS support	PCF	PCF	ATM/802.1p/RSVP/DiffServ (full control)
Frequency selection	DSSS	Single carrier	Single carrier with Dynamic Frequency Selection
Authentication	No	No	NAI/IEEE address/X.509
Encryption	40-bit RC4	40-bit RC4	DES, Triple-DES
Handover support	No	No	No
Fixed network support	Ethernet	Ethernet	Ethernet, IP, ATM, UMTS, FireWire, PPP
Management	802.11 MIB	802.11 MIB	HiperLAN/2 MIB
Radio link quality control	No	No	Link adaptation

## Spartan-II FPGAs Enable WLAN Products

Figure 10 shows the wireless LAN radio, MAC, and baseband controller. The Spartan-II FPGAs provide functionality of the MAC and the ability to interface with different home networking and wireless LAN technologies such as HiperLAN2, Ethernet, USB 2.0, etc. Spartan-II FPGAs also allow advanced and/or proprietary encryption and forward error correction capabilities for advanced applications such as industrial, etc. While several companies manufacture both the radio and MAC chipsets, Spartan-II FPGAs provide the ability to interface between radio and MAC chips from different manufacturers.

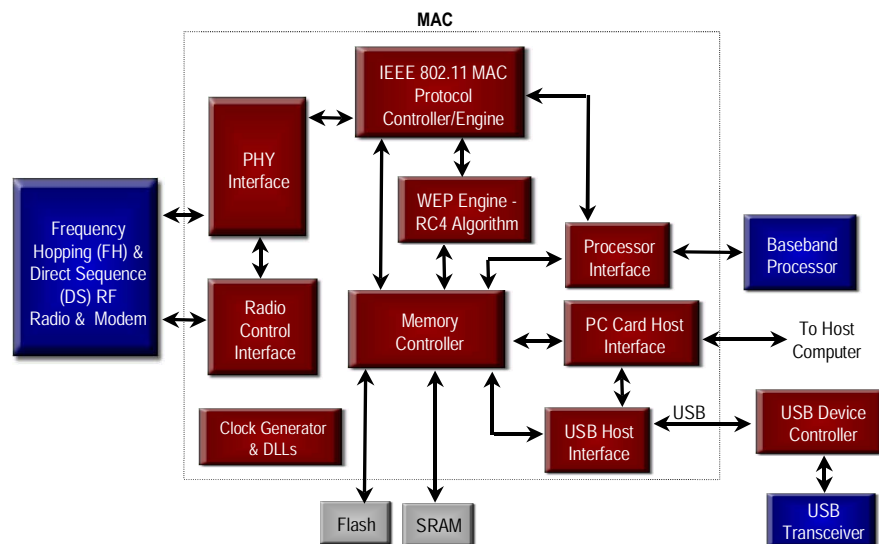


Figure 10: Wireless LAN Radio, MAC, and Baseband Controller

**NIC/PC Cards**

Figure 11 shows the WLAN card, which consists of the antenna, radio/PHY, baseband controller, and the MAC. The block diagram of the PC card shows that the Spartan-II FPGA provides functionality of a WLAN MAC (radio control, packet header generator, MAC protocol engine, DMA engine, RAM packet buffer, host interface, configuration storage, and MAC management), memory controller, and as an interface to the PC.

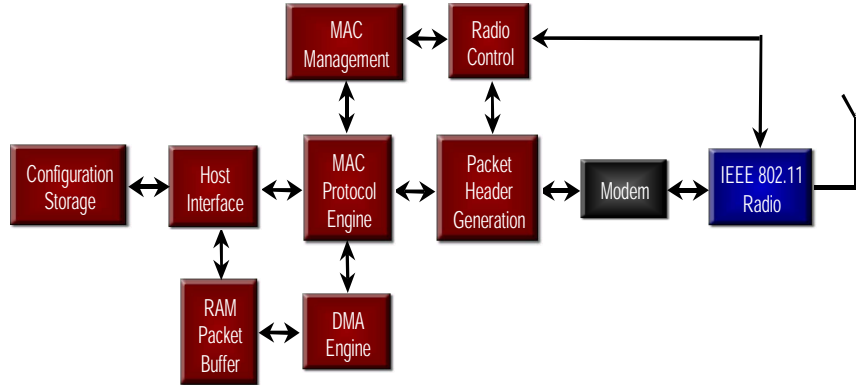


Figure 11: Spartan-II FPGAs in NIC/PC Cards

**Access Points**

The access points are devices that provide a wireless hub or a gateway for non-wireless networks to wireless networks. They also act as the network police and perform network management. They receive, buffer, and transmit data between wireless LAN and the wired network infrastructure. Access points function within a range of 100 to several hundred feet. They also connect WLANs to other technologies such as USB and Ethernet. In Figure 12, Spartan-II FPGAs provide solutions in the access point such as memory controller, Ethernet MAC, USB device controller and IEEE 802.11 MAC.

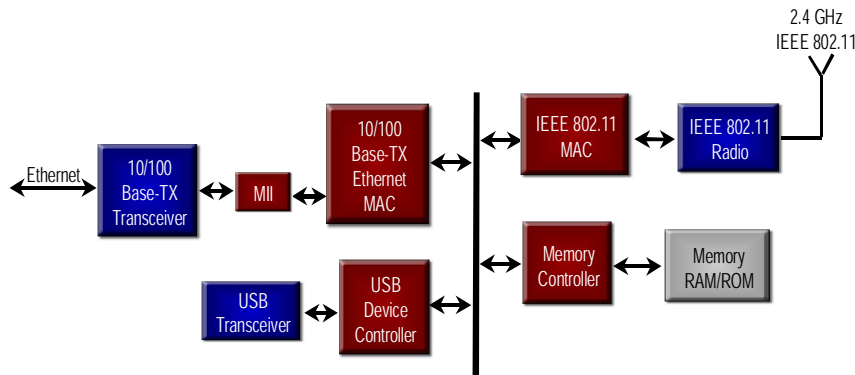


Figure 12: Spartan-II FPGAs in Wireless LAN Access Points

**Technology Bridges**

Conflicting specifications and lack of a clear direction create the need for FPGA-based technology bridges. It is also quite likely that some of these conflicts may never get resolved. It would be nearly impossible and cost-prohibitive for a supplier of home networking and wireless LAN products to cater to all the various specifications and changing needs. At the same time betting on the success of one single product may preclude them from being successful in the marketplace. An example of a wireless LAN to Ethernet technology bridge is shown in Figure 13.

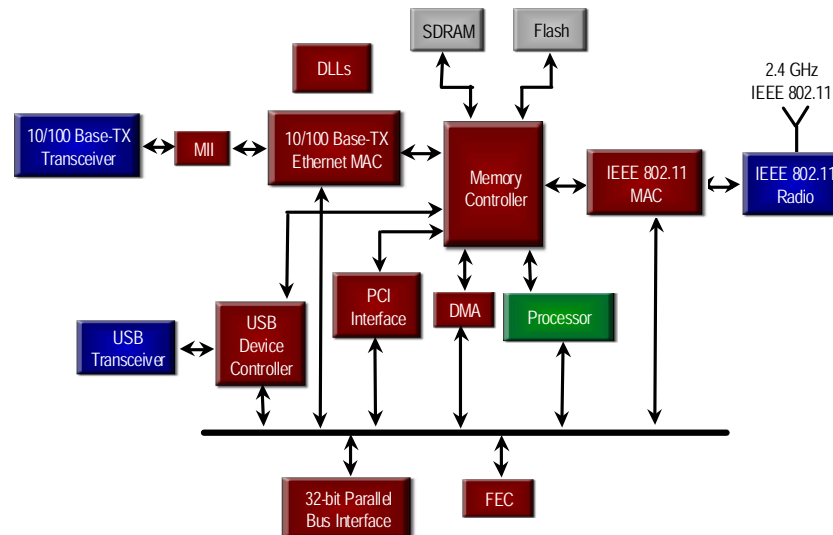


Figure 13: Spartan-II FPGAs in (Wireless LAN to Ethernet) Technology Bridges

In the technology bridge example, Xilinx Spartan-II FPGAs are at the heart of the technology bridges, which usually connect unlike technologies—such as wireless LANs to Ethernet. While the Ethernet MAC has been around for a long time, the IEEE 802.11 specification that defines the MAC and PHY layers continue to evolve. With IEEE 802.11a and HiperLAN2 specifications still not defined, it seems ideal for the MAC and MII (media independent interface) to be programmed in an FPGA. Similarly, the HomePNA, HomeRF, FireWire, USB, HiperLAN2, and Bluetooth are all technologies with evolving specifications.

WLAN products will extend beyond NICs, access points, and technology bridges, and will enable every device in the home, SOHO, and enterprise with WLAN capabilities. For example, devices such as digital TV, residential gateways, set-top boxes, digital modems, PC peripherals, gaming consoles, and other appliances. Spartan-II devices are used for:

- I/O control: Multiple front-end interfaces (DSL, cable, satellite, powerline, wireless, analog) and multiple back-end interfaces (USB/USB 2.0, HomePNA, HomeRF, FireWire, Bluetooth, and Ethernet)
- Hard disk drive interface
- Clock distribution using on-chip DLL circuits
- MPEG decoder
- MAC (Fast Ethernet)
- Forward error correction algorithms: Reed-Solomon, Viterbi
- Memory solutions: On-chip memory (distributed memory, block RAM,) and memory controllers (flash controller, SRAM controllers, DRAM controllers)
- CPU (microprocessor and microcontrollers)
- HDLC controller, ADPCM
- PCI and interface to other system interconnectivity technologies
- Glue logic (LCD controllers, UARTs, DMA controllers)

## Conclusion

Wireless technologies truly provide a viable way of networking information appliances with the home. Several technologies exist to provide wireless home networking. HomeRF was formed in 1997 to address these issues and develop a standard that allows you to connect A/V digital appliances and PCs without laying any cables. Since its formation, the group has developed a specification for wireless communications in the home called SWAP-CA.

What started as a purely European initiative, to develop a unified digital radio standard for cordless phones, DECT has attracted World-wide attention. So far, the DECT standard has been adopted for use in 26 countries, and the number is growing.

Bluetooth technology is another popular solution for people who want to deploy wireless in-home networks. The Bluetooth technology facilitates real-time voice and data transmissions between devices on a home network. It eliminates the need for numerous, often proprietary, cable attachments for connection of practically any kind of communication device. Connections are instant and they are maintained even when devices are not within line of sight. While Bluetooth's technical specifications are modest in comparison to other technologies, they are acceptable for almost every application except high-quality video, and are key to achieving low cost. The combination of low cost and Bluetooth's unique functional capabilities position the technology to enable many new and innovative markets and applications, thus making it one of the highest volume emerging wireless application opportunities.

IEEE 802.11 and HiperLAN are effectively wireless LAN technologies developed for the corporate and single office homeowners market.

Xilinx programmable solutions provide the flexibility, performance, and densities needed by wireless LAN technologies and products.

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## Revision History

The following table shows the revision history for this document.

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