



BY RICHARD A QUINNELL • CONTRIBUTING EDITOR

WiFi and Bluetooth fight for bandwidth

BLUETOOTH AND WLAN ARE ON A COLLISION COURSE—NOT IN THE MARKET, BUT IN THE AIRWAVES.

WLAN (wireless LAN) using the WiFi (Wireless Fidelity) IEEE 802.11b/g protocol is becoming standard in PCs and laptop computers, and it is making its way into PDAs and other portable data appliances. At the same time, Bluetooth is arising as a wireless-serial-cable replacement for headsets and microphones in all kinds of mobile-system applications. They are not exactly market competitors, but they share the same frequency band, and, without careful design, that scenario means trouble.

Both wireless protocols operate in the 2.40- to 2.48-GHz ISM (industrial, scientific, and medical) RF band. WiFi uses one of 12 overlapping channels of 22-MHz bandwidth each, and Bluetooth frequency-hops among 79 1-MHz channels evenly spaced across the band. As a result, no matter which channel of WiFi is in use, a risk exists of interference between the two that will result in lowered data throughput for both.

To characterize the impact of this interference, Texas Instruments in 2000 performed a series of tests that measured the throughputs of both WiFi and Bluetooth links in the presence of interference from the other. The results indicate that the distance between the interfering transmitter and the affected receiver strongly influences the impact (Figure 1).

In the case of WiFi, a separation of 10m results in minimal impact for short-range WiFi use, with increasing impact over longer ranges. A separation of only 2 cm, as might occur when an interfering transmitter is in an adjacent PCMCIA card slot in a laptop computer, has a much more profound impact. In that situation, Bluetooth can shut down WiFi for all but short-range use.

In the case of Bluetooth, the effect is different. WiFi has minimal impact on Bluetooth when separated by 10m, regardless of range. A 2-cm separation, however, drastically reduces Bluetooth throughput even for short ranges and quickly shuts it down with increasing range.

To mitigate this impact, the Bluetooth community developed AFH (adaptive fre-

quency hopping), which can automatically avoid such interference. AFH causes the Bluetooth link to selectively remove from the hopping sequence those channels on which interference is present (Figure 2). The result is that Bluetooth can automatically alter its use of the spectrum to avoid an active WiFi channel. To implement the approach, however, the Bluetooth community needed to convince the FCC (Federal Communications Commission) to change its rules. The FCC has finally approved those changes, and Bluetooth 1.2 implementations can now use AFH.

Unfortunately, AFH does not provide a complete solution to making WiFi and Bluetooth work together in harmony. "AFH gets you only partway there," says Andre Parolin, director of wireless data products at SiGe Semiconductor. "It is there for interference, not coexistence."

More recent testing shows that AFH succeeds in virtually eliminating interference when more than 2m separate the interfering transmitter and the affected receiver, but throughput for each link degrades rapidly with less separation. This situation is currently good enough. Bluetooth's initial market has been in wireless headsets for cell phones. Too few situations arise today in which a user is on a cell-phone call while trying to use a laptop computer connected to a WLAN to consider the interference much of a problem. Changes in the market, however, will once again raise the specter of interference.

The problem comes in emerging applications, such as VOWLAN (voice over WLAN) on laptop computers, cell phones, and PDAs, in which both Bluetooth and WiFi will need to operate simultaneously in the same device. Such applications are becoming more common. The United States, for instance, is adopting WLAN in cell phones to improve coverage, whereas Europe is using it for high-bandwidth downloads to smart phones. In addition, industry analysts expect VOWLAN to become popular in enterprise installations. A survey by market-research company In-Stat/MDR shows that 10% of businesses surveyed use VOWLAN handsets, and 48% are considering implementing VOWLAN.

These trends greatly increase the like-



AT A GLANCE

Bluetooth and WiFi share a frequency band and interfere when too close.

Market demands are pushing to include both Bluetooth and WiFi in handheld instruments.

Bluetooth's adaptive frequency hopping (AFH) will substantially mitigate interference beyond 2m but is inadequate at closer distances.

Other coexistence approaches are available, the best of which arise when the two MAC layers communicate to arbitrate spectrum usage. Manufacturers that offer ICs for both links are in a position to offer such coexistence options.

likelihood of manufacturers implementing Bluetooth and WiFi in the same handset device. With both carrying voice data, neither can afford a major reduction in bandwidth. Yet, in the case of implementing both links in the same handset, maintaining a separation of 2m becomes impossible, and Bluetooth AFH becomes inadequate as a stand-alone approach.

Fortunately, chip-set and other vendors are making available several other coexistence approaches. Some are collaborative, requiring communications between the WLAN and Bluetooth devices to coordinate their actions. Others are non-

collaborative, able to operate independently in one or both links. Each approach has its benefits and limitations, although the noncollaborative approaches are better for situations in which only one link is carrying voice traffic.

NONCOLLABORATION

One noncollaborative technique that can reduce the impact of interference is APSS (adaptive packet selection and scheduling) in the Bluetooth link. Bluetooth provides a range of packet types with various payload lengths and FEC (forward-error-correction) options. By adapting the packet types and transmission timing to the channel condition of the current hop, the Bluetooth system can reduce data loss due to interference. Using shorter packets, for instance, reduces the amount of data that the device needs to resend when interference occurs and can improve throughput compared with that of larger packets.

Dropping the use of FEC in Bluetooth when a WiFi system is the cause of interference can also help. Because the packet loss is due primarily to collisions rather than random noise, the FEC overhead adds no significant value. Dropping it thus reduces overhead and increases data throughput.

Developers can implement the APSS technique predominantly in the MAC (media-access-control) layer, keeping the hardware structure virtually unchanged. Several channel-condition-estimation

methods are available, including BER (bit-error-rate) and PER (packet-error-rate) profiling. By maintaining a frequency-usage table at the master and slave nodes, with the slave node's updating the master's table every update interval, the systems can also estimate the interference present. By scheduling master/slave transmissions on only the "good" frequencies, the system can avoid the interference, although a possibility of collisions still remains. This technique does have a surprising benefit, however: It saves power because little transmission time goes to waste in a bad channel.

The APSS technique reduces overall throughput by waiting for clear channels, but that situation may not be a problem in many applications. One application in which you cannot use APSS, however, is for handling SCO (synchronous-connection-oriented) voice-data packets. These packets cannot be delayed, waiting for a good channel, without compromising voice quality. Thus, APSS is an inappropriate technique for Bluetooth voice applications.

COLLABORATIVE TECHNIQUES

Collaborative techniques for mitigating interference are alternative approaches that can function when you in some way coordinate the operation of both the Bluetooth and the WiFi channels. One simple example is to control operations at the driver level and to switch between the two radio devices to prevent one from func-

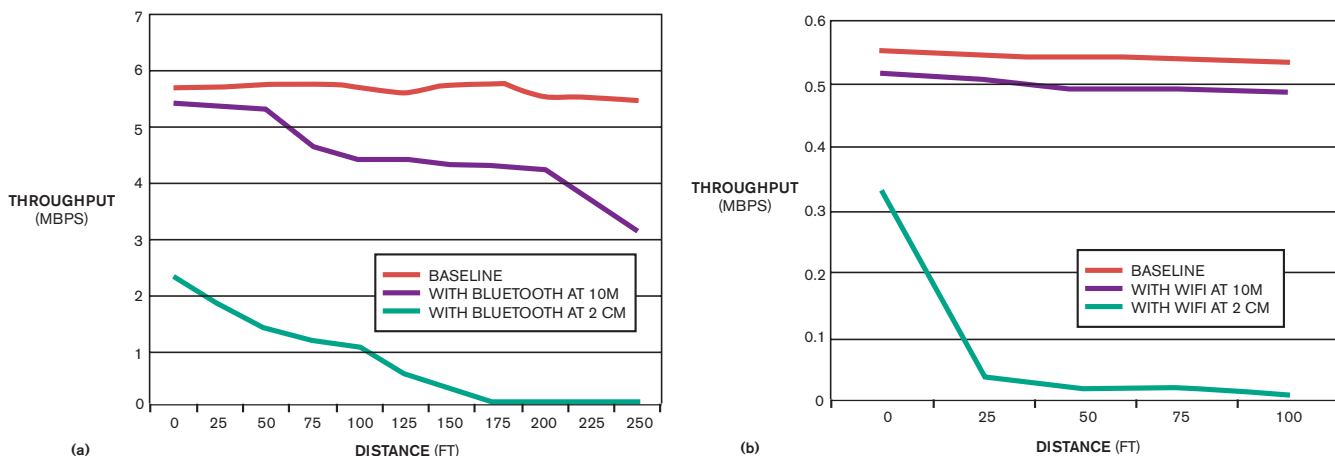


Figure 1 The data rates of WiFi suffer whenever Bluetooth is operating, especially if Bluetooth is close by (a). Bluetooth, however, sees little degradation unless the WiFi transmitter is close (b, courtesy Texas Instruments).



tioning when the other is transmitting. This simple technique severely reduces throughput for both links, however.

Coordination is also possible at a hardware level when both the Bluetooth and the WiFi devices can communicate with each other. Such communication is possible among chips from different manufacturers only when a standardized means of communications is available. Such standards do not currently exist, although the IEEE 802.15.2 task group is developing recommended practices for resolving Bluetooth and WiFi interference. In the absence of such standards, developers should consider proprietary offerings from companies such as Broadcom, Intel, STMicroelectronics, and Texas Instruments that manufacture both types of devices.

One simple collaborative technique is the use of AWMA (alternating-wireless-media access). In this technique, higher level software partitions the WLAN beacon-to-beacon interval into two time segments. One is dedicated to the WLAN, and the other is dedicated to the Bluetooth signal. The Bluetooth device then restricts its transmissions to its allocated time segment. This approach prevents the two devices from interfering with each other.

For this technique to work, the WLAN and Bluetooth devices must be connected, implying that they are collocated in the same physical unit. In addition, all nodes in the WLAN must connect to the same access point so that they are synchronized. The WLAN node in the unit with the Bluetooth device signals the Bluetooth device over a wired connection when the medium is free of traffic, and the Bluetooth device controls the timing allocation. The Bluetooth device must be in its master mode.

As with APSS, this technique does not guarantee a Bluetooth slave timely access to the channel. The slave device can transmit only if it receives permission from the master, and the master must wait until the WLAN node signals a free channel. This approach makes for uncertain timing. Even

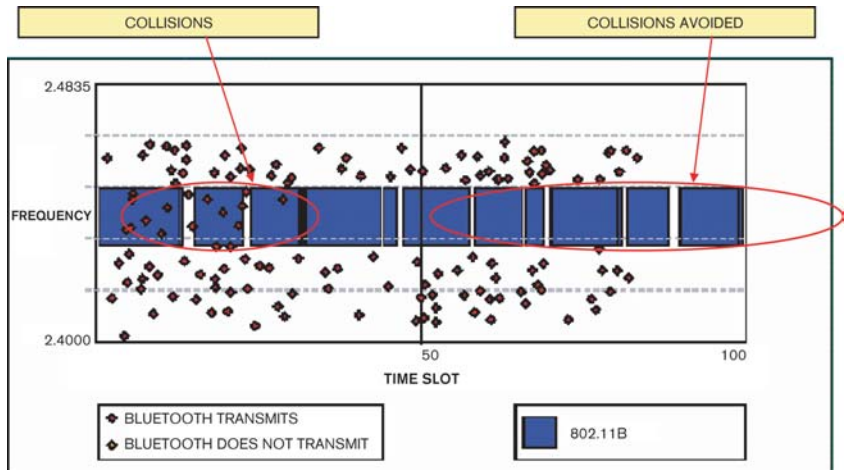


Figure 2 Adaptive frequency hopping uses features available in Bluetooth 1.2 to restrict transmissions on channels on which another transmitter is occupying a fixed bandwidth. The result is fewer collisions and greater throughput (courtesy STMicroelectronics).

if the WLAN master tries to allocate time for the Bluetooth transmissions, it cannot control other WLAN nodes in the network. As a result, timing is uncertain, and the technique cannot support SCO voice-data transmissions.

VOICE DURING INTERFERENCE

One technique that does support voice is PTA (packet-traffic arbitration),

which uses the MAC layer to control traffic. The PTA technique uses a control entity that receives per-transmission transmit requests from each network stack and issues transmission-confirmation signals to the stacks to indicate whether the transmission can proceed. The networks exchange these discrete signals for every packet-transmission attempt.

This technique removes many of the restrictions inherent in other collaborative techniques. For one, it does not require that either network device be a master device. The PTA controller can simply deny any requests that would result in a collision. Because the controller can assign priorities based on packet-traffic classes, it can ensure that Bluetooth SCO packets receive timely handling.

Implementing the PTA approach requires a number of status signals from the two wireless devices in addition to the transmission-request and -confirmation signals. The controller needs to know the traffic priority of each packet, as well as status information from the wireless MAC layer. In addition, it needs to know the Bluetooth frequency in use to determine whether a collision is likely. This additional information requires at least two

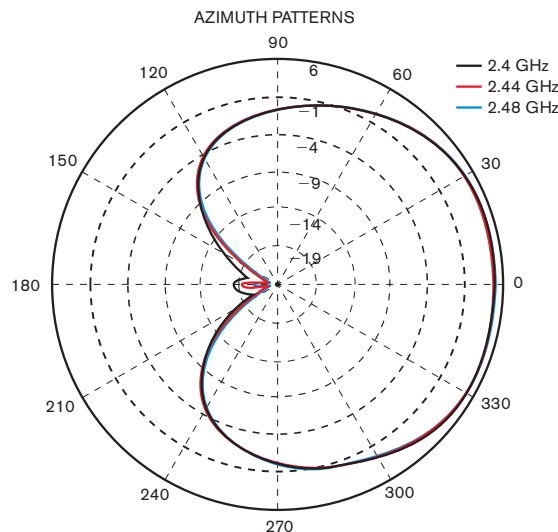


Figure 3 Instead of using an omnidirectional antenna, InterDigital gives developers a means of creating a directional-antenna pattern to reduce the magnitude of interference from collocated transmitters.



additional wires to communicate.

Clearly, implementing the PTA approach carries a high potential for dramatically reducing the impact of collocation for Bluetooth and WiFi transmitters. Its complexity and need for special signaling, however, mean that designers can implement the approach only when the hardware designs of the two wireless chips are compatible. Developers seeking to use this method will do best obtaining hardware and PTA software support from a single vendor.

OTHER POSSIBILITIES EXIST

Other interference-reduction techniques are possible. One is to control the direction of the antennas in use. InterDigital, an RF-component company, has developed AIM (adaptive-interference-management) technology that can enable WiFi networks to adapt their operating frequencies in response to interference. The company's AIM PerformWare, which it implements in WLAN routers and access points, allows them to automatically select the optimum operating channel in the presence of interference.

The company also offers an AIM antenna. Most wireless systems today use an omnidirectional antenna. The AIM antenna uses beam forming to create a directional antenna that has a strong null in one direction (**Figure 3**). The approach allows the system to switch among omnidirectional and two opposite-pointing directional antennas to find the pattern that minimizes interference. This approach can extend the effective distance between the WiFi and Bluetooth antennas in a device, allowing Bluetooth AFH to handle the remaining interference effects.

Designers can also mitigate the effects of interference. At the receiver end of a

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Bluetooth voice transmission, for instance, the receiver can apply error-concealment techniques, such as pitch-period error concealment, to remove some of the artifacts of packet loss in the received speech. Designers can also employ adaptive-interference cancellation at the PHY (physical) layer. Such techniques cannot handle significant interference and data loss, but they can smooth out minor problems.

It may even become possible to completely avoid the problem. The Bluetooth SIG (Special Interest Group) is working with supporters of UWB (ultrawideband) technology to define how Bluetooth can use the greater signal-bandwidth opportunities that UWB provides. If the two successfully merge, the interference issue may disappear.

Another vanishing trick might be to simply eliminate Bluetooth. In the opinion of Fanny Mlinarsky, chief technical officer for test-system vendor Azimuth Systems, WiFi can simply replace Bluetooth. "Bluetooth isn't simpler than WiFi; it simply has lower power. So, simply turn down the WiFi power and use the same data rate, and you'll get the same power as Bluetooth. WiFi has the volume and pricing advantage."

For now, however, if Bluetooth and WiFi must coexist, combining mitigation techniques with more active interference mitigation is the best choice. The techniques that designers can apply depend on the chip sets in use, but the greatest flexibility comes from devices that can coordinate their activities. Whichever techniques developers use, however, the result is a design that produces a more satisfactory user experience when WiFi and Bluetooth operate simultaneously. **EDN**

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Contributing Editor Richard Quinnell was a practicing engineer, designing embedded systems for more than 15 years. He then switched to covering high technology for the last 15 years.

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