WIRELESS TECHNOLOGIES, WIRELESS FIDELITY (WI-FI) & WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS (WIMAX)

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ABSTRACT

One of the technological advances that are having a major impact on the way we do business is the increase in wireless networks. This paper references how Wi-Fi technology is deployed and some of its advantages over traditional means. It also explores how Wi-Fi technologies communicate in the spread spectrum and how they differ from one another.

Keywords: Wireless Technologies, Wireless Fidelity, Wi-Fi, WiMax, 802.16a

INTRODUCTION

Although there are concerns about how long it can continue, or at least when it will slow down, new technology continues to enter the market on a regular basis. One of the technological advances that are having a major impact on the way we do business is the increase in wireless networks. "Since the turn of the millennium, wireless networks have proliferated. Wi-Fi… has freed us to move around our office and many public places with our laptops and handhelds, yet still have instant, unencumbered access to our companies' intranets and the internet" [5].

Since Wi-Fi technology is being deployed in homes, offices, and public places one can naturally wonder what the future holds for wireless communications. This paper references how Wi-Fi technology is deployed and some of its advantages over traditional means. It also explores how Wi-Fi technologies communicate in the spread spectrum and how they differ from one another.

WIRELESS FIDELITY

The Institute of Electrical and Electronics Engineers Inc. (IEEE) is the organization responsible for setting the standards on how technology and products work, communicate and operate. The 802.11 technology standards, better known as Wi-Fi technology, is being deployed into Broadband Wireless Access (BWA) equipment and Local Area Network (LAN) access points to quickly and efficiently connect computers to internet service providers and to LAN's respectively. Wireless communication has a few problems that plague this service. These include data rate, distance and reliability. All three of these problems can be directly linked to one major issue. The congested air waves and lack of Federal Communication Commission (FCC) regulations on transmission etiquette lead to the one major downfall of wireless communications: interference. However, the FCC does mandate that equipment must use one of two types of transmitting schemes using the 802.11 standard: Frequency Hopping Spread Spectrum (FHSS) or Direct Sequence Spread Spectrum (DSSS).

Since the available unlicensed frequency for transmitting communications is limited and there are a number of wireless schemes attempting to use this limited frequency, mid-air collisions are a common occurrence. A wireless phone running in the 2.4 GHz frequency in someone's house can render a BWA or LAN inoperable. Bluetooth, HomeRF, and other schemes do not cooperate with each other's transmitting scheme. This lack of cooperation increases the number of mid-air collisions. Many transmissions devices will not cooperate or avoid collisions with each other even when it in their best interest to do so simply because the FCC does not require a common etiquette. Any of these communication schemes can render any of the other schemes inoperable. Another key issue to understand with Wi-Fi technologies is that sending a signal over water can greatly affect the connection. It may be impossible for a connection to be maintained even if the user is within the distance requirement for Wi-Fi.

FHSS

As previously stated, the FCC mandates that BWA equipment use either FHSS or DSSS. The FHSS signal is the easier of the two to understand. "The FHSS carrier will hop on pre-determined; pseudo random pattern defined using a pool of 1 MHz sub-channels defined across the entire band. The FCC requires the band to be divided into at least 75 sub-channels" [2].

The amount of time that an FHSS radio can stay on one band, also known as dwell time, is 400 microseconds. After the 400 microsecond dwell time, the FHSS Broadband wireless access equipment will "hop" to the next predetermined, pseudo-random band. The equipment will then have to re-synchronize before the data transmission can resume. If there is interference on a certain band in the frequency, the equipment will hop to the next predetermined band and resend the transmission after the re-synchronization takes place. According to the FCC regulations the band that contains the interference cannot be excluded from the pattern.

Since the power regulation is 1 MHz per sub-channel across the entire band, the BWA equipment that uses the FHSS transmission scheme can transmit data at a maximum of 1 Mbps. There is degradation of the signal as the distance from the end user's BWA equipment to the access point on the tower increases. "The intent of the pseudo-random hopping pattern is to avoid interfering signals by not spending very much time on any specific frequency" [2].

This hopping ability creates additional security for FHSS. It is very difficult for any unauthorized retrieval of the data that is being transmitted to occur because FHSS stays on a certain band in the frequency for a maximum of 400 microseconds and then hops randomly to the next band for another 400 microseconds. Retrieval by unauthorized sources would require equipment capable of following the same hopping pattern as the BWA access point. Since the transmitting equipment does not broadcast the next random hop, the likelihood of external equipment being tuned into the correct pattern is quite low.

On the other hand, the maximum dwell time of 400 microseconds creates a problem with the overhead required to transmit data. The Institute of Electrical and Electronics Engineers Inc. recommends the maximum packet size to be only 400 bytes for FHSS equipment. The overall overhead of the FHSS signals will be increased because of the need to send a transmission preamble and MAC header as well as fragmenting all long packets.

The outdoor range of FHSS is limited to 10 km, which is approximately 6.211 miles. BWA equipment that is using the FHSS transmission scheme must also be located along a line of sight. The 6.211 miles distance is in an optimal situation. FHSS does not use processing gain, since the FHSS signal is not spread. "Processing gain, which provides the decrease in power density when a signal is processed for transmission and the increase in power density when the signal is de-spread, improves the received signal's S/N ratio (Signal to Noise ratio)" [2].

Since the unlicensed 2.4 GHz frequency band has the same limitations of overall power the FHSS systems can't achieve the same Signal to Noise ratio as the DSSS systems. The FHSS systems would have to increase the overall power transmitted to achieve the same S/N ratio. S/N ratio is the measurement of useful information from a specific communication medium (access point) and any other communication signal received (noise). An issue that must be considered in a point to multipoint environment is the speed of each end user to the BWA access point. For example, let's assume that we have two end users that connect to the same access point. End user A connects with a connection speed of 768 kbps and end user B can only get a connection at 384 kbps. The overall tower connection speed will be closer to 384 kbps because the transmission speed of end user B is slowing the overall tower speed.

DSSS

Direct sequence spread spectrum is the second type of spread spectrum signal transmission allowed for BWA equipment by the FCC. Direct sequence spread spectrum transmitters use power levels for transmission that are similar to narrow band transmitters. Because Spread Spectrum signals are so wide, they transmit at a much lower spectral power density than narrowband transmitters. This lower transmitted power density characteristic allows spread and narrow band signals to occupy the same band with little or no interference. This capability is the main reason for all the interest in Spread Spectrum today. Combining the lower power density with the noise-like signals of DSSS makes it quite difficult to detect the presence of a spread spectrum signal. This allows the DSSS signal to maintain an extremely secure communication link.

Since the signal is spread across a large range of bands in the frequency there is a possibility of interfering signals transmitting on some of the bands. The DSSS signal has a redundancy factor built into the equipment. The equipment actually transmits at least 10 fully redundant copies of the data. This signal redundancy helps to resist interference from other signals. Although the signal is sent multiple times, the equipment must receive only one of the signals. If there is interference in the band the DSSS equipment can take partial transmissions from any number of the redundant transmission and correctly assemble them together. This is a very valuable and reliable benefit of the DSSS signal.

DSSS has a process called de-spreading that helps reduce or possibly eliminate interference (see Figure 1). De-spreading of the DSSS signal is accomplished by rearranging the random wideband signals making them equally wide and equally random. If the original DSSS signal is stronger than the interference, the spreading of the interfering signal by the receiver's code generator is rejected in favor of the more powerful DSSS narrowed data signal. In this situation the DSSS signal has overcome the interference and 100% of the data gets through. If there is interference within the signal it will typically be a narrow high powered signal. Since DSSS uses processing gain, the interfering signal will be spread out during the de-spreading process on the receiving end. This will cause a dramatic reduction in the power density of the interfering signal making the impact of the interference significantly reduced or possibly even eliminated. The Signal to Noise ratio is better for DSSS since the de-spreading helps reduce the amount of noise being received by the equipment.

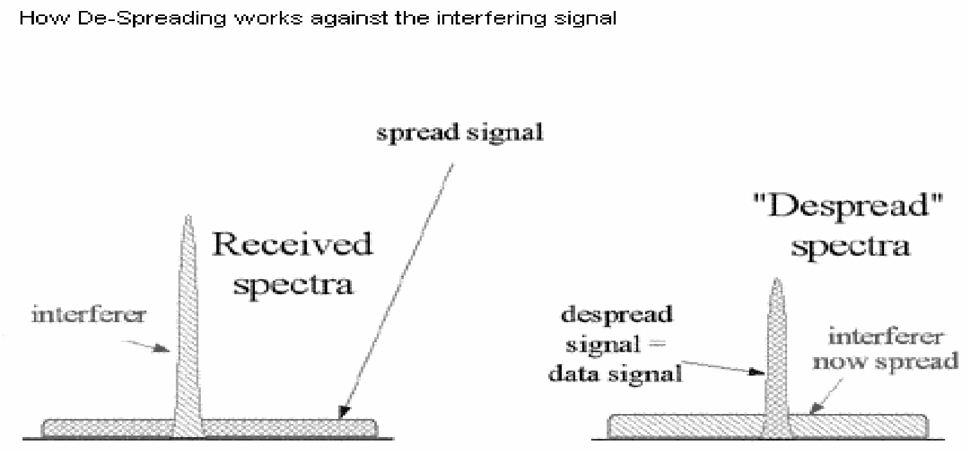

Figure 1. Process of De-Spreading

When the strength of the interfering signal exceeds that of the original data signal by some margin, errors occur repeatedly and data throughput of the DSSS radio ceases. The DSSS equipment only changes bands in the frequency when the administrator of the equipment decides to change it; therefore dwell time does not exist since the equipment remains on the same band for the duration of the transmissions. Also, since the band does not change, there is no re-synchronization process for the DSSS equipment.

The DSSS equipment has a considerable outdoor range of 40km or approximately 24.8 miles. Also, the DSSS systems can send 1500 or 2400 bytes of data; thus long data packets will not have to be divided into extremely small segments as is necessary with FHSS equipment. This helps decrease the overhead that a DSSS transmission requires. The DSSS wireless signal allows for a higher data rate per access point than does FHSS (11 Mbps versus 2 Mbps). This type of connection speed can provide new services previously unaffordable to many companies. Video transmissions can now be transmitted in real time when typically a user's connection to the internet would have been a bottleneck. Another service that has become increasingly important to business owners is remote video surveillance. Allowing a business owner to view the cash register, observe employees' work ethic, or monitor inventory is a great benefit and selling point for this type of high-speed connection.

The success of wireless technology is pressing technology companies to produce more wireless "gadgets" based on newer standards that fix some of Wi-Fi's shortcomings. This is where WiMax enters the wireless industry.

WiMax

WiMax, which stands for Worldwide Interoperability for Microwave Access, appears to be the future of wireless communications. “WiMax is the popular name of the (IEEE’s) 802.16 wireless metropolitan-area network standard that’s currently being developed”[5]. According to Sean Captain, “In late 2004 or early 2005 some homes and offices in areas without sufficient wired connections for DSL or cable service may receive broadband from a version of WiMax called 802.16a” [1]. WiMax can span distances of up to 31 miles, non line of sight. Each base station can transmit up to 280 Mbps with individual signals ranging up to 70 Mbps. WiMax uses low frequencies, in the 2 to 11 GHz range. Alvarion gives the following technical specifications on their website:

- Server area range 50km
- Non Line of Sight
- QoS (Quality of Service) designed in for voice/Video, differentiated services
- Very high spectrum utilization: 3.8 bit/Hz
- Up to 280 Mbps per base stations
- True broadband for portable users - based on IEEE 802.16e enables the creation of a ‘CPE-less’ broadband market, providing broadband connectivity for laptops and PDAs with integrated WiMax technology [7]

WiMax is being called Wi-Fi on steroids [1]. WiMax is expected to help create internet access for millions of users that are in foreign markets that would be too expensive and time consuming for copper wires or coaxial cable. Thus, WiMax may provide the salvation for fixed wireless broadband connectivity in “last mile” situations. Last Mile broadband connectivity is directed to the end users who can’t get broadband connectivity at their location due to the distance between the site and the internet service provider’s central office, or the lack of service equipment in the area. In addition to this advantage, according to Brad Stone in Newsweek, “… since you can achieve significantly higher data rates [with WiMax] than you can over the current wires, a richer set of services can be provided, such as video” [6]. This will be another reason why the adoption of WiMax could soon bring a huge increase in the number of users with broadband connectivity.

Intel sees WiMax as a technology that will help shrink the “broadband divide.” According to Andy Reinhardt, “The real buzz about WiMax is that Intel Corporation is aiming to shrink the technology down to a chip so that it can be built directly into PCs and laptops”[4]. Intel accomplished the same feat with Wi-Fi that they are attempting to perform with WiMax. If Intel accomplishes the task of getting the technology onto a chip that will fit into PCs and laptops this could very well change the market for wireless internet service. Users will be able to connect to ISP’s using the 802.16 technology and also be able to connect to their home or office network using the 802.11 technology.

WiMax developers are attempting to design WiMax connections that will allow users to travel up to 60 miles per hour and still maintain a connection to the internet. Many people are forecasting a large boom in users coming online with the introduction of the 802.16e standard. The 802.16e standard will allow users to travel with their laptops and maintain a constant connection. This technology may be deployed in a manner very similar to the development of the mobile phone industry. It is also possible that WiMax will affect the competition of internet service between Internet service providers and telecommunication companies such as Southwestern Bell Telephone Company. "…WiMax could reinvigorate competition between dominant telecom and cable companies and rivals using a whole new infrastructure - not just leasing space on existing networks [4].

Since WiMax has the ability to transfer up to 70 Mbps per individual user, this technology could allow users to move away from expensive digital and fiber optic equipment and lines by deploying WiMax technologies in regions without digital equipment in place. "Craig J. Mathias, a principal analyst with the Farpoint Group said that 65 percent of American households with Internet access still do not have broadband connections, and that hopes for broader deployment of high-speed fiber optic lines were fading. 'There is no great fiber build-out going on,' he said. 'Some kind of wireless capacity is necessary to reach the last mile' [3]. The time for laying fiber optic lines to the home has passed, he argued, because deployment costs have skyrocketed in recent years. It can now cost as much as $300 a foot to lay fiber optic cable.

Another reason Wi-Fi and WiMax technologies are being deployed by Internet Service Providers is to help minimize costs. Each DS-3, DS-1, xDSL or ISDN line that is used by Internet Service Providers for backhaul purposes has an associated recurring monthly lease payment. If Internet Service Providers can move a majority of their customers off this type of connection and into a WiMax connection, they can minimize their overall overhead while maintaining a high quality service. Each wireless cell site will cost Internet Service Providers thousands of dollars for initial setup and installation or they will have to lease cell tower space from current tower owners. This is very similar to what cell phone companies must do to ensure good connections.

The economic impact of WiMax could be enormous. The ability to use one cell tower to extend coverage over an area previously requiring three towers will help companies reinvest money into expanding their overall coverage. This could lead to more rural areas being covered in a more timely fashion. The installation cost for end users will likely be reduced as a result of major companies such as Intel attempting to develop WiMax technology small enough to fit on a chip that will work in a laptop computer. If routers are built with both Wi-Fi and WiMax technologies and both antennas are installed, the WiMax technology could be deployed and possibly replace the major portion of modem users.

WiMax technology is not likely to completely replace Wi-Fi technology. Wi-Fi is an excellent technology for creating "hot spots" in coffee houses, bookstores and other similar urban settings. WiMax complements Wi-Fi and will likely take over as the back haul service of choice. This will greatly reduce the cost of expensive monthly telecommunication loop charges. The 802.16e standard that is being developed has been predicted to allow users to travel at speeds of up to 60 miles per hour and still maintain a steady reliable connection. This could decrease the number of future Wi-Fi "hot spots" and allow the WiMax 802.16e standard to replace them with WiMax "hot spots."

CONCLUSION

Wi-Fi technologies have been expanding into rural and under developed markets in the past few years. The technology has helped consumers in rural areas receive high-speed internet service.

Wi-Fi "hot spots" are becoming more popular throughout urban environments. Wi-Fi technologies have helped drive down the price of broadband internet access to urban and rural areas. It has also helped increase profits for Internet Service Providers by helping minimize monthly recurring cost of back haul circuits. This paper has examined some of the advantages and disadvantages of Wi-Fi's two types of spread spectrum communication standards. We have seen how telecom companies, cable companies, and Internet Service Providers are anticipating that WiMax technologies will help extend the reach of broadband service to outlying areas. We have indicated that WiMax is expected to increase the quality of service that will be delivered to end users by its exceptional speed and distance coverage. The expectation that WiMax will lead to an "internet anywhere" environment much like that of the cellular phone industry has been documented. We have also indicated that WiMax is not expected to completely eliminate the Wi-Fi technology in the near future, but will be a complement to Wi-Fi as its primary backhaul service of choice.

WiMax promises to help corporations expand business, drive down costs, increase overall profitability, increase the quality of service, and increase the number of users that connect to the internet. The WiMax technology in its current form will complement the 802.11 or Wi-Fi standard. The deployment and adoption of the 802.16e standard could decrease the number of users deploying and using Wi-Fi while increasing WiMax users and WiMax "hot spots." The 802.16a standard will help corporations and internet service providers expand their services to the rural markets or the "last mile."

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