April 08, 2008

Real-world deployments of wireless HD video: Is 802.11 ready?

Although one typically thinks that wireless anti-jamming technologies are used solely by the military and public safety entities, there is actually a growing need for commercial wireless systems to employ anti-jamming technology as well

By David McCartney, COO,
Silvus Technologies

As evidenced by the ability to watch videos on demand over current 802.11g WLAN networks, wireless video—the latest 'Killer App'—is here.

While streaming video has been around for some time, the market's attention must now focus on the immediate future and determine if the industry is prepared to meet the ever-increasing demand for wireless High Definition (HD) video transmissions. In addressing this issue, it will be important to research and identify what real world issues we must overcome in order to achieve HD video capability wirelessly. Current IEEE 802.11 WLANs operate with raw data rates up to 54M bit/sec with actual throughputs of no more than 20 to 30Mbit/sec (depending on the type of overhead).

Although fine for many applications in use today, future applications will demand an even higher throughput. These emerging wireless video applications such as HDTV (720p up to 1080i) video demand throughput rates of 100M bit/sec and higher.

It is important to have an understanding of the use of the ISM bands that the FCC has designated for unlicensed applications (i.e. Bluetooth, garage door openers, cordless phones, microwave ovens, baby monitors, video surveillance, etc.), and now WLAN (802.11) applications.

The FCC revolutionized the wireless industry by opening up unlicensed ISM bands. Today, spectrum is selling for millions of dollars and there are delays associated with obtaining an FCC license for a specific frequency band.

These unlicensed ISM bands reduce the barrier to entry allowing companies to introduce wireless products and services without the expense. The price paid for utilization of the ISM bands however, is interference.

Despite the fact that these bands have typically been sparsely occupied, the ever increasing adoption of Bluetooth and WLANs in this band will make the challenge of overcoming interference more prevalent. Over the past few years, the use of the ISM bands for data communications has grown dramatically and today three main applications of the ISM bands remain—Bluetooth devices, cordless phones and WLAN.

Interference and congestion affect Wi-Fi in the 2.4GHz and 5GHz ISM bands in unmanaged/uncontrolled environments such as homes, apartments, small offices, and 802.11 Wi-Fi Networks.

Some of the factors contributing to this problem include, but are not limited to, no control over interfering sources; higher data rates, which are more susceptible to the effects of interference; and growing portability and mobility of interference sources (i.e. Voice Over Wi-Fi handsets—VoIP).

A focused look at wireless video

RF environment. The most promising new applications to enter the market will be the use of Wi-Fi systems, 802.11n in particular, for streaming video, and HDTV distribution in the home.

In order to support these emerging technologies, new approaches to mitigating a dirty RF environment while still enabling even higher throughput wireless communications (100's of Mbps) must be developed. As already noted, higher throughput transmission schemes are typically more sensitive to interference, so this creates a particularly challenging task for the engineering team.

The migration to high-definition content along with the proliferation of digital source devices has intensified the consumer's desire to simply and flexibly connect to the highest quality, high-definition displays and consumer electronics systems—thus the drive to wireless connectivity.

Today, experience with devices attempting to use wireless local area network (WLAN) technology for video distribution have fallen well short of consumer expectations in picture quality and range (distance from router for effective transmissions). Their biggest deficiency has been the lack of adequate effective throughput.

While it's not the sole solution to all video-handling hurdles, higher throughput improves immunity to interference while delivering a means to handle degraded environmental (dirty RF) conditions.

The throughput requirements for wireless video transmission of streaming video (non HD) are limited to the data rates of the wireless system. For an optimal viewing experience, a connection rate of at least 128 Kbps is required.

The faster the connection download is, the less buffering time is needed, which ultimately enables the seamless viewing of the video. Streaming video is a sequence of "moving images" that are sent in compressed form and displayed by the viewer as they arrive.

With streaming video, a wireless user does not have to wait to download a large file before seeing the video or hearing the sound. Instead, the media is sent in a continuous stream and is played as it arrives. Wireless vehicles for this type of video transmissions are EVDO CDMA and the current 802.11 a/b/g standard (others are coming but have not yet been commercially deployed).

While existing EVDO CDMA and 802.11 standards provide 575 Kbps and 20 Mbps of effective throughput with overhead respectively, these wireless platforms fall short of meeting the critical demands for HD Video.

High-definition content typically demands a minimum of 24 Mbps, with throughput requirements ranging from 53.3 Mbps to 480 Mbps (including overhead). The need for such a high throughput range is fueled by the difficulty associated with sending high-def video wirelessly at resolutions of 720p and 1080p at fast speeds without losing the crispness or color quality.

Where is the market headed?
The emergence and commercialization of several technological approaches in 802.11n, UWB and WirelessHD is growing. A deeper look into the developments that are underway in these markets will help engineers understand what will enable wireless networks to achieve the high throughput required in a real-world environment.

Throughput in excess of 100M bit/sec in 20-MHz to 40-MHz of bandwidth that will be operational in a real world environment is a very challenging engineering task.

To achieve this higher, effective throughput demand, companies are now looking at several key techniques including, but not limited to, improvements to the physical layer; multiple-input, multiple-output (MIMO) technology; wireless interference mitigation; and spatial cancellation.

As mentioned above, the first approach to ensuring higher throughput is to modify the *physical layer.* Companies such as wireless design services provider, Silvus Technologies, are making improvements at the physical layer so that the effective throughput is closer to the raw data rate.

In the context of the 802.11n space, this results in throughput rates of 100 Mbps with overhead to rates of 288 Mbps with no overhead. The outcome of these improvements is the target achievement of 150 Mbps of throughput.

Advanced PHYs enable WLAN systems to optimize the performance-enhancing benefits of MIMO technology in the 2.4 GHz and the 5.8 GHz ISM bands used today for WLANs (see Figure 1).

Click here for Figure 1.
Figure 1: Improving the PHY layer implementation of 802.11 can deliver impressive throughput enhancements.

Although it has been deployed in WLAN and other applications, *MIMO technology* is another technique for enabling higher throughput, which is being taken to new levels of implementation and sophistication.

MIMO is the use of multiple transmitters and receivers (multiple antennas) on wireless devices for improved performance. When two or more transmitters and two or more receivers are used, multiple simultaneous data streams can be sent, which significantly increases the data rate. Multiple receivers alone allow greater distances between devices.

The IEEE 802.11n wireless standard uses MIMO to increase maximum speed to 100 Mbps and beyond. Companies like Silvus Technologies have developed a 4x4 MIMO spatial multiplexing 802.11n compliant solution (see Figure 2).

Click here for Figure 2.
Figure 2: Silvus technologies has designed a fully configurable 4x4 MIMO OFDM PHY.

These are more than just antenna solutions. They are complete baseband solutions, which include the MIMO encoder and MIMO decoder. Studies on 802.11n devices reveal the short range throughput being measured at nearly 140 Mbps for 3x3 MIMO devices, at around 110 Mbps for 2x3 MIMO devices, and close to 100 Mbps for 2x2 MIMO devices.

High wireless throughput rates can be significantly degraded or completely disrupted by the presence of an out of network interferer. Today we live, work, and play in a 'dirty RF' environment. Our environment is full of wireless interference.

Some of these interference sources that are currently causing problems include Bluetooth devices currently in play (these all work on the ISM band of 2.4 GHz), microwave ovens (probably the most destructive to 802.11 systems), 2.4/5 GHz cordless phones, wireless headphones, wireless motion detectors, wireless video cameras, fluorescent lights, outdoor microwave links, and even today's wireless game controllers.

These devices represent just a small segment of the 'dirty RF' environment that surrounds each and every one of us on a daily basis.

To help solve this problem, companies are developing techniques that will improve the underlying radio system, enhance its sensing and characterization functionality, and reliably identify the presence of the interference, as well as its degree of sophistication (i.e. microwave oven, or 802.11g).

This is when *wireless interference mitigation* comes into play. By examining methods that enable the radio to take evasive action, the effects of the interference can be mitigated and throughput is ensured.

One technique being used is the classical approach of sensing, in which the transmitter scans the spectrum to identify holes where data communication can take place, and tries to take advantage of those spectral holes.

This poses a challenge since the sense and transmit function in a broadband wireless system requires more sophistication and the variability of the interference environment in both space and frequency is much higher. The second approach is to use multiple antenna techniques to gather information about the spatial distribution of the interference.

Although one would think that wireless *anti-jamming* technologies would be used solely by the military and public safety entities, there is actually a growing need for commercial wireless systems to have this technology as well.

The massive use of devices in the ISM bands has resulted in a number of potential threats to the integrity of the wireless systems. When very high throughput wireless HD video transmissions start to be deployed, they will be even more vulnerable to jamming and signals that disrupt, reduce throughput, or even prevent wireless distribution of data or video.

This jamming will likely not come from intentional sources but via the dirty RF environment itself. As a result, companies are attempting to improve the receiver side of these wireless technologies by developing a receiver that is capable of receiving a signal carrying data or video in the presence of jamming interference.

These anti-jamming techniques process the received signal in an effort to determine a frequency, phase and amplitude of the jamming interference. Then, through various technological approaches, they remove the jamming interference from the received signal and demodulate the signal so as to recover the data.

Conclusion
As we migrate to HD wireless video, the development and implementation of wireless solutions that allow for a high utilization of ISM bands for optimal throughput and high-fidelity broadband applications grows more crucial.

The development of this market will fuel the consumer demand for a high Quality of Service (QoS) and a wireless broadband throughput that can support the over-the-air demands for wireless HD video transmissions.

To properly optimize a system so that it will provide the maximum possible performance irrespective of environment, QoS and hardware limitations, engineers must evaluate, develop and catalog the most effective techniques that will optimize wireless performance in real-world applications.

The focus will have to be on attacking the QoS parameters of Max Packet Error Rate, Max Latency and Max jitter. For wireless HD video, this will mean Max Packet Error Rates of 3.6 v10^{-5} with a Max Latency of 90ms and a Max Jitter of +/-10ms. Couple this with the linkage budget (range) expectations of the consumer and it is easy to see that advanced technology beyond current standard based solutions will need to truly provide a wireless HD video solution.

About the author
***David McCartney** is the COO of Silvus Technologies and has more than 25 years of experience in the wireless industry. With a B.S. from Iowa State University and an MBA from Lynchburg College, he has authored/co-authored 3 patents. Silvus Technologies develops and licenses complex wireless IP technologies that enable a unique approach to enhance the performance of broadband wireless.*