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Introduction

I am Kevin Kahn, Intel Fellow and Director of Intel's Communications and Interconnect Technology Laboratory. In my current position, I manage a research and development lab that explores future technologies in optics as well as wired and wireless communications. During my 26 years at Intel, I have worked in a variety of areas including software design, processor and systems architecture, and data communications. Intel Fellows, our company's highest technical position, provide strategic technical guidance to the company. Therefore, I have been deeply involved in the development of Intel's technology policy positions in broadband and wireless communications. I have also served on advisory committees and panels at the Federal Communications Commission, the National Science Foundation, and the National Academy of Sciences.

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As the Committee members know, Intel is the world's largest semiconductor manufacturer and a leader in technical innovation. Since one of our founders first articulated it over 30 years ago, Moore's Law has guided the semiconductor industry. Less well known, Intel is also a leading manufacturer of communications and networking chips. We believe that, in the future, all computers will communicate and all communications devices will compute. Our mission is to drive or to accelerate that convergence through silicon-based integration. The revolution in converging computation and communications has brought amazing benefits to the American public and the rest of the world.

It is an honor to appear before this Committee to testify on the important topic of how the FCC's management of the electromagnetic spectrum can be improved. We are at the dawning of what will likely be the most significant technical revolution in radio technology in 70 years. Put briefly, Moore's Law is going to meet Marconi's transmitter. Rapid improvements in microprocessors will soon make possible radios that are much smarter and more flexible than those in use today. In the not too distant future, any device that might benefit from being able to communicate will have a radio designed into it.

One of the biggest obstacles in the path of this revolution is the artificial scarcity created by the current spectrum management system. Thus, spectrum reform represents a substantial opportunity to promote technical innovation, foster competition and benefit the American public. Today I would like to address three topics: (1) the benefits of making spectrum less scarce--using the Wi-Fi** market as a case study, (2) the problem

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with the current spectrum management system and (3) suggestions for reform, particularly increased reliance on unlicensed spectrum use.

Spectrum Reform Benefits—the Wi-Fi Case Study

All of the benefits from innovative spectrum usage are illustrated by the marketplace and technical success of Wi-Fi. Wi-Fi is the name that the Wireless Ethernet Compatibility Alliance (now the Wi-Fi Alliance) gave to the wireless standards collectively known as 802.11—defined by the Institute for Electrical and Electronic Engineers (IEEE). Wi-Fi devices operate today in the 2.4 and 5 GHz unlicensed bands. The key to Wi-Fi's astonishing success has been the regulatory regime that prevails in these bands – which allows anyone to sell and use equipment in these bands without first obtaining a license from the FCC, provided only that the equipment meet certain technical specifications. This regime allowed manufacturers enormous freedom to innovate and to respond to changing market forces – knowing that no government licensing process would create a roadblock between their technology and consumers. This regime also allowed consumers, schools and businesses to build their own Wi-Fi networks by spending their own money as quickly or as slowly as they wished, without the need for government approval or having to navigate any kind of licensing process.

As result of the freedom enjoyed both by technology manufacturers and technology users, the pace of Wi-Fi innovation has been brisk. The speed of Wi-Fi equipment has jumped from 1-2 Mbps to 54 Mbps. The range of the equipment has also improved, while its costs have plummeted. Products have moved from 4 to 5 chip solutions in 1999 to the 2-chip solutions prevalent today with much more of the radio

frequency circuits integrated, allowing broad expansion into a number of products. In 1999, only 802.11b PC cards and enterprise access points were available. Today, users can choose between 802.11a, 802.11b, or dual-band (802.11a and 802.11b) products for enterprise, small offices, or homes.

The pace of Wi-Fi deployment and the expansion of Wi-Fi product lines has also been brisk. Wi-Fi products have extended beyond PC cards and access points to PDAs, printers, and a host of consumer electronic goods. In addition to providing portable Internet access, Wi-Fi home networks are enabling consumers to use multiple computers with their broadband connections and peripherals. One company already incorporates a Wi-Fi (802.11a) transmitter in its personal media center allowing video streaming to TVs. These technological innovations have and will continue to generate a strong consumer response. Although 802.11 products did not begin shipping in significant volume until 1999, the growth has been staggering. Sales have increased from 7.9 million wireless LAN chipsets in 2001 to a projected 23-25 million chipsets in 2002, according to Allied Business Intelligence.[1] Gartner estimated that over $2 billion worth of wireless LAN equipment was sold last year.[2] In-Stat projects that the Wi-Fi hardware market will grow to nearly $4 billion in 2004.[3]

The Wi-Fi Alliance, the leading Wi-Fi trade organization, has grown to over 200 companies and certified over 500 products in just three years. PublicInternetProject.org detected the presence of nearly 14,000 access points in Manhattan alone.[4] According to the Yankee Group, over 700,000 U.S. companies are now using more than one million

[1] http://www.alliedworld.com/prhtml/wlic03pr.pdf.html
[2] "Wireless LAN Equipment: Worldwide, 2001-2007", Gartner, January 2003.
[3] "It's Cheap and It Works: Wi-Fi Brings Wireless Networking to the Masses", Instat, December 2002.
[4] http://publicinternetproject.org/research/research_sum.html

access points.[5] Public access locations are multiplying worldwide from airports to hotels to neighborhood coffee shops, and most recently, onboard commercial aircraft. In the United States, AT&T Wireless, Wayport, T-Mobile and others sell access for notebook users with wireless networking capability.

And we believe that this is just the beginning. Many in the high-tech community believe this technology – and the license exempt regulatory model – can be used to create wireless broadband networks to the home. From Athens, Georgia to Dartmouth University to Tacoma, Washington to San Jose, California, "WLAN clouds" providing wireless access for entire neighborhoods are appearing.

The Wi-Fi phenomenon is also going global. Korea, already the world's broadband leader, also seems ready to lead in wireless networking. Leading Korean telecom providers have rolled out over 10,000 public access locations since their launch last year. The 2003 World Radio Conference, to be held in Geneva this June, seems poised to make a global spectrum allocation at 5 GHz for wireless data networking. From the UK to France to Hong Kong, regulators have already considered, or are now considering, the ability of this technology to provide a wireless broadband connection to the home or office. The Wi-Fi Alliance recently announced the creation of Wi-Fi Zone, a logo program/ database directory for Wi-Fi public access worldwide.[6]

Intel has been a leader in the effort to accelerate Wi-Fi adoption worldwide. We will continue to actively participate in multiple standards bodies that are working on further improving this technology. We will soon introduce Intel Centrino™ Mobile Technology branded products, which will include a microprocessor (code-named

[5] http://www.nwfusion.com/news/2002/0801wlan.html
[6] http://www.wi-fizone.org

"Banias"), related chipsets, and Wireless LAN networking capability. These components are designed, optimized and validated by Intel to maximize the wireless mobile computing experience. Over the past three years, Intel has increased our investment in wireless technologies fourfold. In addition to our research and development investments, Intel Capital's Communications Fund plans to invest $150 million in wireless networking technologies. We are making these investments in an attempt to accelerate the deployment of Wi-Fi networks and remove technical barriers to Wi-Fi growth and adoption.

We are undertaking these efforts because we are excited by the promise that Wi-Fi holds. Especially noteworthy, recent Wi-Fi-related innovations may accelerate broadband adoption nationwide. Cometa plans on creating a network of wireless LAN access points in the top 50 metropolitan service areas so that users will always be within five minutes of connectivity. Additional locations will be added as customer and usage grows. Technologies like Vivato's smart antennas offer promise by extending the range of wireless Internet access to up to 4 miles. In the future, mesh configurations of access points could enable Wi-Fi to deliver Internet access over even longer distances in competition with DSL and cable modem service.

I believe Wi-Fi is a success because we can operate in unlicensed bands, which allows technologists to innovate, while it allows consumers, businesses, schools and carriers to build their own networks at their own speed without government intervention. I invite Committee members to visit our lab in Oregon to see the future of wireless computing. I am certain that you will share my excitement about the possibilities.

General Critique of Current Spectrum Management

As recognized by the FCC's Spectrum Policy Task Force, the current "command and control" spectrum management system is cumbersome, litigation-prone and politicized. Its tendency to "lock in" inefficient uses and technologies has become more costly with the burgeoning demand for diverse wireless uses and the increased ability of technology to minimize interference. The existing spectrum management approach was not illogical when created. But it was based on a technology in which the tuning range of a radio was necessarily quite limited, and the designs of radio were fixed and tightly tied to the specifics of the application they were intended for. Today, the advent of incredible computational power in microprocessors and related semiconductors has revolutionized what is technically possible. Moore's Law is moving us inexorably toward a technology in which extremely flexible and adaptable radio will become the standard. Shackling these advanced radios with the static spectrum management of the past will severely limit the benefits that can be gained from them.

The Spectrum Policy Task Force identified some promising spectrum management techniques—for example, the creation of largely unregulated, unlicensed bands and the grant of increasing use and technical flexibility to exclusive licensees—that can serve as a guide for reform. These techniques give users more freedom to innovate and respond to changing market forces without seeking government approval. But they also require that the FCC specify interference and other rights and obligations objectively and in a manner designed to foster industry planning and private cooperation. These reforms need not be mutually exclusive and should be considered simultaneously.

Unlicensed Band Reforms

Today, I want to focus on two unlicensed band reforms. First, there is an immediate need to allocate additional spectrum for unlicensed use to foster new applications and accommodate growth. Second, the FCC should follow-through on the proceedings it has begun to determine whether spectrum "non-interfering easements" or "underlays" for new technologies such as agile radios could be created that would not impose significant interference on existing licensees. Both reforms would create valuable new uses without creating significant interference to other users.

1. Additional Spectrum

As a starting point, an additional 255 MHz in the 5 GHz band should be allocated to unlicensed uses to facilitate growth and harmonization. In this regard, Intel supports the "Jumpstart Broadband Act" introduced by Senators Boxer and Allen. If enacted, this legislation would make the needed 5 GHz spectrum available for unlicensed use. This legislation recognizes the importance of Wi-Fi broadband access to the economy and ordinary citizens.

The main obstacle to the allocation of additional unlicensed spectrum at 5 GHz had been concerns that unlicensed devices in part of this band could harm US military radars, thereby posing a threat to our troops and homeland security. However, Intel and other high tech companies worked closely with the Department of Defense to find a technical solution to these concerns – and did so. We believed it was possible both to protect our military assets, and at the same time allow consumers to reap the benefits of innovation in wireless technology. A solution was possible because a Wi-Fi system can

be designed with sufficient intelligence to identify when military radar begins to operate in its channel and rapidly move its operation to a different unused channel – thus avoiding interference to the radar.

With this technical solution in place, the United States has now joined other countries in calling for a global 5 GHz allocation for Wi-Fi and similar systems – but with a regulatory regime that would incorporate the technical solution to protect our military radars around the world. We believe that with industry and the U.S. Government jointly advocating this position at the World Radio Conference, common worldwide rules can be created to our mutual benefit. Intel applauds the efforts of those at the NTIA, FCC and DoD to develop acceptable technical parameters that will increase the amount of spectrum available for Wi-Fi operation at 5 GHz.

2. ***Non-interfering Easements***

The FCC should also determine whether non-interfering easements for new technologies such as agile radios could be created that would not impose significant interference on existing licensees. Much of the spectrum has already been allocated to dedicated uses, but at any instant little of the spectrum is typically being used, even in densely populated cities. Many applications use spectrum only intermittently or only in certain places, but foreclose all other uses because current radios have limited tuning range and use simple encoding methodologies. Moore's Law has begun to change that. Soon radios will be spectrally agile and very flexible in how they encode information in their signal. As a result, radio systems will be able to share the spectrum in much more efficient ways, thereby greatly relieving spectrum scarcity.

For example, the FCC recently opened a Notice of Inquiry considering unlicensed use on broadcast television and the 3650-3700 MHz bands. Given the current limitations of television receivers, most of the TV channels in any geographical area are unused. Advanced radio techniques, however, might permit unlicensed use, without any adverse impact on the broadcasters. Indeed, because the channels "in use" seldom change, agile radios within current technical capability may be able share these frequencies. Another method under consideration is to use Global Positioning System receivers built into the unlicensed devices to determine the device location relative to fixed broadcast transmitters. Experience in these bands could facilitate the development of more advanced applications where use varies much more rapidly over time and space.

For this approach to work, the FCC will have to set interference limits for particular technologies specified in objective terms. Radio use of spectrum is not an "all or nothing" proposition. Rather, radios add to the background noise over which other radios must "shout" to be "heard." By analogy, someone whispering in the hallway creates far less "interference" than would someone shouting in the first row of this hearing room. The FCC will have to determine the amount of interference that a particular radio system adds to the environment and when that is too much (that is, when it should move elsewhere). These limits could define the boundaries of a non-interfering easement. For example, a user of a particular frequency would be required to shut off within a few micro-seconds once it detects an incumbent user begins transmitting.

Together with limitations on the amount of power such underlay radios might use, this approach could allow valuable transmissions with virtually no impact on the allocated users of the various bands. Using my previous analogy, we don't prohibit

people from talking in the hallway – we just don't want them doing so during the hearing! The current FCC rules allow a person to scream here, a person to scream in Pittsburgh and everyone else has to remain quiet. Clearly, there are better ways to utilize a precious resource like spectrum. Given the pace of innovation in the electronics industry, we should begin reworking our regulatory structure to anticipate the future now.

Conclusion

In closing I would like to make two points. First, serious spectrum reform is going to require hard work. The technical questions before the FCC are formidable. And incumbent users have a legitimate interest in assuring that their use is not significantly interfered with. The policy and political issues will also be difficult. But thanks to the work of the FCC and its Spectrum Task Force we are off to a promising start.

Second, policy makers should always keep the consumer interest front and center. Some of the existing holders of spectrum or businesses that might face competition as a result of technological innovation may oppose these reforms. Let me be clear. Protectionist efforts should be resisted. In the end, the public and U.S. economy will benefit enormously if improved spectrum management techniques can eliminate the artificial scarcity created by the current system.

Thank you.