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Increasing Wireless Communication Technology's Bandwidth
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Introduction

Wireless communications is a recent addition to network-communication technology. It allows the transmission of packets of information, which would ordinarily be communicated over wires, to be sent over radio frequencies. This technology has been widely adopted by home users and corporations alike and has substantially increased the portability of computing devices. This widespread adoption has placed pressures on the weaknesses of wireless communications. Limited bandwidth, quality of transmission, and finite frequencies available for communication are of great concern. This paper will focus possible solutions to these issues and issues, which in turn, are caused by these solutions.

Technologies for Improving Wireless Communications

Since its inception, the use of wireless technology has received widespread acceptance. Increasing demands for more bandwidth with greater reliability and noise reduction in both wired and wireless networking will likely never be satisfied. These pressures are particularly potent in the wireless communications environment where there is far less control over obstacles that a signal will encounter. Noise from external sources, power/radiation considerations limiting transmission range, and obstacles such as walls and doors pose significant challenges to meeting these goals. The widespread acceptance of wireless communications has resulted in a severe decrease in the useable EM spectrum. In spite of these difficulties new wireless applications such as wireless High-Definition Television and other Audio/Video applications requiring high-fidelity and large-bandwidth capabilities are still on the horizon. In order to meet these needs new generations of wireless technologies have been approved. Versions 'a' through 'g' of the IEEE Standard have all come and gone in the past years. Currently, debate over version 'n' of the standard is underway. Various alternatives are being considered from smart antennae to Multiple-Input Multiple-Output (MIMO) communications. MIMO is the most promising of these alternatives; it has the potential of offering 100-mbps transmission rates.

MIMO Underlying Concepts

Current wireless routers transmit their data streams over one transceiver and antenna. The transmission is subject to spatial distortions that arise as a result of reflecting off of surfaces between the source and transmission destination point. Standard wireless routers are also subject to noise generated by other electronics including other wireless routers. Multiple transmissions in the same spectrum at different phases can produce significant noise. Smart antennae use several antennae and transceivers to facilitate communications – producing communications with reduced distortion and interference. MIMO is multidimensional whereas smart-antenna technology is one dimensional. MIMO builds on smart-antennae technology by simultaneously transmitting multiple data streams over the same frequency. This technique drastically increases wireless communication's capacity. The following analogy is very instructive:

> "You can think of conventional radio transmission as traveling on a one-lane highway. The speed limit governs the maximum allowable flow of traffic through that lane. Compared with conventional radios, one-dimensional smart antenna systems help move traffic through that lane faster and more reliably so that it travels at a rate closer to the speed limit. MIMO helps traffic move at the speed limit and opens more lanes. The rate of traffic flow is multiplied by the number of lanes that are opened."[1]

MIMO Communications

The multidimensionality of MIMO allows it to achieve a spatial dimension in addition to that of time - the standard dimension of communications. Multiple antennae allow MIMO routers to select data streams, filter out noise and improve transmission reception to receivers by exploiting the geometric orientation of their antennae. Typical EM communication technologies experience significant distortion from signals being bounced along multiple paths. MIMO takes advantage of this effect and employs multi-path communication as a means of opening several other channels of communications that operate efficiently in line-of-sight and none line-of-sight environments. This is analogous to having a bundle of wires connecting two sources – allowing multiple streams of data to occur simultaneously. MIMO encodes a high-speed data stream across multiple antennae. Multi-path "virtual wires" are used to send the lower-speed streams simultaneously. Beyond these immediate advantages, the spectral efficiency that results through the use of MIMO is the predominant reason for its success. MIMO achieves multiplicative increases in bandwidth with no further costs to EM spectrum availability. The same frequency for multiple users is possible because of the use of user-specific encoded transmissions. "The idea behind MIMO is that the signals on the transmit (TX) antennas at one end and the receive (RX) antennas at the other end are 'combined' in such a way that the quality (bit-error rate or BER) or the data rate (bits/sec) of the communication for each MIMO user will be improved."[2]

MIMO Complications

When multi-path transmissions are received, they need to be recombined and filtered. The techniques necessary to perform this task under MIMO are considerably

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[1] Temme, Carl. "MIMO – Wireless Links that Operate in Parallel," (26 July 2004) Retrieved from the World Wide Web on 27 March 2005 from http://www.techworld.com/mobility/features/index.cfm?FeatureID=740 .

[2] Gesbert, Shafi, Shiu, et al. "From Theory to Practice – An Overview of MIMO Space-Time Coded Wireless Systems," IEEE Journal on Selected Communication Technologies (Vol 21, Issue 3) April 2003.

more advanced than signal processing used with single antennae or even some smart antennae. Not only do time distortions have to be considered but spatial distortions must also be considered. A dog walking in the transmission signal of a MIMO router can impact the quality of service delivered. Environment variables significantly complicate MIMO signal processing as decisions as to whether or not a signal has been compromised by external factors are considerably more complicated. Significant research in algorithms for signal processing of MIMO communications is underway. At present antennae geometry and signal processing algorithm development are conducted separately.[3] [Forenza] believes that significant gains can be seen by intertwining the development of these two aspects. Synergies can be achieved by factoring in fading and distortion into both aspects of design simultaneously.

Conclusion

MIMO provides multiplicative increases in bandwidth through the use of multi-path propagation of radio transmissions. It is adaptive in that it can select different paths for data flow when previous paths result in too much signal-to-noise ratio. They provide increases in bandwidth with no further costs to the EM spectrum. MIMO also has a longer range than traditional wireless communication technologies because of its use of multi-path propagation. For these reasons, the n[th] version of the IEEE standard will concentrate on MIMO. At present multiple vendors are developing multiple flavours of the standard for immediate use. A wide variety of choice through research and implementation is available to the IEEE selection committee as a result of MIMO's popularity.

[3] Forenza, Heath. "Miniaturized Antenna Design for MIMO Communication Systems" (2002) "Retrieved from the World Wide Web 28 March 2005 from http://www.ece.utexas.edu/~rheath/research/mimo/antenna/ .

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