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The Battle for Bigger, Better, and Faster Wireless Networks

As more and more people rely on wireless technology to transfer data, the wireless medium becomes an increasingly valuable limited resource. In order to regulate and manage what traverses across this medium, the FCC came into existence after the Communications Act of 1934. The FCC started to auction off this scarce spectrum to the highest bidder at lofty prices to raise money for the U.S. Treasury. However, a small portion was reserved for industrial, scientific, and medical uses, and thus the unlicensed ISM radio bands were born. It is on these ISM radio bands that 802.11 devices use radio waves at the physical layer of the OSI model to transmit data via electromagnetic radiation. However, ISM bandwidth is scarce and becomes very congested due to other devices trying to take advantage of the unreserved frequencies. The result is an unstable wireless network on which certain devices overpower others. By increasing the amount of bandwidth available and by restricting it to a certain purpose, the rise of high-speed WiMAX municipal area networks becomes more feasible and practical.

The ISM radio bandwidth allocated for unlicensed use to the public is of nominal size and becomes ever more congested as new technologies, which make use of these wireless mediums for transmissions, are being rapidly deployed. Devices such as microwave ovens, certain cordless phones, and even Bluetooth share the 2.4GHz frequency with 802.11b/g WLAN devices, whereas some police and military radars share the 5GHz frequencies that are used by 802.11a. To respond to these threats, IEEE802.11 relies on dynamic frequency selection (DFS) as well as transmit power control (TPC) as spectrum management utilities. However, higher frequency signals are more susceptible to increased levels of attenuation in the atmosphere due to moisture in the air, and therefore, the distance the signal is capable of traveling decreases. For this reason, even though there is 150MHz of ISM bandwidth available at the 5.8 GHz frequency, which is used by 802.11a, the amount of power required to operate the radio's amplifier to allow for similar range enjoyed by 802.11b/g networks has a significant negative impact on battery life and overall battery performance due to the heat created as a result of thermodynamics. In order to deploy cost effective WiMAX (802.16) networks that are capable of spanning long distances, the use of lower frequencies is preferred to save power and minimize heat while complying with FCC transmission regulations. However, low frequency bands contain less radio spectrum than high frequency bands, and thus have reduced bandwidth capacity. For this reason, WiMAX contains specifications that span the 2GHz to the 66GHz frequencies, however most of this range is already reserved licensed spectrum for private usages. Because WiMAX does not have internationally allocated spectrum on which it can operate like the 2.4GHz frequency used by 802.11b/g, it will most likely span various different frequencies depending on the geographic location and the imposed regional restrictions.

The prime C-Band spectrum, which is primarily used by satellite transmissions, is particularly at risk of being taken over for use as a broadband wireless access (BWA) medium for products that are WiMAX certified. Unfortunately, terrestrial and satellite systems cannot both coexist within the same spectrum due to the fact that the incoming low power signal emitted from the fixed service satellite (FSS) satellite is highly susceptible to interference before being received by the dish's low noise block. The European Satellite Operators Association (ESOA) has noted increased interference in satellite services throughout the world as the C-Band has been used for an increasing number of terrestrial services and fears chaos should the European Union devout the 3.7-8.0 GHz frequencies to mobile broadband services as some have been planning on doing. Because a robust wired infrastructure often does not exist in third world countries, redistributing the C-Band spectrum would not only have a negative effect on satellite owners, but could cause major international communication gaps. While organizations such as the Global VSAT Forum and the ESOA are against such usage of the C-Band spectrum, others believe that deploying WiMAX certified devices that make use of these prime frequencies is the best plan of action.

Adding spectrum is one of the many ways to speed up a wireless network. By using more sensitive encoding schemes, the receiver is forced to recognize slight signal alteration, which requires a high signal-to-noise ratio and thus increased receiver proximity to the base station. In order to take full advantage of the limited available spectrum, both 802.11 a and g make use of orthogonal frequency division multiplexing (OFDM), which allows for a 20-MHz channel to be split up into 48 subcarriers capable of transmitting actual data in parallel. 64-QAM allows for 6 coded bits per subcarrier, whereas 16-QAM only allows for 4 coded bits. The greater the number of coded bits per subcarrier, and the more subcarriers used to transmit actual data, the faster the network. Draft 802.11n makes use of channel bonding, which allows for 112 subcarriers per 40 MHz channel in total. If OFDM is used, this doubles the throughput over the wireless network by allowing twice as many low-rate streams to run in parallel, assuming that the number of coded bits per subcarrier and the code rate remains the same. However, channel bonding, while technically possible, is not practical on the 2.4 GHz frequency due to fewer available channels (three non-overlapping channels assuming adherence to power regulations) and international government limitations such as those imposed in Japan. Draft 802.11n also invokes the usage of spatial streams via multiple RF chains that are the basis of MIMO (Multipule-Input/Multiple-Output) technology, which allows for an additional increase in throughput without allocating more bandwidth from the electromagnetic spectrum. The fact that frames on a 802.11n network undergo fragmentation before being multiplexed across various spatial streams via a MIMO interleaver allows for increased throughput proportional to the number of actual data subcarriers per spatial streams. Techniques such as packet bursting and frame aggregation also improve throughput, assuming that few packets are lost and the need to retransmit is low. Even if the FCC did not allocate additional spectrum to be used for BWA products that are WiMAX certified, draft 802.11n demonstrates that certain techniques can be applied to allow for 540 Mbps of throughput over wireless networks given only a small amount of spectrum.

As wireless networks continue to grow in size and support higher throughput levels, an increasing number of users will be relying on radio waves to transfer important data. While mathematicians think up of new coding schemes and electrical engineers research more efficient ways of making use of the available bandwidth, by allocating more spectrum for BWA, products that support WiMAX will flourish, and the United States will be better connected than ever before.

Additional Resources and Works Used:

Association for Progressive Communications. *Business Takes on Regulators Over Satellite*. [updated 10 September 2006, cited 10 December 2006]. Available from http://africa.rights.apc.org/index.shtml?apc=n30084e_1&x=5040209.

European Satellite Operators Association. *C Band Spectrum Threat to Satellite Services.* [cited 10 December 2006]. Available from http://www.esoa.net/v2/docs/public_markets/200609_CBand_InfoPaper.pdf.

Gast, Matthew S.. *802.11 Wireless Networks: The Definitive Guide*. Sebastool: O'Reilly, 2005.

Solomon, Yoram. *Defining and Improving Data Throughput in Wireless LAN*. [updated March 2003, cited 10 December 2006]. Available from http://focus.ti.com/lit/ml/sply001/sply001.pdf.