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39 Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues

May 2003

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Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues

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Abstract

In this paper, we present a survey of the origins of unlicensed wireless devices, their governing regulation, the current technological state of the art, an overview of the market with information from publicly available sources, and an analysis of the potential regulatory issues. Unlicensed wireless devices are permitted to emit radio frequency energy, without specific authorization, registration, or grant of a license. Today, millions of unlicensed devices are already in operation in a multitude of important uses for industry, medicine, government, national defense, and in the homes. The market for unlicensed wireless communications devices is experiencing unprecedented growth into a multi-billion dollar industry – quite striking in light of the severe downturn in the U.S. telecommunications and technology sectors. Unlicensed devices advance the public interest, necessity, and convenience for the American people by enabling applications not possible with wires or that do not require the acquisition of spectrum rights through the licensing process. However, without a forward-looking approach to policy reform addressing the fundamental problem of interference and maintaining these low entry barriers to spectrum, much of the benefit and promise of unlicensed devices may be delayed, or unrealized. We conclude that the effective policy reform includes enabling more unlicensed spectrum and promulgating rules to encourage technological and market-based solutions to optimize efficient use and sharing of spectrum.

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Executive Summary

In this paper, we present a survey of the origins of unlicensed wireless devices, their governing regulation, the current technological state of the art, and an overview of the market, using information gathered from publicly available sources. We close with an analysis of the potential regulatory issues associated with this dynamic and growing area of communications. Applications spawned by unlicensed technology hold great promise for the American people, but the FCC must continue to review, reconsider, and evolve its regulatory treatment of unlicensed devices.

Unlicensed wireless devices are permitted to emit radio frequency energy, without specific authorization, registration, or grant of a license. Unlicensed devices trace their origins back to 1938 when the FCC first authorized radio devices on a sufferance basis. Today, millions of unlicensed devices are already in operation. Driven by rapid advances in technology, entrepreneurship, and policy liberalization, this once sleepy area of communications, relegated to the province of technophiles, has diversified into a multitude of important uses for industry, medicine, government, national defense, and in the homes.

The market for unlicensed wireless communications devices is experiencing unprecedented growth – quite striking in light of the severe downturn in the U.S. telecommunications and technology sectors. In our review of this market, we look first at cordless phones which have historically been the most important segment of the market. Surpassing corded phone sales in 1997, sales of cordless phones constituted $1.653 billion in 2002. They have proven to be a leading indicator of advances in technology and overcrowding in the unlicensed bands, but are now giving away that position to wireless computer networking devices – an almost unheard of technology three years ago. Sales of wireless computer networking devices have experienced double-digit annual growth since 2000 and are likely to top $2.3 billion in 2003. These numbers are exclusive of commercial wireless networks and services. We also look at other important segments of unlicensed devices such as radio frequency identification (RFID), which will constitute another $1.2 billion market in 2003.

Unlicensed devices continue to advance the public interest, necessity, and convenience, enabling applications not possible with wires or that do not require the acquisition of spectrum rights through the licensing process. However, without a well-considered and forward-looking approach to policy reform, much the benefit and promise of unlicensed devices may be delayed, or unrealized. Considering the complexity of issues involved, the FCC should promulgate rules which are as clear as practicable, strictly enforced, and maximize utility to address the fundamental problem of interference. We conclude that effective policy reform includes enabling more unlicensed spectrum and promulgating rules to encourage technological and market-based solutions to optimize efficient use and sharing of spectrum. The FCC must be mindful of balancing competing interests and retain the low entry barriers that have proven so successful for unlicensed spectrum.

I. Introduction

Driven by rapid advances in technology, entrepreneurship, and policy liberalization, the market for wireless communications devices that operate on an unlicensed basis is experiencing unprecedented growth. This growth is even more remarkable when viewed in light of the current downturn in the U.S. economy where both the telecommunications and technology sectors are experiencing financial stress.

Unlicensed wireless devices are products that are permitted to emit radio frequency (RF) energy, but require no specific device or user authorization, either through registration or grant of a license. This area of communications has become a province of continuous change. In recent years, these devices have diversified into a variety of different uses in daily life and are finding application in all areas of industry, government, and in private homes.

In this paper, we present a survey of the origins of unlicensed technology and its governing regulations, describe the current state of the art, and review the market for these devices.[1] The purpose of this exercise is to help policymakers understand significant implications of Part 15 and help plan for future actions and regulations.

A Day in the Life of Unlicensed Devices
By Neal McNeil

It is difficult to convey the impact that unlicensed operation has on the life of every day citizens. Attempting to provide a list of available unlicensed devices will prove inadequate in so far as there are new devices continually introduced to the market. In order to demonstrate the ubiquity of unlicensed operation, it is more useful to describe the morning commute of a fictional "Mr. and Mrs. Smith" from their home in the suburbs to their workplace in Any City, USA. (Unless otherwise indicated, all of the wireless devices they use operate on an unlicensed basis.

The morning begins with our couple eating breakfast. The sound of an infant's crying emanates from a baby monitor. As Mrs. Smith leaves the room to attend to the baby, Mr. Smith uses a cordless telephone to call their respective offices to inform co-workers that they will both be arriving late today. After attending to their child, Mrs. Smith activates a wireless connection to the Internet to check her email.

The doorbell rings. Mr. Smith smiles. Two years ago, the wiring for the Smith's original doorbell was accidentally cut in several places during a self-help remodeling project. Had Mr. Smith employed a stud-finder, which uses wireless ultra-wideband technology, he could have avoided severing the original wires. Instead of running replacement wiring all over the house, Mr. Smith disconnected power to the old doorbell and installed a new wireless doorbell on all three entries. It works perfectly.

Before answering the door, Mrs. Smith deactivates the wireless home security system and proceeds to greet the nanny. Meanwhile, Mr. Smith checks the settings on the "nanny-cam" in the baby's room. The camera uses a wireless video transmitter to send images to a neatly tucked away VCR.

At departure time, Mrs. Smith picks up the TV remote control, flips the channel from the morning news to Sesame Street, and our couple bustles into the garage. It will be early evening by the time they return, but there will be no need to activate an outside light. Thanks to a motion-activated exterior lighting fixture, their return path will brighten automatically. Mr. Smith opens the garage door with a wireless transmitter, and then uses keyless entry transmitter to unlock the doors to the family mini-van in preparation for departure.

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[1] For the market survey, we gathered information from publicly available sources, but no effort was made to verify the actual information or the underlying methodology with which it was assembled. However, we believe this market information is sufficiently accurate, in its current form, to be used as a fair indication of market size and trends

This paper proceeds as follows: Section II provides a description of the rules governing unlicensed devices and outlines a number of different unlicensed applications. Section III offers our analysis of the market and the relative economic value of these devices. In Section IV, we call attention to some regulatory issues that emerge from the dynamic growth of these new markets. And finally, Section V offers a summary of the paper. The Appendices contain information about the technologies that underlie unlicensed devices and a discussion of another category of device that may be operated without the need for an individual license.

As they leave their driveway and remotely close their garage door, they notice a utility truck from the local electric company driving slowly along their street. The driver is taking meter readings in the neighborhood with no need for physical access to any of the meters. That makes the driver one happy fellow because the Smith's meter is next to a doghouse. The dog's name, "Mangler," is emblazoned on the roof, and the utility worker is terrified of dogs. His wireless meter-reading device allows him to collect usage information from all the meters in the neighborhood without ever leaving the safety of his truck.

As he passes by, the utility worker wonders why a dog with such an appropriate name is not locked behind a tall fence. However, Mangler does indeed have a fence; an invisible one made of a license-free transmitter attached to an antenna buried around the perimeter of the Smith's yard. If Mangler were to stray too near that boundary, a receiver on his collar would give him a gentle shock to let him know not to go any further

The ride time from the Smith home to the freeway is much abbreviated and is far more predictable than it was several months ago. Mr. Smith speculates that there must just be fewer cars on the road. Actually, he has overlooked the fact that his local government has installed an automatic traffic light system using radiofrequency devices to improve the flow of traffic by synchronizing traffic signals. Because the system is active, the mini-van reaches the freeway in record time and after merging into traffic, Mr. Smith activates the vehicle's intelligent cruise control system. This system uses radar technology to control the van's speed and the distance between other cars on the freeway. The trip is thus less stressful and much safer than in years past.

Along the way, Mr. Smith's cellular phone rings. Being safety conscious, he answers the call using his hands-free wireless headset. Just then, the mini-van zips through a toll booth without slowing, while another unlicensed transceiver identifies the vehicle and charges the Smiths' "EZ Pass" account for the passage. Murphy, a highway patrol officer is sitting in his cruiser by the side of the toll plaza. The gun in his holster is a Colt RF controlled smart gun. It has a trigger lock which keeps the gun from being fired when it is not in proximity to a transponder, which is contained in Murphy's wrist watch. This authentication system will prevent the gun from being used against him, or other members of the public, should someone be able to wrestle the gun away from him.

As he finishes his telephone conversation, Mr. Smith notices that the mini-van is low on gas. Fortunately, he will be able to re-fuel quickly and continue, thanks to the pen-shaped transponder on his key ring. Pulling into a gas station, he hops out of the vehicle and waves the small wand in front of the closest pump. Like magic, the metering device reads his "Speed Pass," activates the pump, allows him to fill his tank, and debits his associated credit card, all automatically. Then, he is on the road again with almost no time lost.

The mini-van arrives on the campus of City U where Mrs. Smith is a professor of literature. She hops out of the van as Mr. Smith drives off and immediately notices a construction crew operating next to the building in which she is about to lecture. One of the construction workers seems to be pushing a lawn-mower like machine along the ground, marking his path as he proceeds. She can see that the crew is about to begin digging. What she does not realize is that the machine she is looking at is a ground penetrating radar device that the crew is using to locate existing underground cables and pipes.

Because Mrs. Smith does not wish to be disturbed by the digging that is about to take place, and since it's a nice sunny day, she decides that to hold her class under a tree in the Quad as she occasionally does. She leaves a note on the classroom door instructing her students to bring their laptop computers, each equipped with a wireless LAN card, to the usual meeting place outside.

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II. What are Unlicensed Devices? – A Taxonomy of Wireless Devices

A. Overview

It is generally easier to explain unlicensed devices in terms of what they are not, rather than what they are. To that end, let's first explore the primary characteristics of licensed devices and services. A prime example of such a licensed service is broadcast television. In order to prevent harmful interference, the Federal Communications Commission (FCC) grants licenses to operators permitting them to broadcast at a particular power level, at a specified location, and in an assigned frequency band. These licenses are normally exclusive with respect to all of these dimensions, and they last for a finite period of time. The licensee can expect to be free from harmful interference which will disrupt the normal operation within the licensed service area. The amount of protection granted to licensees varies from service to service.

In contrast, unlicensed devices have no exclusivity even in the bands within which they are authorized to operate. Part 15 of the FCC rules permits the operation of authorized low power radio frequency (RF) devices without a license from the Commission.[2] The technical standards contained in Part 15 are designed to ensure that there is a low probability that these unlicensed devices will cause harmful interference to other users of the radio spectrum.[3] Part 15 intentional radiators,

Types of Part 15 Intentional Radiators

General Low Power Devices
Low power devices are permitted to operate in a variety of specific bands and they emit only minimal levels of RF energy. Products such as baby monitors, garage door openers, and toy wireless microphones fall into this category.

Spread Spectrum and Digitally Modulated Devices
Spread spectrum transmitters generally use a code sequence to spread a normally narrow band information signal over a wider band of frequencies. This allows for more devices to operate in a given frequency band and thus promotes spectrum efficiency. Many new cordless phones use spread spectrum techniques. Systems that use new forms of digital modulation techniques that have spectral occupancy characteristics similar to spread spectrum devices are also permitted to operate under the same rules as spread spectrum devices.

Unlicensed PCS Devices
Unlicensed Personal Communications Services devices use digital modulation techniques for transmission. Service requirements reserve some frequencies for voice communication while the remaining spectrum is allocated for high-speed data transfer applications. U-PCS is widely used for wireless intra-office telephone systems like wireless PBX systems.

Unlicensed NII Devices
Unlicensed National Information Infrastructure devices also use digital modulation techniques similar to spread spectrum devices. They are intended to provide short-range, high-speed wireless digital communications such as wireless local area networks ("W-LANs"), and to facilitate wireless access to the National Information Infrastructure.

Ultra-Wideband (UWB) Devices - Ultra-Wideband ("UWB"), a technology recently approved (February, 2002) by the FCC for a number of communications and sensing applications, is a signaling method which relies on extremely short pulses that generate signals with very wide bandwidths, sometimes up to several gigahertz. UWB signals go undetected by most conventional receivers, minimizing their threat as harmful interferers. UWB technologies are currently being used in a variety of applications such as ground penetrating radar and are likely to be used in a variety of emerging applications such as through-wall imaging and high-speed data transmission.

[2] Devices are permitted to operate after they have been verified to comply with existing operational restrictions. *See* 47 C.F.R. Chapter 2, Subpart J and 47 C.F.R. §§ 15.1 *et seq.*

[3] In addition to limiting the technical constraints, one of the primary operating conditions under Part 15 is that the operator must accept whatever interference is received and must correct whatever interference is caused. Should

i.e., radio transmitters, are permitted to operate under a set of general emission limits[4] or under provisions that allow higher emission levels in certain frequency bands.[5] Part 15 radio transmitters generally are not permitted to operate in certain sensitive[6] or safety-related frequency bands that are designated as restricted bands.[7] Only out-of-band or spurious emissions from Part 15 transmitters are permitted in these restricted bands. In exchange for operating on an interference sufferance basis, unlicensed devices are free from the burden of the normal delays associated with the licensing process and, as a bonus, spectrum use is free of charge.

In the end, consumers reap the benefit of lower costs, less hassle (no need for a license to operate the device), and more rapid development cycles. Because they are free from the delays inherent in the licensing process, unlicensed devices can frequently be designed to fill a unique need and be introduced into the marketplace rather quickly. The availability of spectrum for use by unlicensed devices has spawned a variety of new applications. This huge and growing market now includes devices ranging

City U's students all enjoy Professor Smith's outdoor lectures. Via the campus-wide wireless network, they are able to download homework assignments, visit relevant Internet sites, and share the professor's lecture notes with the click of a button, all while relaxing in the shade of their favorite tree.

Meanwhile, back in the van, Mr. Smith arrives at his office. He backs the mini-van into the first available parking space as a sensor on the bumper lets him know exactly when he nears the vehicle behind him. As he makes his way through the front entrance of his office building, the doors open automatically triggered by sensors mounted above. As Mr. Smith places his identification badge near a small plastic window on the entry turnstile, a tag reader in the turnstile emits an electronic beep that notifies the building security officer standing nearby that the Mr. Smith has clearance to continue.

Mr. Smith is almost ready to begin his workday. But first, he finds a restroom to wash his hands before grabbing a breakfast sandwich from the deli shop in the lobby. Water pours from a faucet as he waves his hands beneath the spout and the hand drier activates in response to a similar motion. Both of these devices are activated by motion sensor transmitters. Now, it is time to grab a cup of coffee and begin the day.

The commute was its own usual nuisance, but license-free devices made it far more enjoyable than it otherwise might have been. For certain, neither Mr. nor Mrs. Smith has given a single thought to the number of license-free wireless devices they have come into contact with in just this one brief period during the day. In fact, Mr. Smith will learn later in the morning that he has to make an appointment to see a gastroenterologist tomorrow. Once more, license-free devices will make his tomorrow more pleasant than he will ever know. But that's another story.

The Smith' story shows how our lives may be affected on a daily basis by unlicensed devices. However, unlicensed devices are not relegated to consumer convenience applications. They are also being used in hospitals and businesses and by government agencies to provide important communication, tracking, or other services. -NM

harmful interference occur, the operator is required to immediately correct the interference problem, even if correction of the problem requires ceasing operation of the Part 15 system causing the interference. *See* 47 C.F.R. § 15.5.

[4] *See* 47 C.F.R. § 15.209.

[5] *See* 47 C.F.R. §§ 15.215-15.407. In some cases, operation at the higher emission levels within these designated frequency band is limited to specific applications.

[6] The sensitive bands referenced here are bands employed by radio services that must function, as a nature of their operation, using extremely low received signal levels. These systems may be passive, such as radio astronomy, or active, such as satellite down links and wildlife tracking systems.

[7] *See* 47 C.F.R. § 15.205.

from remote control toys and cordless telephones to wireless computer networks and inventory control systems.

B. Rules Governing Unlicensed Devices

1. History

Chaos in the 1920's. During the 1920's, radio communication was a veritable free-for-all; anyone possessing radio equipment was allowed to broadcast signals over the air. The result was chaos. Because interference resulted any time several transmitters operated in near proximity, no one could be assured of reliable communications. By the early 1930's, radio sales and usage plummeted, and the market failure created by this chaos predestined today's regulatory environment. Accordingly, with the passage of the Communications Act of 1934, Congress created the Federal Communications Commission to regulate radio communications in the United States, the District of Columbia, and all U.S. possessions.[8] The FCC has historically controlled access to radio spectrum by allocating specific frequency bands for use by licensed service providers.

Unlicensed Precedent Set in 1938. In 1938 the FCC first allowed unlicensed devices, expected to operate without causing harmful interference, to be sold and operated. Conditions were set to ensure that the devices would not generate emissions or field strength levels greater than a specified maximum.[9] At that time, typical qualifying devices included wireless record players, carrier current communication systems, and control devices.

When these rules were first adopted, most unlicensed devices were designed to operate in the medium frequency (0.3-3 MHz) and high frequency (3-30 MHz) frequency bands, and compliance with FCC regulations was relatively easy to achieve. However, as the industry designed new products intended for operation on higher frequencies, it became more difficult for manufacturers to design useful devices that complied with the maximum field strength limit imposed in this early standard since the signal propagation distance decreases as the operating frequency increases. Accordingly, over the years the FCC amended and expanded the Part 15 rules to permit the use of higher power for unlicensed operation in higher frequency bands where it deemed that the mass-marketing of such products would not result in harmful interference to authorized radio services.

Expanding the Applications Base. In the period from 1960s through the 1970s, provisions were made under Part 15 to permit the operation of many new devices including wireless microphones, telemetry systems, garage door openers, TV interface devices (*e.g.*, video cassette

[8] While the FCC administers spectrum allocated for use by non-federal government entities, the National Telecommunications and Information Administration (NTIA) performs the same function for spectrum allocated for use by the Federal Government. More information regarding NTIA can be found at http://www.ntia.doc.gov/.

[9] The limit applied to these early devices was 15 microvolts per meter (uV/m) at a distance equivalent to the wavelength of the operating frequency divided by 2 Pi. *See In The matter of Revision of Part 15 of the Rules Regarding the Operation of Radio Frequency Devices Without An Individual License*, First Report and Order, Gen. Docket 87-389, 4 FCC Rcd. 3493 at 3554 (1989) (adopted Mar. 30, 1989).

recorders), field disturbance sensors (*e.g.*, anti-pilferage systems for retail stores), auditory assistance devices, control and security alarm apparatus, and cordless telephones.

Spread Spectrum and Other Changes. In 1985, the FCC expanded its Part 15 rules to encompass the operation of low power, unlicensed spread spectrum systems in the 900 – 928 MHz, 2400 – 2483.5 MHz, and 5725 – 5850 MHz bands.[10] Spread spectrum techniques, developed in the 1940s for military applications, are characterized by high immunity to interference and low probability of intercept. These qualities, coupled with their low potential for causing interference to other devices, make spread spectrum systems an attractive technology for consumer use.[11]

In the late 1980's, as technology made possible the introduction of devices designed to operate at higher frequencies than the rules had to date contemplated, the general field strength limit was again becoming too restrictive. In response to petitions for rule making, the FCC completed an omnibus revision of its technical and administrative provisions for the operation of Part 15 devices.[12] In this rulemaking, the FCC standardized the emission limits in various bands and established a number of general usage frequency bands placing limits on peak emissions.

This revision also gave structure to the Part 15 rules which, until that time, had been revised on an ad hoc basis each time a new device was introduced. First, the revision re-classified unlicensed devices into three broad categories:

- **Unintentional Radiators** are devices that generate RF energy internally, or sends RF signals to associated equipment via connecting wiring, but which are not intended to radiate RF energy through the air. Examples include computer CPU boards and power supplies. The components and enclosures of these devices must be shielded sufficiently to limit the amount of RF energy that escapes.

- **Incidental Radiators** are devices, like electric motors, that generate radio frequency energy during the course of operation although the devices are not intentionally designed to generate or emit RF energy.

- **Intentional Radiators** are devices that intentionally generate and emit RF energy by radiation or induction.

Second, the revision created general categories that allow intentional radiators to operate at very low powers in any band except where expressly prohibited. Greater emissions were permitted in certain bands where the FCC deemed such operation would not result in production of harmful

[10] *See Authorization of Spread Spectrum systems Under Parts 15 and 90,* First Report and Order, Gen. Docket No. 81-413, 50 Fed. Reg. 25234 (June 18, 1985), (adopted May 9, 1985).

[11] *See* Appendix A. The Technology of Unlicensed Wireless Devices.

[12] *See In The matter of Revision of Part 15 of the Rules Regarding the Operation of Radio Frequency Devices Without An Individual License,* First Report and Order, Gen. Docket 87-389, 4 FCC Rcd. 3493 (1989) (adopted Mar. 30, 1989).

interference. After this re-write, the FCC continued to modify the Part 15 rules in a more orderly fashion as advances in technology dictated.

Unlicensed Personal Communications Services (U-PCS). In 1993, the FCC first permitted U-PCS devices operate in the 1910-1920, 1920-1930 and 2390-2400 MHz bands.[13] The devices must use digital modulation techniques to transmit information. The operating conditions established for the 1920 – 1930 MHz portion of the allocated spectrum are reserved for voice communication while the remaining spectrum is allocated for high-speed data transfer applications. The 1920-1930 MHz spectrum is used for wireless intra-office telephone systems like wireless PBX systems.[14]

Millimeter Wave Technology. In 1995, the FCC made the 59-64 GHz band, commonly referred to as the millimeter wave band, available for use by unlicensed devices. An additional two gigahertz of spectrum was later made available, widening the band to 57-64 GHz. The FCC noted that the spectrum would be appropriate for novel broadband applications such as wireless computer-to-computer communications. The Commission noted that interference potential to licensed services would also be limited by both high propagation loss at these frequencies and the narrow beamwidth of point-to-point antennas normally operating in this range.

Introduction of U-NII. In 1997, the FCC again amended the Part 15 rules, this time to provide for operation of Unlicensed National Information Infrastructure (U-NII)[15] devices in the 5 GHz Frequency Range (5.15-5.35 GHz and 5.725-5.825 GHz).[16] Once more, the FCC recognized that

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[13] *See Amendment of the Commission's Rules to Establish New Narrowband Personal Communications Services,* First Report and Order, Gen. Docket 90-314, 8 FCC Rcd. 7162 (1993) (adopted June 24, 1993).

[14] At the time of this writing, the FCC was considering proposals that would change the allocation of unlicensed PCS devices in the 1910-1920 MHz band. *In The Matter of Amendment of Part 2 of the Commission's Rules to Allocate Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless,* Third Report and Order, Third Notice of Proposed Rulemaking and Second Memorandum Opinion and Order, ET Docket 00-258, 18 FCC Rcd 2223 (2003) (adopted Jan. 29, 2003), the FCC is considering a proposal by the Wireless Communications Association International ("WCA") to relocate channels assigned to the MDS service to the 1910-1916 MHz and 1990-1996 MHz bands. The relocation would clear spectrum at higher frequencies for use by third generation mobile services ("3G"). Under the WCA proposal, the service rules for the 1916-1920 MHz band would be modified to accommodate isochronous unlicensed PCS service suitable for voice communications, the same as in the 1920-1930 MHz band. Also in Docket 00-258, Nextel Communications, Inc. ("Nextel") has requested that it relinquish spectrum at 800 MHz and 900 MHz to provide a more interference-free environment for public safety licensees. In exchange, Nextel would seek to relocate operations in the 1910-1915 MHz unlicensed PCS and 1990-1995 MHz bands.

[15] The National Information Infrastructure, or NII, is a group of networks, including the public switched telecommunications network, radio and television networks, private communications networks, and other networks not yet built, which together will serve the communications and information processing needs of the people of the United States in the future. *See In the Matter of Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII Devices in the 5 GHz Range,* Report and Order, ET Docket 96-102, 12 FCC Rcd. 1576 (1997) (adopted Jan. 9, 1997).

[16] *See In the Matter of Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII Devices in the 5 GHz Range,*Report and Order, ET Docket 96-102, 12 FCC Rcd 1576 (1997) (adopted Jan. 9, 1997). *See also* 47 C.F.R. § 15.401. It is important to note that the 5 GHz band is also used on an unlicensed basis in Europe. However, the available spectrum, referred to as the HiperLAN2 bands, is slightly different than the US U-NII bands. While the two share the 5.15 – 5.25 GHz portion, the HiperLAN2 upper band is 5.470 – 5.725 GHz. In view of this

developments in a number of different digital technologies greatly increased the need to transfer large amounts of data from one network or system to another. In making this spectrum available, the FCC concluded that providing additional spectrum for unlicensed wideband operation would benefit a vast number of medical, educational, business, and industrial users. U-NII devices use digital modulation techniques similar to spread spectrum devices. They are intended to provide short-range, high-speed wireless digital communications such as wireless local area networks ("W-LANs"), and to facilitate wireless access to the National Information Infrastructure. With the use of a high-gain directional antenna, these devices may be used to complete point-to-point links of over 1 kilometer.

Making Way for Ultra-Wideband. In February 2002, the FCC adopted an Order allowing use of devices that incorporate ultra-wideband ("UWB") technology.[17] UWB devices operate by employing very narrow pulses that spread energy over a broad swath of spectrum, sometimes as much as several gigahertz wide. Because, UWB devices operate across such wide reaches of spectrum, they must share spectrum with an extensive variety of licensed and Federal Government services. The UWB Order defined workable technical standards and emissions restrictions in order to permit UWB devices to operate without causing interference to primary users of the spectrum. To achieve this objective, the FCC adopted very conservative standards based in large measure on limits that the National Telecommunications and Information Administration (NTIA) deemed necessary to protect against interference to existing Federal Government uses such as global positioning systems ("GPS"). The FCC established differing technical standards and operating restrictions for three distinct UWB applications:

- imaging systems including Ground Penetrating Radars (GPRs), through-wall, medical imaging, and surveillance devices,
- vehicular radar systems, and
- communications and measurement systems.

2. Current Issues

70-80-90 GHz. In an effort to anticipate future needs, the FCC has underway a proceeding in which it seeks to promote the commercial development of spectrum in the 71-76 GHz, 81-86 GHz and 92-95 GHz bands.[18] Specifically, the Notice proposed to make the 92-95 GHz band available for unlicensed use and suggested rules for unlicensed operation in that band. While not proposing specific rules in the 71-76 GHz and 81-86 GHz bands, the Notice sought comment on providing for operation of unlicensed devices at those frequencies. These bands have never

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difference, the Wi-Fi Alliance (formerly known as WECA) has petitioned the FCC to modify its rules to permit operation in the 5.470 – 5.725 GHz band. The FCC has not yet acted on that request. A recent agreement between the Department of Defense, NTIA, and the FCC to promote co-existence of unlicensed devices and government radar may help to speed action on the Wi-Fi alliance petition. The Commission has initiated a rulemaking proceeding (RM-10371) to determine the best method to implement proposals contained in the Wi-Fi Alliance petition and the agency agreement.

[17] *Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*, First Report and Order, ET Docket No. 98-153, 17 FCC Rcd. 7435 (2002) (adopted Feb. 24, 2002).

[18] *See In the Matter of Allocations of Services Rules for the 71-76 GHz, 81-86 GHz, 92-95 GHz Bands,* Notice of Proposed Rulemaking, WT Docket No. 02-146, 17 FCC Rcd. 12182 (2002) (adopted June 132002).

before been occupied by non-government users and they may prove particularly attractive to entities seeking to establish new high-speed links because they are essentially devoid of incumbents. The FCC is reviewing comments filed in response to its proposal. Potential uses of this spectrum may include high-speed wireless local area networks, broadband access systems for the Internet, and point-to-point or point-to-multipoint communications systems. These applications are especially well suited for higher frequencies primarily because, as noted earlier, transmissions on frequencies this high travel for shorter distances, making it possible to locate several transmitters in close proximity with less risk of receiving or producing harmful interference.

The FCC seeks to develop a flexible and streamlined regulatory framework that will encourage innovative uses of these three new bands and further promote competition in communications services, equipment, and related markets. Use of these bands may also make it possible to advance the potential sharing between non-Federal Government and Federal Government users and further stimulate the use of technologies developed in military and scientific applications in a broad range of new commercial products and services.

Spectrum Policy Task Force. In a more recent effort to address spectrum access issues, the FCC established a Spectrum Policy Task Force in June 2002. The Task Force was composed of senior staff members from several FCC Bureaus and Offices who were asked to assist the FCC in identifying and evaluating changes in spectrum policy necessary to reflect advances in technology that were likely to increase the public benefits from spectrum use. In November 2002, the Task Force released its findings. Its report noted that, while certain frequency bands are heavily used, many bands either are not in use in all geographic areas or are only heavily used part of the time. Furthermore, the Task Force determined, that these characteristics served to limit access to available spectrum and that such limitations are a more significant problem than the physical scarcity of spectrum itself. The report identified three unique approaches to spectrum policy based on the establishment of a set of legal rights: 1) an exclusive use approach; 2) a commons approach; and 3) a command-and-control approach.[19]

The Task Force urged that the FCC evolve its spectrum policy from its traditional "command and control" model to a more market-oriented approach to achieve spectral efficiency. The Task Force set out four key recommendations to accomplish this policy reform. Recommendations include:

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[19] The Task Force report defined these three legal rights approaches as:

> "Exclusive use" model. A licensing model in which a licensee has exclusive and transferable flexible use rights for specified spectrum within a defined geographic area, with flexible use rights that are governed primarily by technical rules to protect spectrum users against interference.
> "Commons" model. Allows unlimited numbers of unlicensed users to share frequencies, with usage rights that are governed by technical standards or etiquettes but with no right to protection from interference.
> "Command-and-control" model. The traditional process of spectrum management in the United States, currently used for most spectrum within the Commission's jurisdiction, in which allowable spectrum uses are limited based on regulatory judgments.

See generally Spectrum Policy Task Force Report at 5, __ FCC Rcd __ (November 2002) (*Spectrum PolicyTtask Force)*.

1. Migrate toward more flexible, consumer-oriented policies. The Task Force recommended that the Commission evolve its spectrum policy toward more flexible and market-oriented spectrum policies that will provide incentives for users to migrate to more technologically innovative and economically efficient uses of spectrum.

2. Adopt quantitative standards to provide interference protection: interference temperature. The Task Force recommended the creation of a quantitative standard for acceptable interference that provides both greater certainty for licensees and greater access to unused spectrum for unlicensed operators.

3. Improve access through the time dimension. The Task Force found that new technological developments now permit the Commission to increasingly consider the use of *time*, in addition to frequency, power and space, as an added dimension permitting more dynamic allocation and assignment of spectrum usage rights. This would provide access to unused or underused spectrum through time-sharing of spectrum between multiple users and lead to more efficient use of the spectrum resource.

4. Shift from "command and control" model to exclusive and commons models. The Task Force recommended that the Commission base its spectrum policy on a balance of three spectrum rights models: an exclusive use approach, a commons approach and, to a more limited degree, a command-and-control approach. While the command-and-control model currently dominates today's policy, the Task Force recommended altering the balance to provide greater use of both the exclusive use and commons models throughout the radio spectrum and limiting the use of the command-and-control model to those instances where there are compelling public policy reasons, such as some public safety applications. To the extent feasible, more spectrum should be identified for both licensed and unlicensed uses under flexible rules and existing spectrum that is subject to more restrictive command-and-control regulation should over time be transitioned to these models.

On of the most notable of the Task Force's recommendations, from an unlicensed device perspective, is that it urges the adoption of an "interference temperature." The new metric would allow the FCC to quantify and manage interference on a band-by-band basis, by establishing limits on the noise environment in which receivers would be required to operate. To the extent, however, that the interference temperature in a particular band is not reached, the report argues, users who emit energy below that temperature could operate more flexibly – with the interference temperature serving as the maximum cap on the potential RF energy any device could introduce into the band.

Unlicensed NOI. In a further attempt to seek opportunities for shared-spectrum unlicensed operation, the FCC has initiated a proceeding to explore the possibility of permitting unlicensed devices to operate in the bands reserved for television broadcasting and also in newly available spectrum at 3650 – 3700 MHz.[20] In December 2002, the Commission released a *Notice of*

[20] The 3600 -3700 MHz band was previously allocated for use by the Federal Government on a primary basis for radiolocation services, and for non-government use in the Fixed Satellite Service. In 1993, the National Telecommunications and Information Administration identified the 3650 – 3700 MHz portion of the band for

Inquiry (*"NOI"*) seeking comment on the feasibility of such a proposal.[21] The *NOI* observed that, there are many broadcast channels that remain unavailable for TV use in specific areas to avoid co-channel interference problems. One example is that Channel 4 is a broadcast channel in New York City and Channel 3 is a broadcast channel in Philadelphia. As a result, Channel 3 is vacant in New York City and Channel 4 is unused in Philadelphia. While high power TV stations in close proximity using the same frequencies would almost certainly interfere with each other (co-channel interference), low-power, unlicensed devices may be able to operate in those vacancies without the risk of producing harmful interference to TV broadcast stations many miles away. When considering the 3650 – 3700 MHz band, the FCC suggested that allowing unlicensed operation with minimal technical requirements could permit the development of innovative types of unlicensed devices, for instance with power levels exceeding 1 Watt, that would not be allowed to operate under the current rules elsewhere. Provided this proceeding leads to manageable implementation strategies, the spectrum available for unlicensed operation will once again increase.

Spectrum Management Reform. The Federal Government through the NTIA is also continuing to reform and modernize its role in managing spectrum. The FCC and the NTIA have been exercising joint jurisdiction over the radio frequency spectrum since the 1940s, and in January 2003, FCC Chairman Michael K. Powell and Nancy J. Victory, head of NTIA, executed a new Memorandum of Understanding to reflect changes necessitated by advances in technology and market structure.[22] This represents the first time the Memorandum of Understanding has been updated since it was originally signed six decades ago. Under the agreement, the two agencies will regularly review issues surrounding the coordination of government and commercial use of the spectrum as well as the efficacy of the unlicensed model in promoting innovation.

3. Authorization Procedures for Unlicensed Devices

All intentional radiators must be pre-approved for use and sale through an authorization procedure under the auspices of the FCC. The authorization process ensures that devices will not be marketed and available to the public unless they comply with the Commission's technical standards. Authorization can take either of two forms, verification or certification. Verification is a statement made by the manufacturer or importer, attesting that the device complies with FCC rules. This form of authorization is generally employed for well understood devices. Device certification, on the other hand, is a more formal process. Certification requires a written application to the FCC stating that the device complies with the FCC rules along with specific information, including technical specifications for the device. Under this procedure, the Commission reviews documentation regarding such characteristics as transmitter frequency, occupied bandwidth, and output power. In addition, where required, manufacturers will supply

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transfer from a Government/non-Government shared use statue to a mixed-use status. The 3650 – 3700 MHz band is currently not available for unlicensed use. The band falls within one of the restricted bands identified in 47 C.F.R. § 15.205(a). However, the change in allocation status provides an opportunity to re-examine its use.

[21] *See In the Matter of Additional spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band,* Notice of Inquiry in ET Docket No. 02-380, 17 FCC Rcd 25632 (2002), (adopted Dec. 11, 2002).

[22] The text of the Memorandum of Understanding may be viewed at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-230835A2.pdf.

supplementary measurements to show that users of a device will not be exposed to excessive amounts of RF radiation. The FCC may then certify the devices based on an engineering review, or may request samples and actually test the device. To help expedite the certification process, the FCC has authorized private organizations known as Telecommunication Certification Bodies (TCB's) to perform equipment authorizations on behalf of the FCC.

C. Uses and Applications

Devices employing unlicensed technology have diffused into a plethora of rich and diverse uses.[23] These uses range from diagnostic and monitoring applications in medicine and productivity-enhancing corporate applications to whimsical applications in toys and consumer gadgets. The following is a partial list of applications for which we employ unlicensed devices:

- Cordless phones
- Networking Computers
- Linking Computer Peripherals
- Consumer Electronics
- Sensors and controller devices
- Toys
- Radiofrequency Identification (RFID)
- Ground Penetrating Radar
- Security Systems for homes and businesses
- Keyless entry
- Cordless PBX's

Our general observation is that unlicensed applications are flexible enough to span the range from fixed to mobile use. In the past, because of their limited range, many devices were useful only in a specific, although not necessarily fixed, location. These were typified by applications like walking around with cordless phones and or observing children remotely using a baby monitor. We now see an emerging trend where the devices are more frequently considered portable, *i.e.*, moving to another place where they may be used once again, like wireless networking devices used in airports or coffee shops. With increasingly better "hand-off" techniques some unlicensed devices are becoming more like cellular applications, truly mobile. Nonetheless, these devices are useful only over short distances due to their limited field strength. However, some visionaries foresee the marriage of today's short range networks with "3G" cellular technology affording users the true ability to "roam."

Since there are so many overlapping uses for unlicensed technology, for purposes of this discussion we have classified them into six types: 1) person to person; 2) computer networking; 3) fixed wireless; 4) monitoring and identification; 5) detection and imaging; and 6) remote sensing and telemetry. Each, in turn, is discussed below. While the discussion will focus primarily on intentional radiators, we will also briefly discuss an unintentional radiator application known as broadband over power line (BPL).

1. Person to Person Communications

Unlicensed devices are commonly used to provide voice communications over a short range. These include devices such as cordless phones, paging devices, baby monitors, wireless microphones, wireless headsets, and walkie-talkies.

[23] See Appendix A for an overview.

Cordless phones, one of the most prevalent of unlicensed devices, can be found in over 80% of US households. The first commercially available cordless phones emerged as high-end consumer products in the very early 1980's.[24] These early cordless phones operated in the 27 MHz band and suffered from poor sound quality, interference, and a lack of security. In 1986, the FCC allowed cordless phones to use spectrum in the 47-49 MHz band, affording the devices an increase in spectrum to reduce interference. Further improving reception and security, phones using digital spread spectrum in the 900 MHz and 2.4 GHz bands began to appear in 1994 and 1995.

Several manufacturers produce walkie-talkies under the Part 15 rules. These devices, generally low in power and limited in range, are typically sold as toys. The Consumer Electronics Association estimates that there is an installed base of nearly 30 million Part 15 walkie-talkies in the US. Surprisingly, despite the widespread adoption of these devices, the FCC authors found only 10 approvals listed in the FCC's authorization database. The companies holding these authorizations are:

Company	Approvals
Hing Yip Electronic Co. Ltd.	4
Fisher-Price Brands	2
GMT Industrial Ltd.	1
Ka Wah Manufacturing Limited	1
Playtech Ltd.	1
Tung Wei Electronics Co. Ltd.	1

Since most of these companies are privately held foreign entities, we were not able to obtain revenue figures associated with walkie-talkie sales.

Beyond home use, businesses, schools, and hospitals are using unlicensed devices to better communicate with each other in a busy work environment. One example is a wireless PBX used by healthcare professionals at Guy's and St. Thomas Hospital in London. This wireless telephone system operates solely within the hospital and improves productivity and response time.[25] The nurses carry portable telephones linked to the hospital's wireless network. With these telephones doctors are able to contact each nurse directly instead of paging and waiting for a return call. The wireless system also allows nurses to remain at a patient's bedside while responding to inquiries about the patient's health or requesting help. The network also supports data, and that feature will eventually enable wireless transfer of patient records. Eighty-five

[24] We note that the idea of a wireless telephone has existed for some time longer. In 1959, Thomas Carter (no relation to the author) introduced a device which allowed mobile radio systems to be interconnected with the Bell System landline telephone network. AT&T attempted to stop Mr. Carter from connecting his radio-wireline equipment. In the ensuing litigation, the FCC opened the telephone network to the interconnection of non-telephone company equipment. This was later codified as Part 68 of its rules.

[25] *See* http://www.spectralink.com/solutions/pdfs/Case_Guys.pdf.

percent of the nurses using the system felt that the wireless network helps to improve patient care.[26]

2. Computer Networking and Peripherals

The growing popularity of computer networking has stimulated a feverish interest in unlicensed technology. Computers can be networked by newly standardized unlicensed devices that employ digital spread spectrum techniques, similar to the technology found in 2.4 GHz cordless telephones.

Because many families and businesses now have several computers operating at the same location, users often find it both desirable and necessary to install a local area network (LAN) to share resources like printers, scanners, or a common broadband internet connection.[27] While many new office buildings may be pre-wired with an Ethernet network to link its computers, this is seldom the case with older offices or homes. In buildings lacking a ready-made network infrastructure, unlicensed networking may provide a cost effective solution. Wireless LANs (W-LANs) are attractive in that the set-up costs can be many times smaller than the cost to set up a wired network, and installing wires usually requires cutting into sections of walls and floors. Wireless technology also offers the added advantage of reducing set-up time over a traditional wired Ethernet network. Studies show that a W-LAN can be installed in a small office in a few hours at a cost of less than $200 per networked computer. And, once installed, rearrangement costs are minor when compared to those of wired networks.

Unlicensed devices may soon provide a networking solution for homes containing multiple broadcast television, cable, or satellite receivers; broadcast or satellite radio receivers; and video and audio recording and/or playback equipment. In order to share content across these devices, generally, users must manually save the content on some media (DVD, CD, etc.) and transport that media from one room to the next. It would be more convenient if all of these devices could be connected in some manner to allow them to share any available content. Companies such as Intel, Sony, and XtremeSpectrum are developing total home network systems that employ spread spectrum and ultra-wideband technology in anticipation of this need. The idea is to give consumers the ability to distribute data or media programming to any room or device. These systems may make it possible to use a stereo in one part of a home to listen to MP3s saved on a computer hard drive in another part of the home. Furthermore, a single video source (DVD, VHS, cable, etc.) may distributed to any computer or television, eliminating the need for multiple players or set-top boxes.

Outside the home or office, unlicensed wireless computer networking offers the advantage of portability and inexpensive connectivity. For example, a business traveler may wish to have broadband internet connectivity for his laptop computer while on the road. Many airports, restaurants, and hotels now offer services which allow the traveler to open his laptop and find a connection while he is at the airport waiting for his luggage or having a cup of coffee.

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[26] *Id.*

[27] Remarks of Chairman Michael K. Powell at the Broadband Technology Summit, U.S. Chamber of Commerce, Washington DC (April 30, 2002).

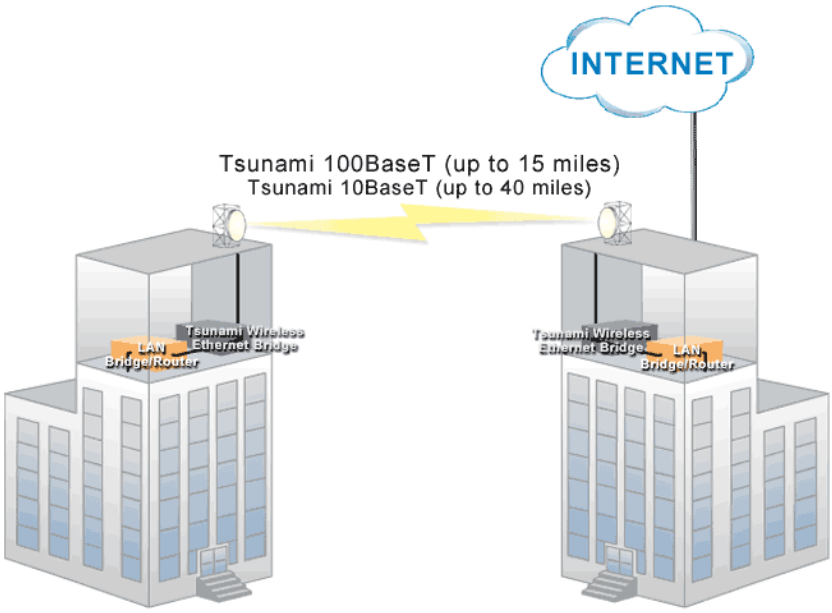
Actually, unlicensed devices need not use the airwaves to provide connectivity. For example, a technology known as Broadband over Power Line (BPL) is now being used in some households. BPL devices use the home's internal electrical power wiring as a communications link to connect computers and peripheral equipment located in different areas of a house. Because most homes have several power outlets in each room, it is easy to connect devices almost anywhere. Although the concept of power line networking has been around for many years, new entrants into the market, fostered by such industry associations as HomePlug, have spawned renewed interest in the technology. In the case of PLC, the devices must comply with Part 15 rules for unintentional radiators.

3. Fixed Wireless Communications

In fixed applications, unlicensed radio equipment is a pure substitute for wires. Multiple fixed wireless links can be implemented as an economical solution for completing a communications bridge over large distances. Here, unlicensed technology offers the convenience of avoiding the time and expense of obtaining a license. Of course, the downside is that if the system causes interference, it must cease operation, and any interference must be tolerated. It has no status, and therefore no protection.

Unlicensed devices in the 2.4 GHz band are often used in this manner. In congested city environments, users are able to quickly set up links to transfer data between structures (buildings, towers, etc.) located across a street or several blocks away from each other. In rural or unpopulated areas, where the likelihood of encountering interference form other users is low, devices in the 2.4 GHz band are used over greater distances.

Figure 1. Wireless Ethernet Bridge



Source: Proxim

Proxim Corporation markets a family of wireless Ethernet bridges under the name Tsunami. Most of the bridges operate in the unlicensed 2.4 GHz and 5 GHz bands. However, a 23 GHz licensed option is also available. Designed to provide a network connection between switches or routers located up to about 40 miles apart, Tsunami's customer base consists of medical centers, school districts, government agencies, and other entities needing to quickly share data among widely dispersed locations. Tsunami operates at aggregate throughput rates ranging from 16 Mbps to 872 Mbps.[28]

Fixed unlicensed links operating in the 57-64 GHz band (millimeter wave band) are also being used for transferring large volumes of data over relatively short distances. At the time of this writing, the FCC had only approved four devices for unlicensed operation in the 57-64 GHz range. However, production of these devices continues and more are being introduced into the marketplace. For example, Harmonix Corporation recently introduced its GigaLink system.[29] This radio system is capable of transmitting up to 622 Mbps using a compact antenna with a focused beam and can be used to link existing fiber optic networks as an affordable alternative to the expensive and time consuming process of installing new fiber.

4. Monitoring and Identification

The combination of low power and localized range offered by unlicensed devices makes them particularly well suited for a variety of uses in monitoring and tracking objects that either cannot be physically touched or are impossible to count individually. These characteristics prove to be even more effective when there are numerous objects or when the objects are in motion.

[28] *See* "What is Tsunami ™?", http://www.proxim.com/products/all/tsunami_bridge/TsunamiAtAGlance.pdf.

[29] *See* Harmonix Corporation, GigaLink Overview at http://www.hxi.com/overview.html.

Unlicensed equipment in this class, referred to as radio frequency identification (RFID) technology, has its origins in radar technology developed during World War II and uses low-power RF emissions in the 125 kHz, 13.56 MHz, 800-1000 MHz, 2.4 GHz, and 5.8 GHz bands. The basic structure of an RFID system includes a small transponder encoded with some relevant information (*i.e.*, personal identification or account information), an antenna, and a transceiver equipped with a decoder. The antenna emits a radio signal to read or write data from or to the tags attached to items to be tracked. The tags may contain information about an item in manufacture; goods in transit; the identity of an animal, person, or vehicle; or a means of payment for a transaction. Some tags are passive and simply re-radiate information to an appropriate transceiver, which then decodes the data and performs some pre-determined action depending on the data received. Other tags can contain internal power sources, are therefore considered active, and are able to independently transmit the information contained within them to an appropriate transceiver.

The first uses of RFID systems were in identifying cattle and railroad cars.[30] Over the past 10 years, these systems have become commonplace around the world for uses as varied as payment, inventory control, and secure entry systems for buildings. These uses yield direct bottom-line savings for many firms. For instance, many stores attach RFID tags to prevent the theft of merchandise, saving billions of dollars in product loss. RFID technology has also been introduced by state municipalities for use with tollbooths. The success of Exxon/Mobil Corporation's "Speedpass" is yet another example of RFID technology. Introduced in 1997, the Exxon/Mobil Speedpass allows drivers to pay for gasoline at Mobil and Exxon stations, among others, simply by waving a small transponder near the gas pump. The transponder automatically transmits a unique, secure ID number that is recognized by an electronic system located in the pump, providing quick and simple access to gasoline and automatically charging fuel purchases to a designated credit or checking account. Exxon/Mobil announced that three million customers had signed up for Speedpass within two years of the introduction of the system.[31]

In a more novel implementation, Federal Express (FedEx), the world's largest express parcel delivery company, is currently testing an RFID based automatic keyless entry and ignition system on 200 of its delivery vehicles. This system uses readers mounted on each of the delivery vehicle doors and one near the ignition switch. The FedEx courier is equipped with an RF transponder embedded in a Velcro wristband. When the courier places his transponder wristband within 6 inches of any reader, the transponder's code is compared to the system's memory. If the codes match, the appropriate door unlocks for five seconds. To start his vehicle, the courier's wristband signals a similar decoder with the proper "digital key" sequence.

When fully implemented, FedEx believes that this system has the potential to save the company and its drivers both time and money. The company's couriers drive millions of miles annually and each time a courier makes a delivery, he must spend time searching for keys and then use them to lock/unlock multiple doors to the vehicle. Furthermore, if a courier misplaces his keys,

[30] Gene Bylinsky, *Hot New Technologies For American Factories Isn't it obvious by now?*, Fortune June 26, 2000.

[31] *See, Mobil Speedpass Surpasses Three Million Users*, http://www.ti.com/snc/docs/news/rel108.htm.

he must wait for someone from a FedEx station to locate and deliver a spare set, and, after each such incident, the vehicle must then be re-keyed at a cost of more than $200. The new RFID system would negate much of this burden. A similar system could conceivably find its way into our personal automobiles in the not too distant future.

Two emerging technologies hold the promise of being able to make almost any object remotely trackable. Soon, even documents like this one may contain RFIDs. RFID tags have become so advanced that one company, KSW-Microtec, has developed a tag that can be ironed on to or sewn directly into the fabric of a garment.[32] The clothing company Benetton has plans to put RFIDs in every article of clothing it makes. Another company, Parelec Inc., claims it has developed an ink which can be used as an antenna for RFID tags. This would allow RFIDs to be printed on paper and polyester, potentially making them part of a product's packaging.[33] The printable antennae also have lower cost and produce less hazardous waste from the manufacturing process than do traditional antennae made from metal. Another technology can be used to create RF antennae and electronic circuits on virtually any object by spraying on a thin film of metal. This technology was developed by NASA which developed a portable vacuum device that could apply the metal film. In September 2002, NASA announced that it was able to apply a metal film using a stencil to create a data matrix containing dark and light squares to make an antenna or a circuit. A company called Vacuum Arc Technology Inc. is planning to commercialize this technology.[34]

5. Detection and Imaging

Unlicensed spectrum can be used as a form of miniature radar for detection and imaging. Such systems emit RF energy in an unlicensed band and receives the reflected waves to sense distance, motion, or even the composition of the material causing the reflection.

One emerging use is UWB ground penetrating radar (GPR). Just recently, the Texas Department of Transportation (DOT) used GPR to determine whether the integrity of Interstate 35 through downtown Austin was compromised as a result of a major underground water main leak. DOT closed a portion of the highway when GPR identified a section of unstable roadway. Hours later, a large sink hole developed in that same section. Law enforcement and other public service agencies are also expected to utilize another UWB technology, "through wall imaging", to aid in the capture of suspected criminals or locate firemen and victims in burning buildings, for instance.

6. Remote Sensing and Telemetry

Unlicensed devices can also be used to provide communications to remote measuring systems via telemetry. Such wireless telemetry technology is finding applications in modern medicine. For several years now, hospitals have been equipped with devices like wireless heart monitors. In fact, some applications for unlicensed technology in medicine are beginning to seem more like

[32] *New Direct-To-Textile Washable Tag*, RFID Journal, November 11, 2002. http://216.121.131.129/article/view/111

[33] *New Ink for Printed RFID Antennas*, RFID Journal, February 5, 2003. http://216.121.131.129/article/view/296

[34] *NASA Unveils Spray-On Circuits*, RFID Journal, September 26, 2002. http://216.121.131.129/article/view/77

what we once regarded as science fiction. In the movie *Fantastic Voyage*, scientists shrunk a submarine and its crew to microscopic proportions and injected it into a human body in order to perform a medical procedure. Now, using a marriage of microscopic optics, robotics, and radio technology, doctors actually can use such a device as part of the practice of internal medicine.

Figure 2. The M2A Pill

Source: Given® Imaging

Given® Imaging has developed a set of optics and electronics that fit into a tiny package, roughly the size of a large cold capsule, that can be swallowed. This device, sold under the name M2A Pill (see Figure 2), after being swallowed makes its way through the patient's digestive system naturally. The pill uses an FCC-approved unlicensed transmitter to send images to a digital recorder about the size of a "Walkman" worn around the patient's waist. The images record the capsule's journey, and the data captured can be downloaded onto a standard computer for review and aid in the patient's diagnosis. The pill is inexpensive enough, only $450 each, to be disposable, after a single-use.[35]

Also in hospital settings, unlicensed medical telemetry devices are used to transmit patient measurement data to a nearby receiver, permitting patient mobility and improved comfort. Medical telemetry devices operate on TV channels 7 - 13 (174 – 216 MHz) and TV channels 14 – 46 (470 – 668 MHz). Presently, they are the only unlicensed devices permitted to operate in the TV broadcast spectrum. Typical applications include heart, blood pressure and respiration monitors. The use of these devices allows increased mobility for patients early in their recovery, while they are still being monitored for adverse symptoms. With such devices, one health care worker can monitor several patients remotely, thus decreasing health care costs. Providing patients the freedom to move about in a limited area while being continually monitored also speeds patient recovery times and shortens lengths of stay.

Figure 3. Grill Alert Talking Remote Thermometer

Source: Brookstone

Not all unlicensed wireless telemetric devices are for scientific and medical purposes, though. For example, a wireless thermometer (see Figure 3) can permit a barbeque enthusiast to monitor the progress of his roasting meat while he is away from the grill. The device incorporates two parts, a transmitter with a stainless steel probe and a remote monitor. The "chef" inserts the probe into the center of the roast, identifies the kind of meat, and indicates how he wants it cooked. When the temperature in the probe reaches a predetermined level, it sends a signal to its wireless monitor up to 300 feet away, with voice prompts reporting, "Almost ready," and, "Ready."

[35] Rob Stein, *Patients Find Technology Easy to Swallow*, Washington Post, December 30, 2002, at A1.

III. The Market for Unlicensed Wireless Devices

The market for wireless devices (both licensed and unlicensed) straddles several broad industries. Because the uses of spectrum are so varied, one must look at a diverse set of manufacturers and distribution channels.

One thing is certain, unlicensed wireless devices have become pervasive, reaching nearly every household in the US. The Consumer Electronics Association estimates that there is an installed base of more than 348.23 million Part 15 consumer electronics devices; that is, more than one for every US citizen.

Table 1. Current Installed Base of Part 15 Devices

Product	Penetration	Number per Households Using	Total Installed Base (in millions)
Cordless Phones	81.00%	1.5	130.01
Garage Door Openers	40.80%	1.29	56.26
Keyless entry systems for cars	26.50%	1.4	39.71
Remote control toys	19.50%	2.61	54.57
Home security systems	18.00%	1.1	21.21
Toy walkie-talkies (not FRS)	15.10%	1.85	29.81
Baby monitors	10.50%	1.38	15.52
Wireless Routers	N/A	N/A	1.14

Number of US Households: 107 million

Source: Consumer Electronics Association

In the previous section, we provided a general overview of how some specific unlicensed devices are used. This section offers more detail by looking at devices by submarket or product type in an effort to depict relative demand.

A. Trends in Authorizations of Part 15 Devices

The number of unlicensed device authorizations issued by the FCC and its TCBs can be an indicator of market trends.[36] Since filing an application represents a fair-sized commitment of time and financial resources, a manufacturer will only file when it believes that it can successfully market a new device or make improvements on an existing product. The greater the number of applications filed and authorizations granted, the greater the number of devices likely to be on their way to the marketplace. Though not a pure indication of success, this measure seems to be "directionally correct."

[36] *See* Section II.B.2 for our discussion on how Part 15 devices are authorized under the FCC's Rules.

By this measure, an analysis of Part 15 authorizations tells a story of continual increase in unlicensed operations. As demonstrated in Table 2, general low power devices (including spread spectrum devices) represents the lion's share of authorizations, while U-PCS and U-NII represent a much smaller percentage of authorizations. Finally, UWB, which was authorized only last year, is off to a fast start with 9 devices authorized.

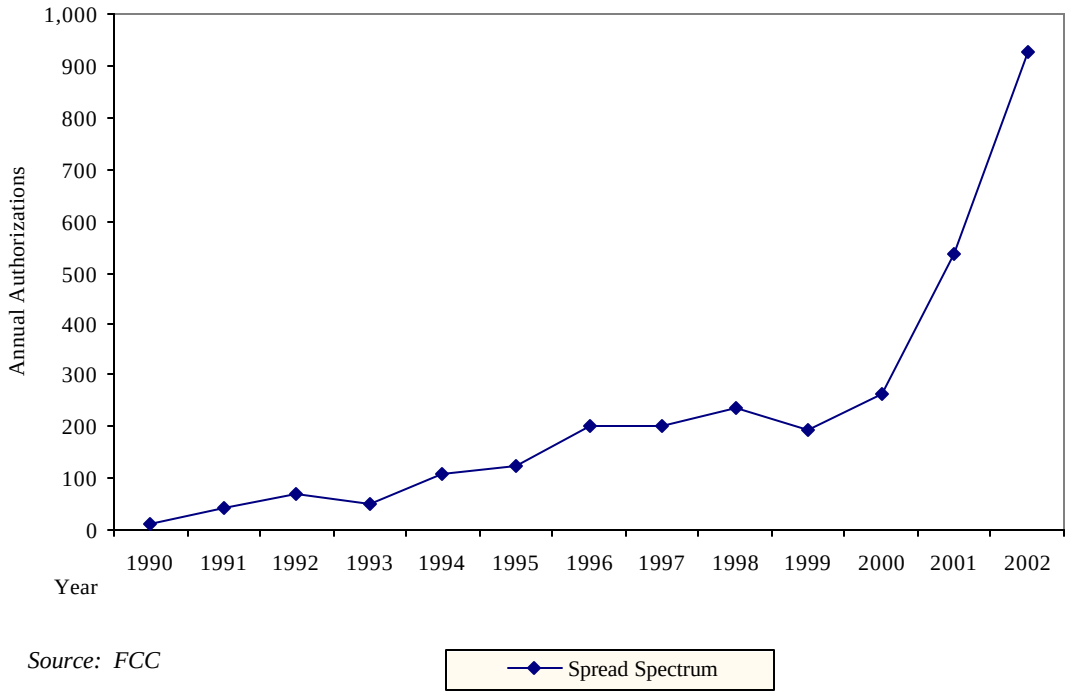
In the five-year period between 1998 and 2002, the FCC issued 7,954 authorizations for unlicensed devices. The number of authorizations represents an increase of over 150% compared to the number of authorizations granted during the five year period from 1993 to 1997, when only 4,998 authorizations were granted.

Table 2 Part 15 Intentional Radiator Authorizations 1993 – 2002

YEAR	General Unlicensed Devices (Part 15C)	Unlicensed PCS (Part 15D)	U-NII (Part 15E)	UWB (15F)	Total Authorizations
1993	706				706
1994	914				914
1995	967				967
1996	1,149	7			1,156
1997	1,244	10	1		1,255
1998	1,128	7	4		1,139
1999	1,188	8	9		1,205
2000	1,477	13	11		1,501
2001	1,664	2	45		1,711
2002	2,286	0	103	9	2,398
Cumulative Totals	12,723	47	173	9	12,952
Note that these numbers include both authorizations for new devices and authorizations for changes to existing devices. The vast majority is original equipment.					

At first look, U-PCS and U-NII's combined total of 220 authorizations appears rather uninteresting when compared to the general low power and spread spectrum device total of 12,723. Yet this does not tell complete story. While the major growth component of the general unlicensed devices category has been spread spectrum devices, the demand for them was initially slow to develop. The FCC first authorized spread spectrum technology for use in Part 15 devices in 1985, yet by 1990 it was only authorizing 12 devices per year. But, as the need to deliver more data economically without wires increased, manufacturers saw spread spectrum as a solution. Inspired largely by computer networking applications, more and more spread spectrum devices were developed. As we see in Figure 4, the number of spread spectrum had climbed slowly to 236 by 1998, and jumped to 537 in 2001. In 2002, the FCC issued 928 such authorizations.

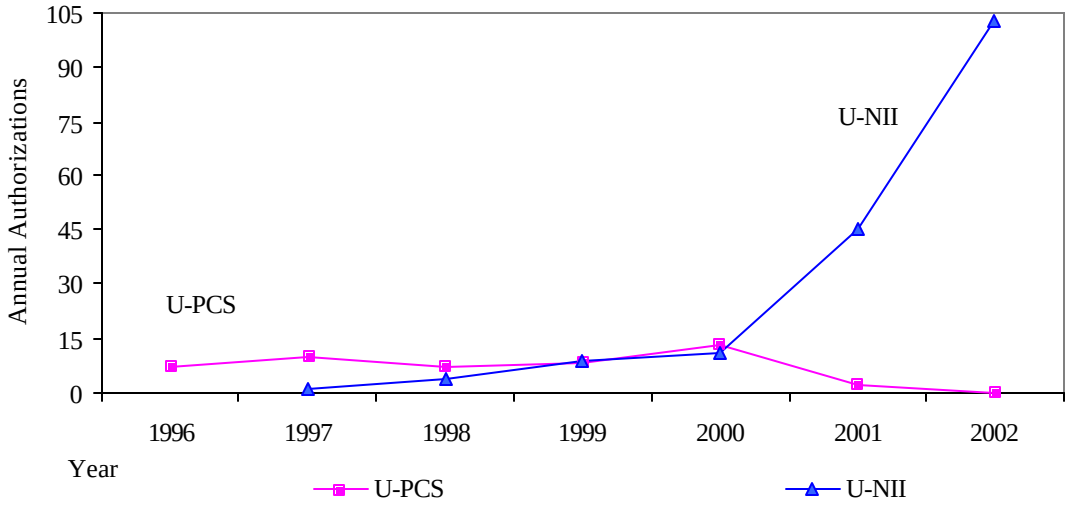
Figure 4. Annual Part 15 Spread Spectrum Device Authorizations (1990 - 2002)



Source: FCC

Similarly, U-NII authorizations are growing and are likely to increase in importance. As shown in Figure 5, U-NII device authorizations have grown from 7 to 103 per year, since their introduction in 1996. Between 1997 and 2002 the average annual growth rate for these approvals was 17%. This rate is comparable to the current growth of spread spectrum and, in fact, greatly exceeds the growth rate of those devices in their first 5 years.

Figure 5. Annual U-NII and U-PCS Authorizations (1996-2002)



Source: FCC

The growth of U-PCS authorizations has been characterized by fits and starts. Many observers expected that U-PCS devices would consist of new cordless telephones, local area networks, and other kinds of short-range communications. Authorizations for U-PCS devices peaked in 2000 and plummeted thereafter (*see* Figure 5). This trend illustrates the cross elasticity of unlicensed spectrum. The lack of U-PCS-approved devices on the market today may be due to a combination of the service limitations placed on the U-PCS bands and the limited amount of spectrum available in the band to support voice communications. Many of the applications foreseen for the U-PCS bands are now being supplied using the spread spectrum and U-NII bands. The 2002 downturn in U-PCS authorizations directly corresponds to a rise in spread spectrum and U-NII devices the same year. We observe that this cross elasticity may work in both directions. As the U-NII bands become more heavily used and congested, it was inevitable that manufacturers and service providers would file petitions to relieve the current restrictions in the U-PCS bands.[37]

Finally, since UWB devices were only permitted under the rules in 2002, it is too early to make any certain conclusions about the success of their adoption. However, the fact that 9 authorizations were issued (ground penetrating radar and through-wall viewing applications) in the first 11 months is an encouraging sign of growth. By comparison, to reach this level of annual authorizations, it took spread spectrum devices 5 years, U-PCS devices 5 years, and U-NII devices 4 years from the time when each was initially introduced. These early UWB authorizations signal a strong interest by manufacturers in the technology. Given the fact that UWB voice and data communication devices are in the developmental pipeline, but not yet authorized by the Commission, one can expect that the number of authorizations will continue to rise dramatically.

Time to reach the same level of Ultra Wide Band authorizations:

Spread spectrum	5 years
U-PCS devices	5 years
U-NII devices	4 years

B. Cordless Phones

Cordless phones have become one of the most pervasive uses of unlicensed technology. Cordless phones have captured the lion's share of revenue of the consumer telecommunications equipment market. Along with Wi-Fi, they are among the most important segments of that market.[38] As such, they have proven to be both a leading indicator of advances in technology and a poster child for overcrowding in the bands available for unlicensed operation.

Major manufacturers of cordless phones include:

- Advance American Telephones
- AT&T
- Sony
- Southwestern Bell

[37] For example, refer to Footnote 14 supra. Also, see petitions for rulemaking filed at the FCC by the Wireless Network Information Forum, Inc. ("WINforum"), (RM-9498); and UTStarcom, Inc. (RM-10024). The FCC has not yet acted on these petitions.

[38] 2001 MultiMedia Telecommunications Review and Forecast, Telecommunications Industry Association, 2001,.at 127.

- Conair
- GE
- Northwestern Bell
- Siemens
- Thompson Consumer Electronics
- Uniden
- Vtech
- Panasonic

Sales of cordless phones now exceed those of their corded equivalents both in the number of units sold and in total dollar sales. Surpassing corded phone sales in 1997, cordless phones are expected to tally $1.653 billion in sales in 2002.[39] Two organizations, Telecommunications Industry Association (TIA) and the Consumer Electronic Association (CEA), provide estimates of the sales of cordless phones in the US. Though their individual estimates of cordless sales vary, they both indicate strong growth over the past decade and statistics from both suggest that the absolute growth rate is leveling off as adoption surpasses 80%.

Table 3. Average Sales of Price and Penetration of Cordless Phones 1997-2001

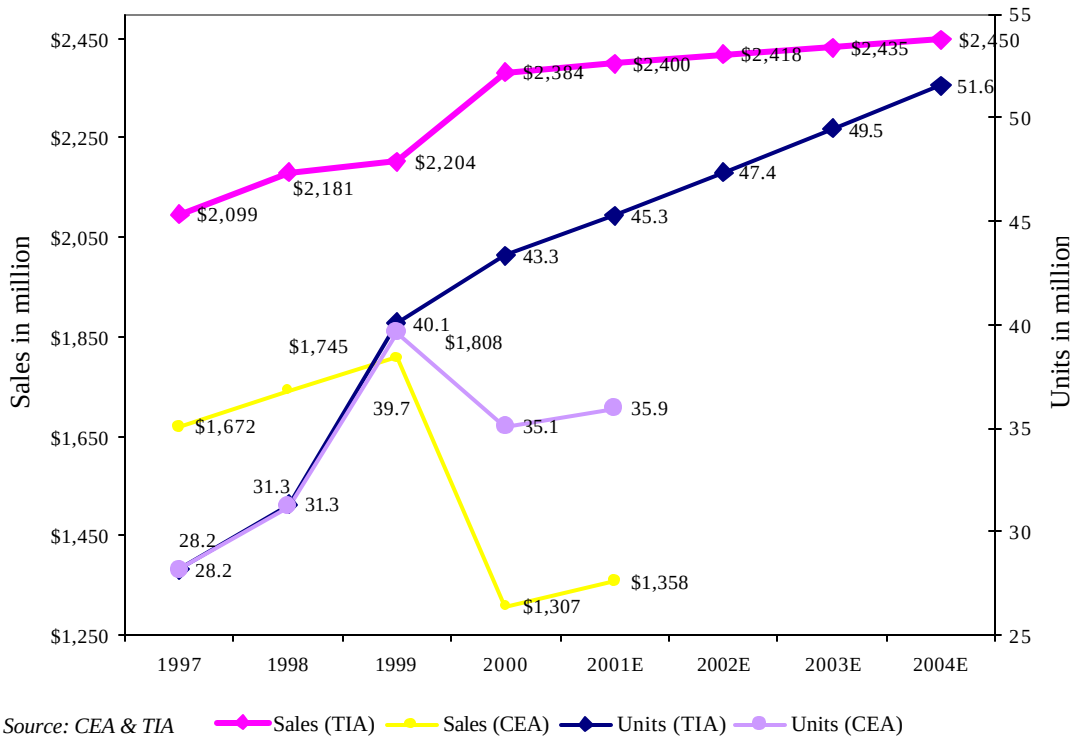
	1997	1998	1999	2000	2001
Avg. Price	$59.38	$55.82	$45.59	$37.25	$37.79
HH%	68.00%	73.00%	78.00%	80.00%	81.00%

Source: Consumer Electronics Association eBrain Market Research

Sales estimates from both TIA and CEA are plotted in Figure 6. The TIA forecasts include the years 1997 through 2004, while the CEA statistics cover the period through 2001. As seen in Table 2, the Consumer Electronics Association estimates that cordless telephone penetration grew from 68% of households in 1997 to 81% in 2001.

[39] Letter from Michael Petricone, Vice President, Technology Policy, Consumer Electronics Association, to Alan Scrime, Chief, Policy and Rules Division, Office of Engineering and Technology, FCC, ET Docket No. 82-135, September 30, 2002.

Figure 6. Sales of Cordless Phones 1997-2004



These estimates vary by roughly 25%, historically, but estimates for recent years vary as much as 83%. One potential source of the variance may be because TIA measures sales of answering machines separately; therefore cordless phones with integrated telephone answering machines may be tallied differently.

C. Wireless LAN and Computer Devices

One widely adopted application of unlicensed spectrum involves linking computers to create wireless local area networks (Wireless LANs or "W-LANs"). Wireless networking has been described not as the killer application, but as the killer platform. This means of connectivity supports two primary applications: 1) the integration of computers into a common resource pool where they can share information and resources and 2) the linking of peripheral devices such as printers, wireless mice, PDA's, and other consumer electronics such as audio video equipment to one or more computers. The sales of W-LAN equipment have experienced double-digit growth since 2000, representing a total growth of over 150%,[40] and W-LAN sales are expected to top $2 billion in 2002. At this rate, wireless LAN sales will eclipse cordless telephones as the leading revenue generator sometime between 2002 and 2004.

[40] *See generally* Spectrum Policy Task Force Report at 54, __ FCC Rcd __, (November 2002) (*Spectrum Policy Task Force Report)*.

Because they are more like consumer electronics and other computer peripherals than telecommunications devices, wireless networking products for the home are generally sold through traditional computer and consumer electronics distribution channels. And, although most W-LAN equipment is currently sold as an aftermarket addition, W-LAN cards are forecast to be integrated as components in about 30% of laptop computers by 2003.[41]

Competition between W-LAN standards to obtain dominance in use in commercial products has been fierce. Among the more popular of the standards is the Institute of Electrical and Electronic Engineers' (IEEE) suite of protocols known as wireless fidelity or "Wi-Fi".[42] Wi-Fi is emerging as the leader, but, as explained below, not all unlicensed wireless networking is Wi-Fi-based.

1. Wi-Fi, Bluetooth, and Home RF Distinguished

> "**Wi-Fi** will be built into everything. It's like trying to imagine all the uses for electricity before it was invented."
>
> Sky Dayton
> Founder of Earthlink

Several industry standards have been developed by manufacturers of devices that use the 2.4 and 5.7 GHz bands. The Wi-Fi suite of protocols includes IEEE 802.11b and 802.11g in the 2.4 GHz band, and IEEE 802.11a in the 5.7 GHz band.[43] In addition to Wi-Fi, there are several widely adopted standards including Bluetooth and HomeRF. While Wi-Fi (with the exception of 802.11a), Bluetooth, and HomeRF operate in 2.4 GHz band, they are not interoperable. Each has strengths and weakness, several of which are listed below in Table 4, best suited for particular applications.[44] Recently, however, the consortium that promotes HomeRF ceased operations.[45] Therefore, it is unlikely that the HomeRF standard will continue to be a prime choice for new products, leaving this segment almost exclusively to the Wi-Fi family. Sky Dayton, the founder of Earthlink, was recently quoted, "Wi-Fi will be built into everything. It's like trying to imagine all the uses for electricity before it was invented."[46]

[41] ARCchart, *73 percent WLAN Growth in 2002*, Blueprint Wi-Fi, September 26, 2002, at 7.

[42] The IEEE is a non-profit technical professional organization. Among other activities, the organization develops operating standards for communication equipment. The IEEE 802.11 Working Group, in particular, develops standards for wireless local area networking devices. Wi-Fi is a trademark owned by the Wi-Fi Alliance, formerly the Wireless Ethernet Compatibility Alliance.

[43] Formerly, the term "Wi-Fi" referred only to 802.11b. The 802.11a standard was referred to as Wi-Fi5.

[44] Several semiconductor companies are planning to introduce 802.11a and b dual-band chipsets. Matt Lewis, *Two Bands or just one band – that is the question*, BluePrint Wi-Fi, August 29, 2002, at 1.

[45] Richard Shim, *HomeRF Working Group Disbands*, CNET News.com, January 7, 2003.

[46] Sky Dayton, *Wi-Fi? Why Not?*, Wired, September 10, 2002.

Table 4. Performance Metrics for Selected Wireless Networking Standards

System Type	Channel Bandwidth	Channel Capacity	Typical Data Rate to Customer	Range
802.11b	22 MHz (2.4 GHz band)	11 Mbps	5.5 Mbps**	250'
802.11a	40 MHz (5.7 GHz band)	54 Mbps	32 Mbps**	75'
802.11g	40 MHz (2.4 GHz band)	54 Mbps	32 Mbps**	150'
Bluetooth	1 MHz (2.4 GHz band)	1 Mbps	721 kbs**	30'
HomeRF	1-5 MHz (2.4 GHz band)	10 Mbps	***	150'
HomePlug (802.11b)	4.3 – 20.9 MHz (power line) (2.4 GHz band wireless)	14 Mbps	11 Mbps	250' (wireless link)
**If WEP (Wireless Equivalent Privacy) security protocol is activated, it may use an additional 10% of the channel capacity.				

a. Wi-Fi

Adopted in 1999, the 802.11b standard provides short-range (800 to 1200 feet in open space or 250 to 400 feet in an enclosed space)[47] wireless connectivity.[48] It is by far the most widely adopted standard. The 802.11a (formerly Wi-Fi5) specification, offering better speed but more limited range, was adopted in 1997 by the IEEE.[49] The performance and speed these standards can provide rivals that of 10BaseT wired Ethernet networks, used in many offices.[50]

b. Bluetooth

Bluetooth is a short-range wireless technology that allows devices to interact at a range of up to 30 feet with a maximum transmission speed of 1 Mbps. Bluetooth is named for 10th Century

[47] *The Spectrum Analyzer* Volume 1, Issue 1, Federal Communications Commission's Office of Engineering and Technology, Summer 2001, at 8.

[48] John Breedem, II and Carlos A. Soto, *Detecting a Wireless Network Hub is only Half the Battle*, Washington Post, October 10, 2002, at E8.

[49] *The Spectrum Analyzer,* Volume 1, Issue 1, Federal Communications Commission's Office of Engineering and Technology, Summer 2001, at 7-8.

[50] *Claims of 802.11a's being able to deliver 54 Mbps and consistent performance are disputed within the industry*, Communications Daily, December 9, 2002 at 4.

Danish King who united the nation and is a trademark for the standard promulgated by a trade association called the Bluetooth Special Interest Group (SIG).[51] Bluetooth was initially envisioned as a cable replacement technology and is primarily used to connect computer devices and peripherals. For example, a mobile phone equipped with a Bluetooth chipset can be used to exchange information such as telephone number lists with a Bluetooth enabled laptop. Similarly, Bluetooth can be used to link a desktop PC to a nearby printer without need for unsightly wires.[52]

Bluetooth is now gaining acceptance for applications other than cable replacement. For instance, Delphi Corporation recently displayed Bluetooth technology in a new Saab 9-3. With Bluetooth, drivers can connect a wireless headset to a mobile telephone and operate more safely in a "hands free" mode, or connect to a PDA right from the vehicle. Bluetooth, coupled with other wireless technologies, is also expected to permit a driver to communicate from an automobile to an external computer or even a home networking systems. Accordingly, a driver will eventually be able to download music, for instance, from a home network and enjoy the music during his commute to work.

c. HomeRF

HomeRF was designed as an open standard to enable a variety of devices to communicate via voice, data, or streaming media within the confines of a home or small office. HomeRF delivers performance comparable to that of IEEE 802.11b products; a range of approximately 150 feet with a peak bit rate of 10 Mbps. Prior to the demise of the HomeRF association, announced in January 2003, advancements were expected to improve the bit rates to reach 20 Mbps in 2003, and potentially reach 100 Mbps eventually.

d. HomePlug

Broadband over Power Line (BPL) is now being used in some households to connect computers. BPL devices function by using a house's electrical power lines as a transmission medium to provide high speed communications capabilities by coupling RF energy onto the power line. Because most homes have multiple power outlets in every room, it is easy to connect multiple devices at almost any location. The concept of powerline networking has been around for many years. However, new entrants into the market such as HomePlug and Current Technologies are expected to spur renewed interest in the technology.

[51] The Bluetooth Special Interest Group (Bluetooth SIG) is a trade organization which promotes the development and marketing of Bluetooth products. Members of the Bluetooth SIG include 3Com, Agere, Ericsson, IBM, Intel, Microsoft, Motorola, Nokia, Toshiba and hundreds of others. Members are granted a royalty-free license to use Bluetooth wireless technology in certain products listed on the Bluetooth qualified products list (QPL). Bluetooth Qualification Bodies (BQBs) authorize products to be on the list. The QPL currently contains 756 licensed end products, subsystems, components, and development tools.

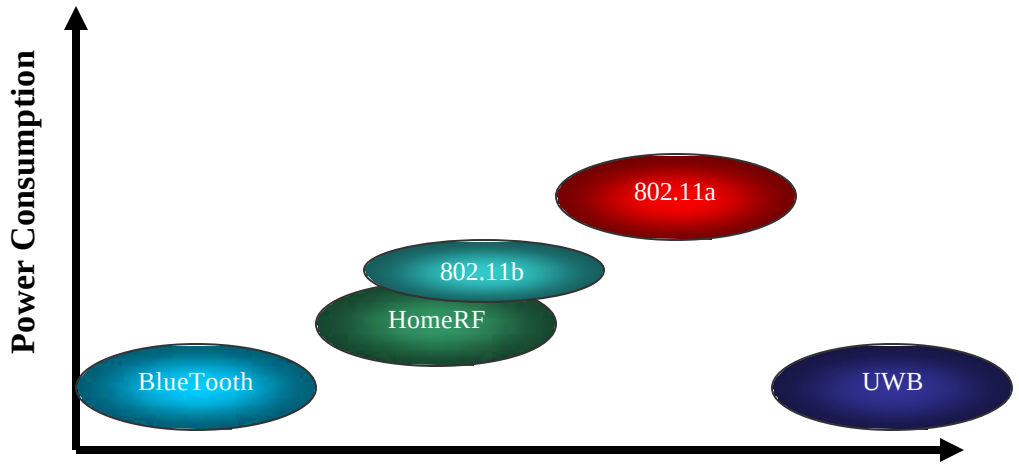
[52] Gillian Law, *Microsoft takes Bluetooth to the desktop*, InfoWorld, October 15, 2002, http://www.infoworld.com/articles/hn/xml/02/10/15/021015hnmsblue.xml?s=IDGNS last visited October 15, 2002.

e. Contrasting the Standards[53]

Each standard offers unique advantages and limitations. One tradeoff, for example, is power consumption versus transmission speed. These differences are displayed in Figure 7. Two other significant differences are cost and range.

Bluetooth requires little power but offers peak speeds of 1 Mbps. In contrast, Wi-Fi offers speeds of 11 Mbps but needs more power, and 802.11a offers speeds of 54 Mbps but requires a significant increase in power. Power consumption is a key factor in the design of portable devices like laptop computers, but so are range and network speed. Bluetooth, given its limited range and speed but low cost and frugal power consumption, is ideal for use in a peripheral device like a wireless mouse. Wireless mice would require long battery life but would not need to communicate large amounts of data to function. Looking ahead, Ultra-WideBand communication devices promise speeds up to 100 Mbps and are expected to subsist on very low power.

Figure 7. Speed vs. Power Consumption for Wireless Networking Protocols



Source: FCC

Each of these protocols offers different trade offs in terms of speed versus effective range as well. Table 4 shows the varying performance in this dimension for the major protocols. Speed, as measured by the effective part of a channel's capacity, is optimized for 802.11g. By comparison, 802.11b offers much greater range, but at a lower throughput speed.

In the future, the choice of protocol might not necessarily be an either/or decision. Increasing flexibility will be afforded by equipment with dual-band and multi-mode capabilities, having the built-in ability to change depending on the conditions. Recently, Netgear and Linksys announced that they will start to ship PC network interface cards that support both 2.4GHz operation for 802.11g and 5GHz operation for 802.11a. A tri-mode 802.11a/b/g card will also soon be available from Netgear for around $157. Netgear's 802.11g card is $79 and its dual-band card is about $109. The company claims the card will support 64, 128, and 152-bit WEP

[53] Homeplug is not included in this analysis because its networked devices are plugged into power outlets, therefore power consumption is not an issue.

encryption and can provide up to 108 Mbps in its 802.11a "Turbo". Linksys' dual-mode card is around $99 and offers regular speeds of 54Mbps in 802.11a/g, or 11Mbps fallback in 802.11b. These products have yet to be ratified by the IEEE for 802.11g support and have not yet received FCC approval. These technologies would select protocols which are the best for a given use in any given moment.

f. Emerging Standards: 802.16 and 802.20

In January 2003 the IEEE released 802.16a, a new computer networking standard which it claims has significant improvements over current generations of Wi-Fi. The new standard will offer an effective range of several miles, compared to Wi-Fi's roughly 300 feet. In addition, 802.16a offers greater security, has the ability to penetrate walls, and can carry voice-grade telephone calls. This new standard is being called "Wi-Max" and "Wider-Fi". The IEEE is also working another standard called 802.20 which can provide a connection a devices in a car or a trains traveling at speeds that can exceed 120 miles an hour. Since 802.20 promises mobile connectivity similar to a cellular network, some are calling it "Mobile-Fi".[54] Nokia, Proxim, and Ensemble Communications are developing 802.16 devices. Flarion is selling equipment using the 802.20 standard. It is clear to us that in the coming months and years wireless networking protocols will offer ever-increasing speed and effective range. These protocols using unlicensed bands are likely to catch up with and may eclipse the speeds, ranges, and handoffs of cell phone networks.

Table 5. Performance Metrics for 802.16 and 802.20 Standards

System Type	Channel Bandwidth	Channel Capacity	Typical Data Rate to Customer	Range
802.16 (Wider-Fi)	20 – 50 MHz	100 Mbps	10 Mbps	Miles
802.20 (Mobile-Fi)	N/A	16 Mbps	6-8 Mbps	Miles

2. Wireless Networking Product Sales

Estimates of wireless network products sales vary; however, they all indicate rapid growth over the past two years and project increasing future sale volumes. The consensus seems to be that worldwide W-LAN sales, including Wi-Fi and all others, range between $1.7 and $2.0 billion in 2002. Of that market, Goldman Sachs reports that sales of Wi-Fi alone are likely to top $1.3 billion, or roughly 65-76% of 2002 sales. The Synergy Research Group reported that the Wireless LAN market posted its eighth consecutive quarter of double-digit growth and grew over 150 percent from 2000 on. Synergy

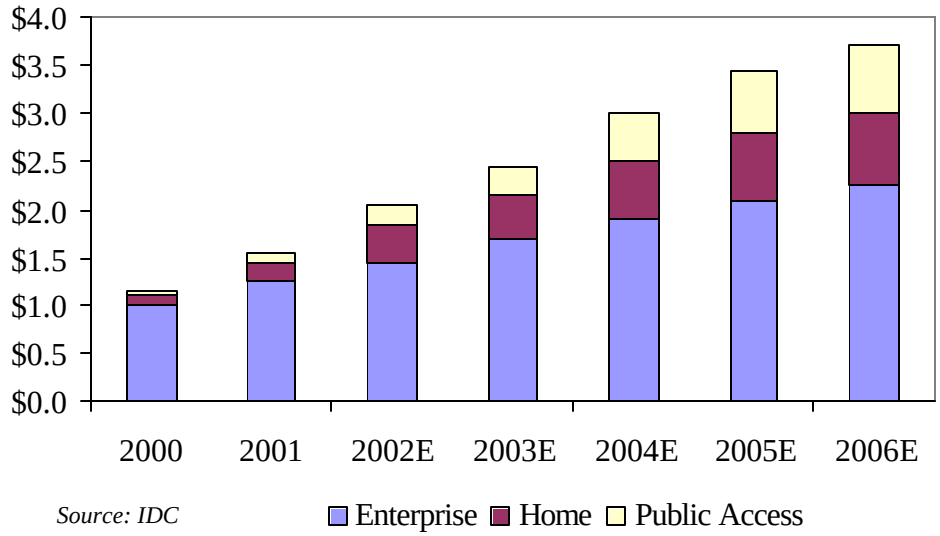
In 2003, sales of Wi-Fi are likely to top $1.3 billion. At this of growth rate, Wi-Fi sales will eclipse cordless telephones in revenue between 2003 and 2004.

[54] Scott Woolley, *Wider-Fi*, Forbes, April 14, 2003, at 200. http://www.forbes.com/forbes/2003/0414/201.html

estimates that 5 million Wireless LAN adapters were shipped in 2001. According to IDC Frost and Sullivan, 2.4 million units of either HomeRF or Wi-Fi systems were sold in 2000, and another 3.7 million systems were sold in 2001. Cahners-InStat/MDR expects that HomePlug will help to increase sales in the power line networking market from under $18 million in 2001 to nearly $190 million in 2002.

The US market represents more than half the estimated world market, about 63% of 2002 shipments. Gartner Dataquest reports that worldwide 2002 W-LAN shipments were 15.5 million units, a 73% growth over 2001. Also in 2002, revenues from W-LAN shipments will increase 26% to $2.1 billion, projected to rise to $2.8 billion in 2003. This growth rate is not expected to taper off until 2007.[55] The sale of W-LAN equipment is expected to grow from $1.1 billion in 2000 to $5.2 billion in 2005.[56] Estimates vary as to which market segments will be the most important for W-LAN sales. As can be seen in Figure 8, IDC is projecting the enterprise segment to comprise the lion's share of Wi-Fi sales. This contrasts with estimates from the Synergy Research Group. Although the two sources project total sales which are very similar in total volume, Synergy expects that sales in the SOHO/residential segment will represent the majority. This view comports with what is happening in the market currently.

Figure 8. Wi-Fi Equipment revenue forecast by business segment (in billions)



While sales figures can illustrate successful marketing strategies, in order to truly understand how widely the technology is being adopted, it is also helpful to look at the actual number of people using the devices. By 2003, more than 5.4 million people worldwide are expected to use the technology regularly, according to Gartner Research. Gartner also believes that more than 560 million Bluetooth-enabled devices will be purchased worldwide by 2005.[57] The number of

[55] ARCchart, *73 percent WLAN Growth in 2002*, Blueprint Wi-Fi, September 26, 2002, at 6.

[56] Jeff Abramowitz, *Wireless LANs – Poised for Untethered Growth*, Mimeo, 2001. Available at http://www.wlana.org/pdf/wlana_industry.pdf, last visited November 26, 2002.

[57] Communications Daily, *Telecom*, September 5, 2002.

unlicensed wireless networks is expected to top 15,000 by the end of 2003, up from 1,100 in 2001.[58] It has also been predicted that 21 million Americans will be using W-LANs by 2007. IDC Frost and Sullivan predicts an installed base of 25 million HomeRF and Wi-Fi systems by 2004.

Given the foregoing data, it is evident that Wi-Fi, and W-LAN equipment sales in general, are experiencing steady increase. In the end, the market for these devices may be limited only by the number of applications that are developed and technical problems that need to be overcome.

There are, to be sure, certain issues that have the potential to keep wireless networking from reaching its full potential as a mass market product. Most notable is security. The sharpest criticism of Wi-Fi and Bluetooth is that both lack sufficient levels of encryption to prevent the eavesdropping on data and that each employs only rudimentary means to block access by would-be hackers. Implementing security features adds support and configuration costs for both end users and product developers. Similarly, it makes it more difficult for wireless products to interoperate. Gartner Research estimates that the added support and usage costs for businesses and consumers could reach $5.6 billion per year (above the device costs) for Bluetooth technology alone by 2005.[59]

Another market challenge for wireless networks is whether equipment manufactures can produce a turn-key product acceptable for the mass market.[60] At present, most home networks require both a significant level of technical sophistication and more than a modest amount of time to set-up and install. Windows XP, the next generation of the Microsoft Windows operating system, has expanded plug and play support for Wi-Fi and other wireless devices.[61] One such device Microsoft is promoting is remote, touch-screen monitors called Smart Screens which allow the computer to be used from remote rooms in one's home. Ease of configuration and use, however, is diametrically opposed to the trend toward greater security. The easier it is to set up, the easier it is to break into.

Despite early successes, a major shakeout of Wi-Fi equipment manufacturers is possible in the future. Projections suggest that there may be room for as many as 6 or 7 manufacturers of wireless computer networking equipment.[62] While overall revenue projections seem impressive, a significant share of this revenue will be directed to large, public companies, for which revenues from Wi-Fi will account for only a small percentage of their overall total.[63] Since this may be a

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[58] Roger O. Crockett, Heather Green, Andy Reinhardt and Jay Greene, *SPECIAL REPORT -- WIRELESS INTERNET, All Net, All the Time High-speed connections, just about anywhere: Wi-Fi looks like a communications breakthrough*, Business Week, April 29, 2002 at 100.

[59] Communications Daily, *Telecom*, September 5, 2002.

[60] Interview with Christopher Fine, Vice President and Chief Technology Strategist, High Technology Investment Banking Group, Goldman, Sachs & Company, New York, Oct. 21, 2002.

[61] ARCchart, *Microsoft launches 802.11b hardware*, BluePrint Wi-Fi, September 26, 2002, at 4.

[62] ARCchart, *73 percent WLAN Growth in 2002*, BluePrint Wi-Fi, September 26, 2002, at 7.

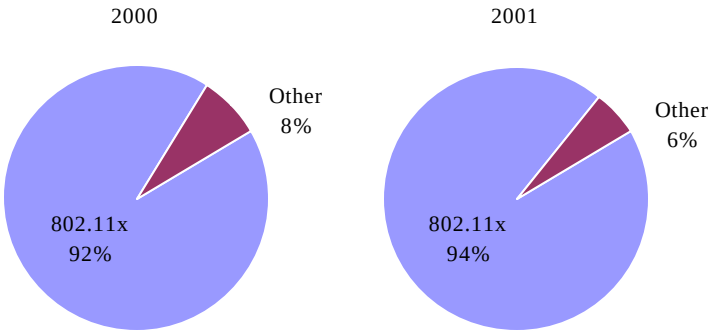
[63] Christopher Fine, *Watch out for Wi-F*, Goldman Sachs, September 26, 2002, at 2.

relatively small revenue line, these companies many not emphasize W-LAN products unless they expect that Wi-Fi products will provide an advantage or "pull-through" in the sales of other products.

The overall economic impact the expanding market for unlicensed devices is creating as a pull-through effect both upstream and downstream in the supply chain. Upstream impacts are being felt by semiconductor manufacturers in the form of demand for chipsets. Gartner expects the market for wireless RF semiconductors to reach $17.6 billion in 2004, based on an average annual growth rate of 15.4 percent from $8.6 billion since 1999. Mobile communications devices dominate this market with cellular/PCS handsets representing the bulk of the total revenue for these chipsets; however, the W-LAN semiconductor market is growing and will be strong for a select few manufacturers.[64]

[64] Gartner, Inc Wireless Applications RF Semiconductor Forecast: 1999 through 2004: January 29, 2001:

Figure 9. W-LAN Chipset Sales by Percentage



Source: International Data Corporation.

Revenues for W-LAN chipsets are expected to explode from $331 million in 2001 to $1.16 billion in 2006.[65] Of this, the Wi-Fi chipset segment alone will grow five fold, from $199 million in 2001 to $960 million in 2006.[66] In fact, unit sales of Wi-Fi chipsets nearly doubled from 8.5 million in 2001 to approximately 15 million in 2002.[67] IDC estimates the current market more conservatively at $211 million, with Wi-Fi chips representing more than 90% of sales.

Table 6. Wireless LAN semiconductor Market Share

	2000	2001	% growth
Intersil	132.9	122.4	-8%
% of total	73%	58%	
Agere	14.6	33.2	127%
% of total	8%	16%	
Philips	7.5	17.1	128%
% of total	4%	8%	
Cisco	9.0	12.0	33%
% of total	5%	6%	
Proxim	13.4	10.5	-22%
% of total	7%	5%	
Other	5.1	16.0	214%
% of total	3%	8%	
Total	**182.5**	**211.2**	**16%**

Source: International Data Corportion.

Intersil and Agere remain the dominant suppliers of semiconductors with embedded RF capabilities. Intersil led with 58% of market for specialized Wi-Fi and HomeRF chips in 2001[68] and W-LAN sales represent one third of Intersil's revenues. Agere is the second player with approximately 30% of the market.[69]

Driven by decreasing power, size, and cost, prices are likely to continue to fall. As a result 50% of laptop computers are expected to be equipped with wireless networking by 2003, with a projection of 90% by 2007.[70] Intel is currently incorporating Wi-Fi capabilities directly into its next generation

[65] ARCchart, *73 percent WLAN Growth in 2002*, Blueprint Wi-Fi, September 26, 2002, at 10.

[66] Christopher Fine, *Watch out for Wi-Fi*, Goldman Sachs, September 26, 2002, at 13.

[67] ARCchart, *73 percent WLAN Growth in 2002*, Blueprint Wi-Fi, September 26, 2002, at 10.

[68] Christopher Fine, *Watch out for Wi-Fi*, Goldman Sachs, September 26, 2002, at 13.

[69] ARCchart, *73 percent WLAN Growth in 2002*, Blueprint Wi-Fi, September 26, 2002, at 10.

[70] ARCchart, *73 percent WLAN Growth in 2002*, Blueprint Wi-Fi, September 26, 2002, at 7.

computer processors. However, a delay in the introduction of its dual-mode chipsets will give other manufacturers time to get their products to market.[71]

Growth in the sales of W-LAN equipment is likely to have positive downstream implications on the demand for complimentary products and services like laptop computers and broadband connectivity, wireless devices, operating systems, and content.[72] Wi-Fi coupled with broadband is generating a pro-cyclical adoption pattern. Both cable and DSL modems are being sold already equipped for Wi-Fi. In fact, Goldman Sachs estimates that a 10% penetration rate of Wi-Fi in residential and SOHO broadband connections will yield an equipment market of between $3 to $4 billion, by 2005. According to its analysis, the effect of the penetration rate rising to 15% will produce an equipment market of $5 to $6 billion.[73] Given the recent trends Goldman Sachs believes that a penetration rate of 15% is certainly achievable within this time horizon. The 5% change in penetration represents is a huge increase in market size. This will of course have added impact on chipset manufactures and other supply chain participants.

3. Hotspot Service Providers

One of the most prevalent uses of wireless networking equipment is to provide connectivity to the internet. In response to this need, new service providers are beginning to offer portable internet access for laptops and handheld computers in airports, hotels, cafes and other public places. Five different hotspot strategies have been identified:

1. Individuals or companies who install in commercial places (*e.g.*, Cometa and WiSE Technologies)
2. Aggregators who combine local installations to provide a national foot print (*e.g.*, Boingo)
3. Major wireless service provider offerings (*e.g.*, Cingular, T-Mobile, and Verizon)
4. Computer and electronic manufacturer consortia (*e.g.*, Cisco, Intel, and IBM)
5. Grass roots individuals offering free or low-cost access (*e.g.*, hobbyists and enthusiasts).[74]

We have not observed many "pure-play" Wi-Fi companies; rather companies are pursuing a combination of these strategies are generally being used in. We discuss these companies in this Section.

When a network operator chooses to install hotpots in partnership with another commercial entity, the offering takes advantage of the special expertise derived from each provider in the partnership. One of the early movers in this arena is T-Mobile, a wireless service provider. T-

[71] ARCchart, *Wi-Fi Predictions for 2003*, Blueprint Wi-Fi, http://www.arcchart.com/mailing/newsletter/mo_130203.htm (February 13, 2003).

[72] Christopher Fine, *Watch out for Wi-Fi*, Goldman Sachs, September 26, 2002, at 4.

[73] Christopher Fine, *Watch out for Wi-Fi*, Goldman Sachs, September 26, 2002, at 9. Even a 10% penetration could be considered low, easily achieving as high as 30 – 50%. Equipment sales included only one access point per connection, and does not include public hotspots or enterprise networks. *Id*.

[74] Wiley Rein & Fielding, *Wi-Fi – 802.11: The Shape of Things to Come*, Mimeo, July 2002, at 7-16.

Mobile made headlines when it purchased a company with contracts to place wireless hotspots in Starbucks coffee shops. Starbucks is offering three subscription plans: a $29.99 per month unlimited plan with a 12 month commitment; a month to month unlimited plan for $39.99; and metered plan for $0.10 per minute with a 60 minute per connection minimum. An organization like Starbucks, clearly not a network operator, finds it more cost effective to outsource Internet access to an organization that specializes in that providing network services. Starbucks anticipates that having the internet access available for its customers will help sell a greater number of $3 cups of coffee. As a PCS operator, T-Mobile can take advantage of its existing mobile service infrastructure to leverage the build-out of more geographically dispersed Wi-Fi services. While T-Mobile does not actually sell access to unlicensed spectrum, as it does with its cellular service, it can offer connectivity to the internet on a subscription basis using unlicensed spectrum as its springboard.

Another new carrier, Boingo, founded by Sky Dayton of Earthlink with funding from Sprint PCS, is acting as an aggregator, creating an affiliate program for local commercial hotspot providers. Offering economies of scale by providing a franchise arrangement, content, and centralized billing, Boingo is a subscription service with three pricing plans: 1) single use: pay-per-use priced at $7.95 per connection for up to 24 hours in a single venue; 2) medium use: $24.95 per month for 10 connections with an added charge of $4.95 per additional connection,; and 3) unlimited use: for $74.95 per month.

AT&T, IBM, and Intel have also recently announced the formation of a joint venture, Cometa Networks, promising to create a nationwide network of more than 20,000 Wi-Fi access points by the end of 2004. Cometa will avoid the retail market and offer private and corporate internet connectivity on a wholesale basis. The company's business plan is to contract with various types of locations such as hotels, stores, and restaurants to set up hotspots on their premises. Cometa will handle issues such as end user billing, security, and connectivity. Cometa's target customers include companies that are already ISPs and those that provide cellular service, wireline telephone facilities, DSL access, or cable modem service in the top 50-100 U.S. metropolitan markets. These companies will retail Cometa's Wi-Fi service to their exisiting customers. Cometa will collect subscription fees and in return will compensate each company where it installs a Wi-Fi hotspot for the internet traffic generated at its location.

McDonald's Restaurants announced it has selected Cometa Networks to provide Wi-Fi service as it begins to test market wireless internet service in three U.S. cities. McDonald's recently began offering one hour of free Wi-Fi access to anyone who buys a combination meal in one of ten stores in Manhattan. The company claims that it will extend the service to 300 stores in New York, Chicago, and a to-be-determined California town before the year's end.

Would you like Wi-Fries with that?

The McDonald's-style model of complementary Wi-Fi is proliferating and may present a serious competitive threat to cellular carriers' efforts to enter this market. However, complementary Wi-Fi may, in fact, prove antithetical to McDonald's fast food business. McDonald's service operations are engineered to get customers in and out of the door; the more and faster, the better. McDonald's stores are also designed with hard plastic seats and other fixtures aimed at getting the customer out of the door in less than 20 minutes. And while

most of the McDonald's-going-public is unlikely to bring a laptop to the drive-thru, those who frequent cybercafés might. A store like Starbucks is very different from McDonald's in that it wants the customer to linger and make repeat purchases.

Wi-Fi is not just going to be in airports. In fact, it may be in the airplanes. Boeing has announced a new venture called Connexion, which will provide Wi-Fi access on major long-haul airline routes. Connexion is launching trials with Lufthansa, British Airways, and SAS. The backhaul connection to the plane will be as fast as 5Mbps downstream and 750Mbps upstream. Despite your Captain's admonition not to use wireless devices in flight, you may still be able to check your email on your way to Europe.[75]

Coffee, Tea, or Wi-Fi?
Hotspots are not just for airports anymore...

To compete effectively, these providers must find ways to differentiate their products. By allowing just any device to attach to its network, a provider can attract more users but simultaneously runs the risk of turning wireless internet into a free-for-all. Unlike the cellular network paradigm in which only approved phones are allowed to connect to a network, Wi-Fi service currently have far less control over the terminal equipment they hope to support. In an open, competitive environment, there are virtually no impediments to the user switching to another provider since his device can also be used on other (presumably competing or free) [76] networks. To attempt to differentiate themselves, carriers may find some means of offering terminal equipment that is not completely interoperable with the networks and features of other carriers, or at the very least, equipment designed to attach to its primary provider's network first.[77]

4. Wireless Internet Service Providers

Wireless access to the Internet is no longer limited to hotspots. A growing number of wireless Internet service providers (WISPs) are emerging with the intention of providing an alternative high-speed connection into the home or office. The unlicensed spectrum is ideally suited to bridge the gap especially in rural areas where cable or DSL services have been slow to arrive.

Similar to Cometa is WiSE Technologies. WiSE is a Washington, DC area firm which bills itself as a wireless ISP (WISP). The company installs and operates hotspots for third parties such as stores, offices, public locations, and multi-tenant residential housing. WiSE bills the subscriber directly then pays the third party (*i.e.*, the coffee shop owner or landlord) a commission from the revenue generated by its subscribers using that particular hotspot.

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[75] ARCchart, Wi-Fi Predictions for 2003, Blueprint Wi-Fi. http://www.arcchart.com/mailing/newsletter/mo_130203.htm (February 13, 2003).

[76] Homebrew Wi-Fi enthusiasts search for hotspot access points in a particular neighborhood using a laptop and mobile detection gear. This is called "war-sniffing" allows them to create a map of where they might gain "free" internet access using other people's W-LAN and connections.

[77] *See generally*, Eli M. Noam, *The Next Frontier for Openness: Wireless Communications*, Proceedings of the 2001 Telecom Policy Research Conference, Alexandria, VA. *See also*, Eli M. Noam, Opening the 'Walled Airwave', in R. Entman, ed., TELECOMMUNICATIONS COMPETITION IN A CONSOLIDATING MARKETPLACE, 35-55, (The Aspen Institute 2002).

SkyPilot Network, Inc. is yet another company organized to provide fixed wireless broadband access for residential use. The network's backbone operates in the 5 GHz U-NII band and the company's product SkyPilot NeighborNet is a mesh network mounted on rooftops. The network employs the 802.11a protocol as a backbone to connect its roof-mounted nodes and 802.11b to provide connectivity to network devices. The company, still in its development stage, has not deployed commercially but intends to sell its service through existing ISPs. SkyPilot, headquartered in Belmont, California and founded in 2000, received its second round of $24.4 million financing in December 2001 from Mobius Venture Capital (the lead investor), AOL Time Warner Ventures, Softbank Asia Infrastructure Fund, L.P., Invesco Private Capital, Selby Venture Partners, Palo Alto Investors and Nexit Ventures.

WISPs even have a trade organization, Part-15.org, formed in 2002. The organization acts as an educational and support resource for emerging and established WISPs. The organization offers certification courses for WISP professionals designed to provide technical background and hands-on experience. Part-15.org conducts conferences twice a year to provide WISPs with learning and networking opportunities. Part-15.org maintains a WISP locator on its website.[78]

5. Carrier Class Equipment Providers

Although W-LAN equipment for residential use has garnered much attention in the press, the emerging market for carrier class equipment will be equally, if not more important. The carrier class equipment necessary to provide retail service to multiple customers in locations such as airports, Starbucks and McDonald's will be very different from the equipment used by private individuals in their homes. Many of the companies developing and marketing unlicensed equipment for carriers are startups. As such, they may be subject to the woes of the dotcom collapse such as limited access to capital and lack of financially viable customers for their middleware. We highlight a few of these firms below.

ArrayComm, Inc. is developing technology that employs adaptive spatial processing antennas. Its division, IntelliCell Products Group is developing and licensing these technologies to wireless system OEMs. The company's antenna is designed to focus RF emissions directly to each active user in an effort to avoid interference with other users. This innovative technique should permit efficiency of spectrum use and re-use by creating unique spatial channels.

Flarion, another fledgling company, offers both a wide area network product and a device-based technology intended to permit connectivity to other Wi-Fi equipped local area networks. Flarion's main infrastructure product, a base station called RadioRouter, can be installed as an overlay to a major carrier's existing cell sites and offers an interface to a standard router in an IP network. Using PCMIA modems, also provided by Flarion for use in laptops and PDAs, users can be connected to an IP network through the Flarion base station. Flarion also plans to sell its chipsets and license its technology to OEMs.

Malibu Networks is organized to offer wireless broadband systems to service providers. It recently introduced a product called the Malibu AirMAX System to provide point-to-multipoint operation in the 2.4 GHz and 5 GHz bands. Malibu distributes AirMAX through a variety of

[78] http://www.part-15.org/maps/WISPSearch.asp

value added resellers, stocking distributors, and network system integrators generally focused on developing world markets in regions such as Asia, India, South America, and Africa. Malibu has also engaged a number of distributors in North America to market and distribute the AirMAX product family in rural areas where wire-line technology for broadband access might be cost prohibitive

MeshNetworks offers technologies for W-LAN, fixed and mobile broadband wireless networks, and telemetry. One advantage MeshNetworks touts is that its network infrastructure is towerless and can be deployed on streetlights, billboards, and buildings. These systems are IP-based, peer-to-peer, ad hoc networks. The company's MeshLAN product employs the 802.11b protocol. MeshNetworks claims that its routing technologies can be used with 802.11a, 802.11g, Ultra Wideband, WCDMA, and OFDM. MeshNetworks, founded in January 2000 and supported by more than $27 million in funding from private investors, plans to market its chipsets, software, and product reference designs to OEMs, system integrators, and network operators.

Vivato is an infrastructure manufacturer which offers a line of products it calls "Wi-Fi switches" geared for enterprises and network service providers, marketed under the brand name PacketSteering. Its Wi-Fi switch is similar to the switch architecture for Ethernet, allowing it to be scaled through a bus network architecture. Vivato's switches use phased-array radio antennas to create highly directed, narrow beams of Wi-Fi transmissions. These beams can be pointed at the desired client device, reducing interference and enabling simultaneous Wi-Fi transmissions. Vivato was founded in December 2000 with $2.5 million in seed funding from Leapfrog Ventures, and in March 2002 completed a $20 million Series B funding round led by U.S. Venture Partners and Walden International. In June 2002, the company completed a $3 million debt-funding round led by Silicon Valley Bank and GATX.

D. Radio Frequency IDs (RFID)

Radio frequency identification systems, used for a variety of monitoring and tracking applications in logistics, provide significant benefits to the companies that use them. Global shipments of RFID products reached nearly $900 million in 2000.

1. Standards

The lack of standards has, to date, inhibited the growth potential for RFID systems, but, in May 2000, the International Standards Organization (ISO) created the ISO/IEC 15693-2 standard for contactless cards and RFID smart labels that operate in the 13.56 MHz band. This standard, sponsored by Texas Instruments and Philips Semiconductor, governs the way data is exchanged between an RFID tag and its reader. There are several other existing and evolving RFID standards including the following:

- ISO 11784/11785 (Animal Identification RFID Standard);
- ISO ANSI/NCITS T6 256 - 1999 (Item Management RFID Standard);
- ISO/IEC 15693-2 (13.56 MHz Vicinity Cards and Smart Labels RFID Standard);
- ISO 18000 series of standards (air interface protocol);
- GTAG (On-going RFID Global Tag Initiative);
- Consumer Products Manufacturers Association (CPMA) Consumer Good ID Proposal (Ongoing RFID Standard Initiative); and

- The MIT Auto-ID Center's on-going RFID standards initiatives.

Since radio spectrum is allocated and regulated by numerous different agencies around the world, organizations like the International Standards Organization (ISO) promulgate standards for RFID applications. These standards help to harmonize technologies to operate on the same frequencies and ensure that information such as secure identifications can be read across devices by different manufacturers. The standards bodies also work with RFID manufacturers and others to choose specific frequencies on which to standardize due to the properties such as range and robustness the specific application must have.[79] For example, the Auto-ID Center is a non-profit collaboration between industry and academia to develop an internet-like infrastructure for tracking goods globally through the use of RFID tags. Firms that utilize less popular standards may face short-term problems, but with the widespread adoption of more recent standards, the industry is poised to grow.

2. Products and Sales

RFID systems, now becoming commonplace in retail markets around the world, are supplied by market leaders such as HID Corporation (formerly a subsidiary of Siemens), Texas Instruments, and Philips. Venture Development Corporation estimates shipments of RFID systems have increased from $900 million in 2000[80] at a rate of approximately 16% annually reaching $1.2 billion by the end of the year 2002 and will reach $2.7 billion in 2005.[81] Of the world market in 2000, the Americas accounted for approximately 48%, or $426.6 million. Much of this growth is derived from traditional, established product lines.[82]

Typical RFID Applications include:

- Access Control
- Air transport baggage control
- Animal Tracking
- Asset Management
- Point-of-Sale Applications
- Replacing Barcodes on Products
- Payment Method
- Supply Chain Management
- Transportation Applications
- Vehicle Immobilizers
- Currency Counterfeit Prevention
- Document Protection
- Brand Protection for Luxury Goods
- Tires
- Sports Timing
- Customer identification and marketing.
- Prepaid metering
- Id cards
- Vending Phone Cards
- Toll Roads
- Medical Information

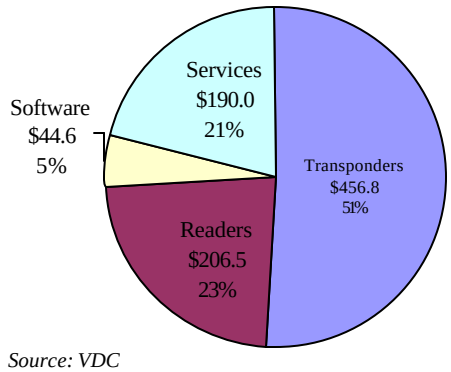
[79] Josef Schuermann, *Information technology – Radio frequency identification (RFID) and the world of radio regulations*, ISO BULLETIN, May 2000. http://www.iso.org/iso/en/commcentre/pdf/Radio0005.pdf

[80] David Krebs and Michael J. Liard, *An Executive White Paper on: Global Markets in Radio Frequency Identification*, Venture Development Corporation, May 2001, at 1.

[81] Communications Daily, *Telecom*, September 5, 2002.

[82] David Krebs and Michael J. Liard, *An Executive White Paper on: Global Markets in Radio Frequency Identification*, Venture Development Corporation, May 2001, at 2.

Figure 10. Global Shipments of RFID Systems in 2000 (in millions)



Source: VDC

In many stores, RFID tags are attached to merchandise and used as part of a theft prevention system. This can help retailers combat the growing amount of inventory lost each year. This lost amounted to $31.3 billion in 2002.[83] Tags provide cost savings that are immediately recognizable to retailers and, because the tags are becoming increasingly disposable, they generate a stable revenue stream for RFID manufacturers. RFID provides distinct advantages over laser-read bar codes. Bar code labels are not as durable and weatherproof as RFID chip tags. In addition, an RFID can hold up to 64 times more information and tags can also be read/write capable.[84] In contrast, bar codes contain little more than an identification number, must be positioned properly under a scanner to be read, and any further critical information must then be retrieved from an external database or a server.[85]

3. Applications and Uses

The range of RFID systems is limited, roughly a couple of feet; however, in certain applications such as those within a factory, the range can extend to several feet. Since there is no contact between the RFID tag and reader there is less wear and tear, lowering maintenance and replacement costs. RFID tags are still comparatively costly at just less than 30 cents each (still more than bar codes which are about a penny).[86] However, RFID tags which cost a nickel are on the horizon and may eventually fall below a penny in cost.[87]

In one of the more interesting applications of RFID technology, shaving product manufacturer Gillette, retailer Wal-Mart, and the British supermarket chain, Tesco, plan to experiment with specially designed shelves equipped with RFID readers for the purpose of tracking inventory. Gillette products on these shelves will contain inexpensive RFID chips costing about 15 cents each. As supplies diminish, the shelf scanner will automatically alert the manager responsible for re-stocking. Eventually, this system may be enhanced to automatically re-order supplies, ensuring continuously available shelf stock. Procter & Gamble is expected to conduct a similar test with some of its products. Given the success of such endeavors, it's not hard to foresee the day when a shopper will be able to simply place all desired products in a shopping cart and walk

[83] Claudia H. Deutsch and Barnaby J. Feder, *A Radio Chip in Every Consumer Product*, New York Times, February 25, 2003, at C1.

[84] Gene Bylinsky, *Hot New Technologies For American Factories Isn't it obvious by now?*, Fortune, June 26, 2000

[85] Gene Bylinsky, *Hot New Technologies For American Factories Isn't it obvious by now?*, Fortune, June 26, 2000.

[86] Gene Bylinsky, *Hot New Technologies For American Factories Isn't it obvious by now?*, Fortune, June 26, 2000.

[87] *Breakthrough on 1-Cent RFID Tag*, RFID Journal, December 2, 2002. http://216.121.131.129/article/view/273

directly out of the store without stopping at a cash register. An "RFID reader-enabled" shopping cart will track all of the purchases, read the shoppers credit card, and complete the transaction, all without human intervention.

4. Manufacturers

One of the leading manufacturers of RFID systems is the HID Corporation. HID's wide ranging product lines include systems for applications such as electronic locks, biometric readers, alarms, time & attendance, special application hazardous location & keypad readers, secure PC log-on and network security, and access control for off-line systems. Philips Semiconductors, headquartered in Eindhoven, The Netherlands, is also a leading manufacture of chips used in RFIDs and other unlicensed wireless devices. In the third quarter 2001, Philips' semiconductor segment revenues were 8% higher than the same quarter in 2000, but 12% lower sequentially.

IV. Potential Regulatory Issues

In this section, we discuss the FCC's efforts to modernize its spectrum policy and examine the implications for unlicensed devices. In doing so, we identify some of the potential regulatory issues unlicensed devices face and assess some possible applications of the Spectrum Policy Task Force's recommendations to unlicensed spectrum. We also suggest some of the unintended consequences of proposed regulatory changes. Based on our observations and projections in the foregoing sections we consider the impact of new technologies on the existing policy and ways to provide incentives to encourage more efficient uses of spectrum. It is beyond the scope of this paper to resolve any of the issues raised here. Many could be subject for proposed future studies. We welcome comments on the value of such studies.

A. Overview

In Section II.B.2, we reviewed the FCC's current initiative to review, improve, and modernize policy for the spectrum under its jurisdiction. The FCC's Spectrum Policy Task Force, formed in June 2002, undertook a critical review and its central recommendation for modernization is that the Commission make a transition from the current command-and-control approach of spectrum regulation to a more flexible, market-based approach. While this review focused primarily on licensed services, which represent the majority of spectrum use, the report also provided an analysis of the regulation of unlicensed devices. Unlicensed devices have gained a foothold as an important use for spectrum and, as we have shown above, the market for these devices, particularly those which are related to computer networking, is prospering.

There is the ever-growing need to better accommodate new technical solutions and to better allocate frequencies. Some experts foresee a need to migrate to unused or even occupied portions of the spectrum in order to accommodate the broadening need for wireless connectivity. The future success of unlicensed operation will hinge in part on how the FCC manages such future migration. Potential solutions include modifying current service rules to promote more efficient use, allowing unlicensed devices to operate as an underlay in bands that are currently allocated to existing licensed services, and allocating more spectrum for unlicensed operation.[88]

The Task Force recognized that unlicensed devices will continue to provide great benefit both to their users and the world economy. Yet, this burgeoning growth raises questions concerning how to regulate these devices to ensure that they reach their full potential. Competing demands will require careful planning and management to maximize value for all services, licensed and unlicensed.

B. Interference Concerns for Unlicensed Devices

At the heart of all spectrum concerns lies the question of interference. A certain amount of interference between devices is acceptable; however, beyond a certain limit interference can be

[88] An argument can be made that the FCC's exclusive use licensing structure represents an inefficient use of available spectrum. It is important to point out that even though bands are reserved for a specific use, all channels within that band may not be licensed or in use in a given geographic area. For example, all of the available television and radio broadcast frequencies will never be occupied at the same time.

considered harmful and, unless locally correctable, may require some form of external intervention. The Task Force recognized that a better construct for this limit would prove advantageous for unlicensed devices.

Interference which may be intolerable in one service might be perfectly acceptable in another. In essence, interference imposes a cost for the user who must protect himself, but for certain low-cost unlicensed devices, the burden imposed by interference may be considered trivial. For example, while interference that causes excessive break-ups or dropped calls would be considered unacceptable by the average cell phone user, a walkie-talkie user, who pays only a pittance for the device and pays no monthly fees, may be willing to accept that interference.

Another analogy is that of the automobile. The system of roads in the United States is open to common access by all. However, since not every driver can use the road at once, some drivers may be required to wait in line sometimes. In densely populated areas such as cities and at times like rush hour, the road system becomes so congested that users experience delays. In contrast, in more rural areas there are fewer cars and thus less congestion. All drivers intuitively understand that when traveling in a city at rush hour, one is likely to experience traffic. Similarly, users of unlicensed spectrum may grudgingly be willing to tolerate "rush hour" congestion in densely populated areas or times when usage is high.

This congestion is one economic means of rationing the resource when it becomes scare. In the wireless systems that existed prior to the formal regulation/licensing, radio systems could not tolerate such interference and congestion. Entry restrictions and other technical regulations were required for rationing the spectrum. An ever-increasing fraction of today's radio applications have ranges measured in yards rather than miles. As radio ranges become smaller, more devices can be used in any given area without ill-effect. As usage patterns evolve, a better definition of what constitutes interference may be necessary. In refining such a definition, a compromise may not fit all users in all areas. In more densely populated areas, spectrum users may be expected to tolerate some congestion before it is considered harmful interference. At the same time, because congestion may not be a problem in rural areas, it would be unfair to impose the same restrictions for rural users that city users incur.

This may temporarily lessen the justification for technical regulation. Eventually, however, users will inevitably place rival demands on the network requiring a novel technical resolution, a pricing system, or some other means to meter competing uses of the network. In the long-run, we would still like to maximize spectrum use efficiency and find new ways to distribute competing uses. In the automobile analogy, this might translate to smaller cars, carpooling, or toll roads.

C. Avoiding Interference

1. Receiver Solution

Currently, licensees in many services are granted the right to operate free from harmful interference. Therefore, there is little incentive for these users to require that their receivers be any more sophisticated than required in order to tolerate the amount of interference present in the

desired band. Theoretically, receivers of this sort are cheaper to manufacture and thus more economical for the licensee to purchase. The hidden cost in this scenario is that few, if any, others can make simultaneous use of this valuable commodity known as spectrum.

Recognizing this phenomenon, the Spectrum Policy Task Force sought comment on development of an "interference temperature"[89] metric which would permit the management of spectrum by establishing a threshold on the noise environment in which receivers would be required to operate. With interference temperature as the cap on potential interfering emissions, presumably more devices could share a given band. In newer receivers we can expect that these thresholds would be raised. By raising the minimum level of tolerance of incumbent receivers, the interference-temperature metric actually encourages manufacturers to permit more efficient use of associated bands.

The interference temperature, if implemented by the Commission, can be complemented by the use of radio devices that have a certain amount of built-in "smarts." For example, unlicensed devices could employ frequency agile, intelligent radios capable of identifying unused or underused spectrum, adjust their power level, or in real time bid for the exclusive right to broadcast before emitting any RF energy into the band. In this way, the interference temperature in any particular geographical area emission band could be dynamically self-regulated by the spectrum users. However, this concept has its detractors. Because unlicensed devices derive much of their benefit from being inexpensive, small, and designed for a particular use, one could argue that including such smart technology will add significant cost, thereby reducing the attractiveness to consumers. Another perceived weakness of the smart radio model is that, in the time such a device's electronics spend looking for so-called "whitespace," it may have to reduce its power so much or change frequencies so often, that its signal may not be detected by another nearby smart receiver.

The above makes the point that the introduction of interference temperature as a concept must be handled carefully. The Spectrum Policy Task Force concedes that studying the feasibility of implementing interference temperature would be time-consuming and expensive. However, it believes that the benefits of undertaking the task would be well worth the effort expended.

[89] The "interference-temperature" or "noise-temperature" concept can be considered as the background emissions in a particular band. It is effectively a measure of the pollution of the electromagnetic spectrum by all devices operating in that band. Once a certain threshold has been reached, interference will begin to occur to licensed users.

2. Spectrum Solution

There is concern that, with increased interest in and competing use of spectrum, the ability for unlicensed devices to effectively share spectrum may eventually be exhausted. In the end, the question whether to make more unlicensed spectrum available will depend on its marginal social benefit when compared to the benefit of allocating the spectrum to licensed uses.

The FCC has already started to address this question. A subcommittee of the Spectrum Policy Task Force, the Unlicensed Devices and Experimental Licensing Working Group (UEWG), found that it is not at present practical to develop estimates of the optimal amount of spectrum that should be provided for unlicensed operations; however, it appears that additional spectrum is needed.

The Spectrum Policy Task Force sought comment from the industry about whether additional spectrum should be set aside for unlicensed use. In response to its July 2002 Public Notice seeking comments on a number of issues regarding spectrum regulation,[90] more than 200 comments were filed. Commenters generally expressed support for the allocation of additional unlicensed spectrum. For example, Microsoft urged the FCC to allocate additional spectrum below 2 GHz and at 5 GHz for unlicensed broadband uses. It argued that such spectrum could be used to supplement cable and DSL services and could "jump-start" the creation of competitive wireless broadband networks in the U.S. Similar support for additional unlicensed spectrum was expressed by Cingular, Cisco Systems, Inc., the Consumer Federation of America, Ericsson, Information Technology Industry Council, Motorola, Proxim, Rural Telecommunications Group, Wireless Ethernet Compatibility Alliance and others. In their joint reply comments, the New America Foundation, Consumers Union, *et al*, state that there is tremendous support in the record for the allocation of additional frequency bands of spectrum for unlicensed use, particularly to facilitate broadband wireless networking.

Based on the comments filed in response to the Public Notice, it is generally perceived that unlicensed operation has been very successful in allowing the rapid introduction of new technologies and that adding bands in which devices may operate without a license would create more such opportunities. However, there was a general lack of specific recommendations on how the FCC should create such unlicensed bands and what priority they should be given relative to other spectrum requests.

The relocation of existing users may be essential to increasing the amount of spectrum available for unlicensed use. What is often said of real estate is also true for spectrum - they are not making any more of it. In order for the FCC to make more spectrum available for unlicensed use, it may have to resolve such scarcity by requiring additional relocation of incumbents of

[90] *See* "Spectrum Policy Task Force Seeks Public Comment on Issues Related to Commission's Spectrum Policies," ET Docket No. 02-135, DA 02-1311 (seeking, among other issues, public comment regarding policy changes that would useful in resolving anticipated congestion in the bands available for unlicensed operation) (released June 6, 2002).

currently used bands. The FCC would then need to set operating parameters for the newly cleared bands. Such parameters could be as simple as setting maximum permissible bandwidth and power limits. Alternatively, the FCC, or an FCC-appointed spectrum coordinator could develop a more complex spectrum sharing etiquette to ensure equitable access to the spectrum.

The Spectrum Policy Task Force drew similar conclusions in its November 15, 2002 final report.[91] Specifically, the report suggests that the FCC create more spectrum opportunities for unlicensed devices by: (1) permitting unlicensed use of spectrum occupied by existing services, (2) use the interference temperature concept to permit unlicensed devices to underlay the signals of existing services, and (3) create new "unlicensed bands" by band clearing. However, relocation does not necessarily require wholesale clearing of the new band. Perhaps the FCC could allocate additional spectrum for unlicensed use through an overlay authorization. Under this scheme, the FCC could issue technical rules to accommodate spectrum sharing between incumbent users and unlicensed devices. Alternatively, licensees could be allowed to charge an interested party, including unlicensed operators, an access charge for use of a portion of its allotted spectrum.

In the end, it may be an act of Congress that makes more unlicensed spectrum available. On January 14 2003, Senators George Allen and Barbara Boxer introduced a bill entitled the "Jumpstart Broadband Act."[92] This proposed legislation, if signed into law, would direct the FCC to allocate no less than an additional 255 MHz of contiguous spectrum in the 5 GHz band to unlicensed devices for use in broadband connections. It would also direct the FCC to establish rules to minimize interference among unlicensed devices and with Department of Defense systems operating in those bands. Under the bill, the NTIA would be required to establish interference protection such unlicensed uses could underlay incumbent Federal government agency users allowing them to continue to use those bands.

[91] *See* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228542A1.pdf

[92] A Bill to Require the Federal Communication Commission to Allocate Additional Spectrum for Unlicensed Use by Wireless Broadband Devices, and for other purposes, S. 159, 108th Cong., (2003).

V. Summary

Applications spawned by unlicensed technology hold great promise for the American people. Today, millions of unlicensed devices are in operation. They have grown to fill a role as an enabler of important business and personal communication needs. Ironically, this explosion of services and providers was largely unanticipated when the devices were first authorized. For example, the FCC realized that that the band in which industrial, scientific, and medical ("ISM") equipment operated represented prime real estate for unlicensed operation.[93] Because ISM equipment is permitted to operate in these bands with no limits on radiated emission, the bands may be considered "hostile territory" for any non-ISM equipment. However, one need only look at Wi-Fi to appreciate how even this "junk" spectrum can be utilized with great success on an unlicensed basis.

It is flexibility which gives unlicensed devices continuing promise. We believe that technologies versatile enough to be used in devices ranging from lifesaving heart monitors to steak monitors for a barbeque will continue to permeate our markets and spur growing sales volumes. Unlicensed devices will continue to offer benefits where they can provide applications that are not achievable with wires or where such devices can tolerate operating in an unprotected environment. In supervising existing unlicensed operation or designating new bands for such devices, the FCC's rules should be as clear as practicable, strictly enforced, and maximize utility. One driver of unlicensed spectrum's success has been its comparatively low barriers to entry. In promulgating rules to encourage more efficient use of spectrum or to allocate spectrum for unlicensed use the FCC must be mindful of balancing competing interests, and protecting against harmful interference while it retains the low entry barriers that have proven so successful.

Given this growth, unlicensed wireless devices present a challenge to the current system of communications networks, their economics, and regulation. However, without a well-considered and forward-looking approach to policy reform, much the benefit and promise of unlicensed devices may be delayed, or unrealized. Therefore, the FCC must continue to review, reconsider and evolve its regulatory treatment of unlicensed devices.

Considering the complexity of issues involved (technological, financial, political, economic, and social) and the need to advance technologies in the public interest, necessity, and convenience, this paper has only begun to address these issues. We believe that in addition to advancing effective policy reform, the FCC should encourage the industries involved to find technologies and to market solutions for problems such as interference.

[93] Equipment such as industrial driers, microwave ovens, and magnetic resonance (MRI) and ultrasonic medical equipment are classified as Industrial, Scientific, and Medical (ISM) equipment under Part 18 of the FCC rules. These devices produce rf energy to perform diagnostic, imaging, heating, or other work with the exception of communications.

Appendix A. The Technology of Unlicensed Wireless Devices

Initially, radio transmitters were designed to broadcast at a reasonably high power over a relatively narrow band. With these higher power levels, only a limited number of devices could use the available spectrum because nearby devices operating on the same frequency alternately amplify and cancel nearby transmissions. The net result is sporadic or unreliable communications for all users.

Today, unlicensed devices use conventional methods of modulation of carrier waves such as AM or FM or simple digital techniques to convey information. Beyond these conventional techniques, devices also utilize sophisticated multiplexing arrangements to effectively increase the efficient use of available bandwidth and permit more users to communicate simultaneously in a particular band. The multiplexing technique used in a transmitter must be duplicated in the receiver to enable detection and decoding of the appropriate signal. Advances in communications technology have continuously improved these techniques making it possible to support more and more simultaneous users. Today, the Part 15 rules accommodate a wide variety of unlicensed intentional radiators using a number of different technologies in various bands.[95] A few of the more interesting modulation techniques permitted under Part 15 are listed below

Spread Spectrum: Direct sequence spread spectrum is the most widely used type of spread spectrum system. It is a digital modulation technique achieved by modulating a narrow band radio frequency carrier with a high speed spreading code sequence. The spreading code spreads the narrow band signal over a wider band of spectrum. Because the total power of the original signal is now spread over a much broader bandwidth, the power level at any given frequency is very low. This feature allows direct sequence spread spectrum systems to operate in the presence of narrow band systems without interfering. Conversely, interference from a narrow band waveform has a limited effect on a spread spectrum signal.

Frequency hopping spread spectrum is a form of signal spreading in which the frequency of the transmitted signal "hops" from channel to channel. This occurs many times a second in accordance with a pseudo-random list of channels. The receiver hops in strict conjunction with the transmitter, thereby collecting all data transmitted. The amount of time the signal is present on any channel, called the dwell time, is usually very short, commonly less than 10 milliseconds. This avoids interference both to and from conventional users. If interference is being received on a particular hopping channel the effect is minimized because the channel is only in service for a very short period before the transmitter hops to a different channel.

New Digital Transmission Systems: New digital transmission technologies have been developed that have spectrum occupancy characteristics similar to direct sequence spread spectrum systems. The Commission permits devices using this technology to operate under the

[95] We note that although these are regulatory classifications within the scope of Part 15, the underlying principles and technologies are sometimes used in both licensed and unlicensed applications. For example, spread spectrum technologies are used widely in cellular communications.

same rules formerly reserved for spread spectrum operation. One such digital technology is orthogonal frequency division multiplexing (OFDM). OFDM offers several access and signal processing benefits not available in other modulation schemes, and allows wireless networks to gain high efficiency from relatively small bandwidths. OFDM is a modulation scheme that divides the information data in a digital signal between large numbers of closely spaced RF carriers. The frequencies of the transmitted carriers are arranged in a precise mathematical relationship such that the sidebands of the individual carriers overlap and the signals are received without adjacent channel interference. The 802.11a and 802.11g protocols incorporate OFDM in order to achieve data rates more than twice those of wireless computer networks using the 802.11b protocol.[96]

Ultra-Wide Band: UWB, a technology which was just recently approved by the FCC for a number of communications and sensing applications,[97] is a signaling method which relies on short pulses that create extremely wide bandwidths, 2 GHz or more depending on system design. UWB is similar to spread spectrum in that the signal is spread across such a wide bandwidth that the power falling across any given ordinary communication channel is low. This makes it possible for UWB device to operate on spectrum occupied by existing services without causing interference. In addition to their potential for communications systems, UWB technology can also support the operation of new low power radar products that can provide precise measurement of distances or detection of objects underground or behind walls or other structures.

The qualities of spread spectrum, digital modulation, and ultra-wideband systems contribute to both increased security of these devices and lower likelihood for the devices to cause interference to other systems. This allows for more devices to operate in a given portion of the spectrum and thus promotes spectrum efficiency.

[96] Theodore S. Rappaport, et al, *Wireless Communications: Past Events and a Future Perspective*, IEEE Communications Magazine, May 2002.

[97] See Section II.A for a discussion about the rulemaking proceeding.

Appendix B. Glossary of Unlicensed Spectrum Terms

A

Amplitude Modulation (AM) A type of radio transmission which uses the amplitude of the carrier wave to transmit information. Amplitude Modulation is used in either the standard radio broadcast band at 535-1705 kilohertz, shortwave broadcasting, and in some private radio services such as citizens band (CB) and aviation.

Analog Signal A signaling method that uses continuous changes in the amplitude or frequency of a radio transmission to convey information.

B

Bandwidth Generally, the term refers to the capacity of a channel to carry signals. More technically, bandwidth refers to the width of the range of frequencies that a signal occupies. The necessary bandwidth is the amount of spectrum required to transmit the signal without distortion or loss of information.

Base Station A land station in the land mobile service and is interconnected with other base stations via a land-line switched network.

Biomedical Telemetry Devices An intentional radiator used to transmit measurements of either human or animal biomedical phenomena to a receiver.

Binary Information Unit (Bit) The smallest unit of digital information. It is equivalent to a "yes" or a "no".

Bits Per Second (bps) A unit used to express the number of bits passing a designated point per second.

Bluetooth A short-range wireless protocol envisioned as a cable replacement technology that is used to connect computer devices and peripherals devices at a range of up to 30 feet with a maximum transmission speed of 1 Mbps. Bluetooth is named for 10^{th} Century Danish King and is a trademark for the standard promulgated by a trade association called the Bluetooth Special Interest Group (SIG).

Broadband Broadband is a descriptive term for evolving digital technologies that provide consumers a signal switched facility offering integrated access to voice, high-speed data service, video-demand services, and interactive delivery services. The FCC defines broadband as transmission speeds greater than 200kbps.

Byte A set of bits that represent a single character. Eight bits comprise a Byte.

C

Cellular Mobile Radio Telephone System A land mobile telephone system in which channels assigned to the system are divided among several geographical "cells" covering a defined service area. These cells encompass localized, low power base stations to cover a specific area. The base stations are sited to give overlapping coverage, fitting together like cells in a tissue, allowing frequencies to be reutilized in adjacent clusters.

Co-channel Interference or Crosstalk A form of interference which occurs when a receiver on one communications channel inadvertently receives information being transmitted on a neighboring communications channel.

Code Division Multiple Access (CDMA) A multiple access systems using a method of spreading spectrum transmission for digital wireless personal communications networks that allows a large number of users simultaneously to access a single radio frequency band without interference.

D

Declaration of Conformity (DoC) An FCC approval procedure for computers and computer peripherals which allows digital devices to be authorized based on a manufacturer's declaration that the device complies with the FCC requirements for controlling radio frequency interference.

Device Authorization An approval is a process required by the FCC for all intentional radiators before they can be used or sold. The authorization procedure ensures that devices they comply with the Commission's technical standards.

Device Certification Certification requires a written application stating that the device complies with the FCC rules along with specific information, including technical specifications for the device such as transmitter frequency, occupied bandwidth, and output power.

Device Verification A statement made by the manufacturer or importer of an unlicensed device, attesting that the device complies with FCC rules. This form of authorization is generally employed for well understood devices.

Direct Sequence Spread Spectrum The most widely used type of spread spectrum system. It is a digital modulation technique achieved by modulating a narrow band radio frequency carrier with a high speed spreading code sequence. The spreading code spreads the narrow band signal over a wider band of spectrum. Because the total power of the original signal is now spread over a much broader bandwidth, the power level at any given frequency is very low. This feature allows direct sequence spread spectrum systems to operate in the presence of narrow band systems without interfering. (See Spread Spectrum).

F

Frequency The number of cycles occurring per second of an electrical or electromagnetic wave; a number representing a specific point in the electromagnetic spectrum.

Frequency Hopping Spread Spectrum A form of signal spreading in which the frequency of the transmitted signal "hops" from channel to channel many times, commonly less than 10 milliseconds, in accordance with a pseudo-random list of channels. The receiver hops in strict conjunction with the transmitter, thereby collecting all data transmitted in order to avoid interference both to and from conventional users. (See Spread Spectrum).

Frequency Modulation (FM) A signaling method that varies the instantaneous frequency of a carrier wave in accordance with the signal to be transmitted.

Further Notice of Proposed Rule Making (FNPRM) An FCC proceeding to further clarify and seek more information and public comment on its proposed rule changes. (See Notice of Proposed Rulemaking)

G

Gigahertz (GHz) The oscillation of a wave at 1,000,000,000 Hz or cycles per second.

Global Positioning System (GPS) A satellite radio system maintained by the U.S. Government which allows receiver sets to determine their geographic position with extreme accuracy.

Ground Penetrating Radar (GPR) A radar system, operating below 960 MHz or in the 3.1-10.6 GHz band, designed to operate in close proximity to the ground for the purpose of detecting or obtaining the images of buried objects. Operation is restricted to law enforcement, fire and rescue organizations, scientific research institutions, commercial mining companies, and construction companies.

General Low Power Devices (See Low Power Devices)

H

Hertz (Hz) A frequency measurement unit which is equivalent to one cycle per second.

HiperLAN A European wireless data networking standard operating in two bands within the 5 GHz range on an unlicensed basis. However, the HiperLAN2 bands, is slightly different than the US U-NII bands. While the two share the 5.15 – 5.25 GHz portion, the HiperLAN2 upper band is 5.470 – 5.725 GHz.

Hotspot A wireless data network access point. Service providers are beginning to offer portable internet hotspot access for laptops and handheld computers in airports, hotels, cafes and other public places.

I

Incidental Radiators Devices, like electric motors, that generate radio frequency energy as a by product of their operation although the devices are not intentionally designed to generate or emit RF energy.

Intentional Radiators Devices that intentionally generate and emit RF energy by radiation or induction.

Interference A radio emission from another transmitter at approximately the same frequency, or having a harmonic frequency approximately the same as, another emission of interest to a given recipient, and which impedes reception of the desired signal by the intended recipient.

Interference-Temperature A proposed metric, also called the "noise-temperature" concept, referring to the background emissions in a particular band. It is effectively threshold a measure of the pollution of the electromagnetic spectrum by all devices operating in that band, beyond which interference is said to begin to occur to licensed users.

K

Kilohertz (KHz) The oscillation of a wave at 1,000 Hz or cycles per second.

L

Local Area Network (LAN) A local data network that is used to interconnect the computers and computer equipment.

Low Power Devices Devices which are permitted under Part 15 the FCC's rules to operate in various specific bands since they emit only small levels of RF energy and their operation is not likely to cause interference. Devices such as baby monitors, garage door openers, toy wireless microphones, and certain kinds of walkie-talkies fall into this category.

M

Megahertz (MHz) The oscillation of a wave at 1,000,000 Hz or cycles per second.

Millimeter Wave Band The 57-64 GHz band available for use by unlicensed devices for novel broadband applications such as wireless computer-to-computer communications. The potential of interference to licensed services is limited by both high propagation loss

at these frequencies and the narrow beamwidth of point-to-point antennas normally operating in this range.

N

Narrowband A term commonly referring to analog facilities and to digital facilities operating at speeds less than 1.544 Mbps which are capable of carrying only voice, facsimile images, slow-scan video images, and data transmissions.

National Information Infrastructure (NII) A group of networks, including the public switched telecommunications network, radio and television networks, private communications networks, and other networks not yet built, which together will serve the communications and information processing needs of the people of the United States in the future.

Notice of Inquiry (NOI) An announcement of an FCC proceeding for fact gathering, by seeking comments from the public or industry on a specific issue. After reviewing comments, the FCC may issue a Notice of Proposed Rulemaking or it may release a Report & Order (R&O) explaining what action or non-action should be taken.

Notice of Proposed Rule Making (NPRM) An FCC document detailing a proceeding to publicly review proposed changes to FCC rules and to seek public comment on these proposals. After reviewing the comments to the NPRM, the FCC may issue a Further NPRM to provide an opportunity for the public to comment further on a related proposal or issue a Report & Order

O

Orthogonal Frequency Division Multiplexing (OFDM) A modulation scheme that divides a single digital signal across 1,000 or more signal carriers simultaneously (FDM). The signals spaced at precise frequencies which prevents the demodulators from seeing frequencies other than their own (hence, orthogonal) so they do not interfere with each other OFDM offers multiple access and signal processing and allows wireless networks to pack high efficiencies into relatively small bandwidths.

P

Paging System A one-way mobile radio service where a user carries a small, lightweight miniature radio receiver capable of responding to coded signals.

Part 15 The section of the FCC's rules governing the operation of authorized low power radio frequency devices without the need for a license or frequency coordination, contained in the Code of Federal Regulations at 47 C.F.R. §§ 15.1, *et seq*.

Personal Communications Service (PCS) Any of several types of wireless, voice or data communications systems, typically incorporating digital technology. PCS encompasses

cordless phones, cellular mobile phone, paging systems, personal communications networks, wireless office phone systems and any other wireless telecommunications systems.

Power Line Communications (PLC) A technology using electrical power wiring to deliver telecommunications services and computer network connectivity. PLC devices use both the home's internal electrical power wiring to create a LAN as well as the national electrical grid to provide broadband internet connectivity.

Public Notice (PN) A document issued by the FCC to notify the public of an action taken or an upcoming event.

R

Radar A radio determination system based on the comparison of reference signals with radio signals reflected, or retransmitted, from the position to be determined.

Radio Frequency (RF) See Spectrum.

Radio Frequency Identification (RFID) A wireless remote tracking system comprising a small transponder with encoded information, an antenna, and a transceiver equipped with a decoder. The antenna emits a radio signal to read or write data from or to the tags attached to the items to be tracked.

Roaming The use of a wireless device outside of the "home" service area defined by a service provider.

S

Software Defined Radio (SDR) A radio using programmable software for digital signal processing that allows the radio's fundamental characteristics such as modulation types, operating frequencies, and access schemes to be easily changed.

Specialized Mobile Radio Services (SMR) A private, two-way radio system providing land mobile communications service to eligible persons on a commercial basis for such uses as dispatch communications or multi-site construction jobs.

Spectrum The range of electromagnetic radio frequencies, ranging from 9 kHz to 3,000 GHz, used in the transmission of sound, data, and television.

Spectrum Allocation and Spectrum Management The coordination and assignment of available spectrum use to maximize efficiency and to prevent interference.

Spectrum Auction A public sale of spectrum access in which the price is increased by bids until the highest bidder becomes the purchaser. The U.S. Treasury receives all proceeds from the FCC spectrum auctions.

Spectrum Policy Task Force An FCC effort to address spectrum access issues composed of senior staff members from several FCC Bureaus and Offices who were asked to assist the FCC in identifying and evaluating changes in spectrum policy necessary to reflect advances in technology that were likely to increase the public benefits from spectrum use.

Spread Spectrum A wireless communication system using special modulation techniques that spread the energy of the signal being transmitted over a very wide bandwidth. This increases the number of users that can share a particular band of frequencies, rather than assigning a discrete frequency to each user. Devices currently marketed in the United States primarily use one of two forms of spread spectrum signal: direct sequence spread spectrum and frequency hopping spread spectrum.

Spurious Emission Any radio emission or part of it which appears outside of the authorized bandwidth.

Surveillance Systems A system which operate as a "security fence" by establishing a stationary RF perimeter field and detecting the intrusion of persons or objects in that field. Their operation, in the 1.99-10.6 GHz band, is limited to law enforcement, fire and rescue organizations, public utilities and industrial entities.

T

Through-wall Imaging Systems Systems designed to detect the location or movement of persons or objects that are located on the other side of a structure such as a wall. Their operation, in the 1.99-10.6 GHz band ,is limited to law enforcement, fire, and rescue organizations.

Time Division Multiple Access (TDMA) A method of digital transmission for wireless communications systems that allows a large number of users simultaneously to access a single radio frequency band without interference by dividing use of a set of frequencies by time.

U

Ultra High Frequency (UHF) The part of the radio spectrum from 300 to 3000 megahertz that includes TV channels 14-83, as well as many land mobile and satellite services.

Ultra-Wideband Devices (UWB) A recently approved technology which relies on extremely short pulses that generate signals with very wide bandwidths, sometimes up to several gigahertz. UWB signals go undetected by most conventional receivers, minimizing their threat as harmful interferers. UWB technologies are currently being used in a variety of applications such as ground penetrating radar and are likely to be used in a variety of emerging applications such as through-wall imaging and high-speed data transmission.

Unlicensed PCS Devices (U-PCS) A type of radio devices enabled under Part 15 subject to service requirements which reserve some frequencies for voice communication while the remaining spectrum is allocated for high-speed data transfer applications. U-PCS is widely used for wireless intra-office telephone systems like wireless PBX (Private Branch Exchange) systems.

Unlicensed NII Devices (U-NII) A type of radio devices enabled under Part 15 intended to provide short-range, high-speed wireless digital communications such as W-LANs and to facilitate wireless access to the National Information Infrastructure.

Unlicensed NOI A December 2002 FCC proceeding seeking comment on the feasibility of permitting unlicensed devices to operate in the bands reserved for television broadcasting and also in newly available spectrum at 3650 – 3700 MHz of such a proposal.

Unlicensed Wireless Devices Radios that are permitted by Part 15 of the FCC's rules to emit RF energy, but require no specific device or user authorization, either through registration or grant of a license.

Unintentional Radiators Devices that generate RF energy internally or send RF signals to associated equipment via connecting wiring, but which is not intended to radiate RF energy through the air because the enclosures of these devices must be shielded sufficiently to limit the amount of RF energy that escapes. Examples include computer CPU boards and power supplies.

V

Vehicular Radar Systems Devices able to detect the location and movement of objects near a vehicle, enabling features such as near collision avoidance, improved airbag activation, and suspension systems that better respond to road conditions.

Very High Frequency (VHF) The part of the radio spectrum from 30 to 300 megahertz, which includes TV Channels 2-13, the FM broadcast band and some marine, aviation and land mobile services.

W

Wide Area Network (WAN) A data network used to interconnect remote sites or widely-dispersed computer equipment.

Wi-Fi (Wireless Fidelity) An IEEE standard adopted in 1999, for short-range wireless digital connectivity. It is by far the most widely adopted WLAN standard and includes the 802.11b, 802.11a, 802.11g standards. The performance and speed these standards can provide rivals that of 10BaseT wired Ethernet networks, used in many offices.

Wireless Local Area Networks (W-LANs) LANs which use wireless data connections to provide short-range, high-speed wireless digital communications.

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