

Opportunities and Challenges in Unlicensed-Band Networks

Srinivasan Seshan
Carnegie Mellon University

Over the past few years, wireless networking technologies have made vast forays into our daily lives. While there have been important licensed applications, we believe the greatest innovation and most rapid deployment of new applications has used unlicensed frequency bands. In this white paper, we focus on the future trends, opportunities and challenges in unlicensed use.

TRENDS

Today, one can find 802.11 hardware and other personal wireless technology employed in homes, shopping malls, coffee shops and airports. As we look to the future, there are a number of critical trends that we must accommodate in the use of wireless networks attached to the Internet. These include:

- **Count.** Market estimates indicate that approximately 4.5 million WiFi access points (APs) were sold during the 3rd quarter of 2004 alone and that the sales of WiFi equipment will triple by 2009. Solutions we develop for this environment must accommodate this rapid growth in number of devices. We should also note that 802.11 is not the only technology using unlicensed wireless spectrum. For example, unlicensed band cordless phones are already ubiquitous and out-sell 802.11 devices each year. IP-based solutions may need to accommodate these devices as well, whether they use IP or not.
- **Density.** The density of unlicensed device deployment varies widely. There are, and will continue to be, many locations where there is little use of wireless technology. At the other end of the spectrum, many metropolitan locations have dozens of 802.11 networks which already overlap in coverage. With the popularity of wireless on the rise, we can expect these densely covered areas to become more common and for their density to rise.
- **Fixed/Mobile Ratio.** The annual sales of laptops have already surpassed those of desktop computers (53% to 47% in early 2005). This trend will not only hold but the gap in sales will likely increase. As a result, we should expect a steady increase in the relative number of mobile end points attached to the Internet.
- **Usage Diversity.** Today, the most common types of unlicensed wireless spectrum links are 802.11 and cordless phones. In the future, there may be a much wider range of link types. For example, while there are only 200,000 wireless sensors in use today, market research suggests they could number 100 million by 2008. Other technology such as Bluetooth and WiMAX may also take off. There will also be a related increase in device/usage diversity as we move past laptops and phone handsets to supporting PDAs, sensors, home media boxes, computer peripherals and entire access networks.
- **Coverage.** Today, unlicensed networks range in size from single homes to campus-sized multi-AP networks. We are also beginning to see the first few metropolitan area networks. In the future, we can expect such metro networks to be far more common. In addition, we can expect the size of the largest network deployments to continue to increase to meet the demand for ubiquitous high-speed connectivity.

While the above trends illustrate how unlicensed spectrum usage will change in the future, there are some properties that are unlikely to change. One such property is how unlicensed band networks are managed. Some networks, such as campus networks, are carefully planned, configured and monitored; while others, such as many residential deployments, are completely unmanaged and left in their default out-of-box configuration. We can expect this diversity in management properties to persist.

OPPORTUNITIES

The above trends create several opportunities for new services. However, to realize this new functionality we need to address a number of shortcomings in today's Internet architecture. Here, we consider two new services: ubiquitous Internet access and localization.

Today, many APs are configured (or misconfigured) to provide open access. As many war-driving Web sites point out, users can, somewhat illicitly, use these open APs to obtain Internet access at almost any location.

Most commonly, these APs are connected to the Internet using DSL or cable modem connections. Unfortunately, the financial and engineering concerns of the Internet service providers associated with these connections result in acceptable use policies (AUP) that preclude allowing open access to roaming users. Changing these AUPs requires addressing a number of technical challenges. For example, the Internet may need better support for accounting and possibly billing guests on a usage basis. APs would also need better support for allowing guest access without introducing security or performance problems. In addition, either Mobile IP would need wider support or new solutions would be needed to support the frequent roaming of users between networks. The end result of changing these AUPs would be to enable legitimate roaming and, as a result, simple, “ubiquitous” high-speed Internet access.

Recent work [1] has shown that the dense deployment of wireless networks provides a simple means by which mobile nodes can determine their location. The Internet provides few standards for exposing this type of context information to applications. The combination of useful standards and wide deployment of such localization software would enable a new generation of context-sensitive Internet software.

CHALLENGES

To ensure that wireless networking technology continues to be useful, we must overcome a number of challenges that the above trends create. Some of these challenges may be solved by modifying only wireless network equipment and standards. However, some of these solutions may benefit from using the Internet and, further still, some challenges may best be solved by making some key changes to the Internet. These challenges include:

- **Interference.** As wireless devices become more common, the interference between them becomes a more significant concern. Our own war driving measurements [2] suggest that interference between 802.11 networks already impacts the performance of the most dense deployment areas. However, differences in transmission range and technology may make direct coordination between wireless devices difficult. Could the Internet provide a backbone for a possible wireless management system? What new services would be necessary to support this management backbone? For example, do we need new services to help discover and contact interfering devices?
- **Incentives and Policing.** Whenever a limited resource, such as spectrum, is shared, the system must address fairness. We envision that distributed algorithms, much like congestion control, will handle the fair allocation of spectrum resources. However, in designing these algorithms, we need a clear understanding of the incentives and optimization goals for different wireless devices/networks. In addition, we need to develop techniques for policing the allocation and use of resources. Could the Internet play an important role both for reporting resource abusers and for coordinating the monitoring activities of spectrum usage in different geographic areas?
- **Routing.** At some point in the not so distant future, it is very likely that mobile or mobile-capable hosts will outnumber fixed location hosts. How would we change Internet routing given the assumption that mobile hosts are the common case?
- **Non-IP Devices.** It seems likely that future wireless environments may have a significant fraction of non-IP capable devices. Should we try to prevent this and make future wireless environments more IP-centric? If not, how can the Internet help solve many of the future problems in wireless networking? Finally, if we assume that IP and non-IP devices must co-exist, what would the wireless non-IP architecture look like and how might it interface with IP oriented solutions?

[1] “Place Lab: A Privacy-Observant Location System”, <http://www.placelab.org>

[2] “Self-Management in Chaotic Wireless Deployments”, Glenn Judd, Aditya Akella, Srini Seshan, and Peter Steenkiste, ACM MOBICOM’05, Cologne, Germany, September, 2005.