



Figure 1 The Belkin CableFree USB hub allows USB 2.0 devices to plug into a hub that connects wirelessly to a PC through a plug-in adapter.

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# CLASH OF THE WIRELESS-USB STANDARDS

WIRELESS USB IS POISED TO ENTER THE MARKET. UNDERSTANDING THE DIFFERENCES BETWEEN THE TWO LEADING APPROACHES WILL HELP DEVELOPERS CHOOSE THE RIGHT ONE FOR THEIR APPLICATION.

Be-coming wireless is a natural step in the evolution of the popular USB (Universal Serial Bus), whose developers aimed at simplifying the cabling of PC systems. Now, two approaches to unwiring the USB have arisen, leaving developers with the difficult choice of which to pursue. Making that choice requires understanding the differences between these two approaches and the trade-offs those differences represent.

The clash of the wireless-USB standards did not begin with the computer community; it came from the wireless industry. Wireless-system developers were looking for a means of establishing short-range, high-speed data communi-

cations that did not conflict with other users of the increasingly crowded radio spectrum. The answer that arose was the UWB (ultrawideband) radio, which works by spreading its radiated energy over many gigahertz, so that it is too weak

to interfere with conventional users of the same frequencies.

Two UWB schemes appeared: DS (direct sequence) and OFDM (orthogonal frequency division multiplexing). Supporters of each approach—the UWB Forum for DS-UWB and the WiMedia Alliance for OFDM-UWB—worked to get the IEEE to adopt their technologies as IEEE standards, but the standards process stalled. That standards conflict has now spawned a market battle for the “killer application” of UWB: a wireless version of the USB. The two main contenders are the CableFree USB, which Freescale Semiconductor and its partners promote, and the Certified Wireless USB, which the

## AT A GLANCE

Two approaches to wireless USB are poised to hit the market.

Protocol differences are more significant than radio differences.

CableFree USB uses USB 2.0 for low cost and ease of implementation.

Certified Wireless USB uses a new protocol for wireless links.

Key protocol differences involve the handling of association, security, and signal-integrity issues.

WiMedia Alliance and the USB-IF (USB Implementers Forum) promote.

Perhaps surprisingly, the most significant differences between these clashing wireless standards occur in the communications protocol, not the radio link. There are radio differences, but the operations of the unwired-USB approaches are relatively indifferent to such physical-layer details (see sidebar “A tale of two radios”). The real differentiation comes in how each approach handles the problem of using a radio in the first place.

Replacing a cable with a wireless link is more difficult than it looks. The replacement link must do more than simply pass along a copy of the bits coming in at each end. It must replace some attributes of a wired connection that are absent from wireless ones, including reliable signal integrity, inherent association, and physical security.

## CABLE-REPLACEMENT ISSUES

Signal integrity becomes an issue for wireless-cable replacement, because wired-communications protocols usually expect a highly reliable data stream. Without special provisions for handling the kinds of delayed or dropped data that can occur with a wireless link, wired protocols can quickly fail. The USB protocol has only a few features to deal with signal issues. One is a CRC (cyclic-redundancy check) to detect noise-corrupted data packets. Another is a turnaround timer to prevent the bus from

waiting forever for a failed peripheral to respond to the host.

The CRC poses no special problems for a wireless link, but the turnaround timer can. The delays inherent in converting the bit stream to a modulated radio signal, and the corresponding demodulation, may be more than the turnaround timer can tolerate. Switching delays may also exist in the wireless channel when the system must use the same antenna for both transmitting and receiving, aggravating the problem.

The issues surrounding association are artifacts of the wireless link’s broadcast nature. “Association” means establishing a well-defined logical connection from one device to another. Defining a connection is inherent in a cable hookup; when you plug two devices together, you are indicating that you want them to communicate. But in a wireless link, association is more ambiguous. If a peripheral device wishes to establish a wireless link with a host and more than one host is within range, the peripheral needs some method of determining which host to link with.

Association is also a key element of communications security. Security in-

volves preventing both the unauthorized communications between two devices and a third party’s interception of authorized communications. In a wired connection, the need for physical access to the wires provides a high degree of security. It’s hard to connect to a host or eavesdrop on wired communications without access to the equipment. The broadcast nature of a wireless link, however, opens the door for both types of activities to occur at a distance.

Encrypting the data stream can provide the needed security. Encrypted data streams are difficult to mimic or to read without possession of the encryption key. Establishing an encrypted data stream, however, first requires a secret exchange of keys between the units. For wireless systems, this exchange occurs during association, with the result that associated devices can communicate with each other, and nonassociated devices cannot.

## NEW VERSUS OLD PROTOCOL

The ability to handle security, association, and signal-integrity issues is essential to any wireless-cable-replacement technology. The competing approaches of CableFree USB and Certified Wireless

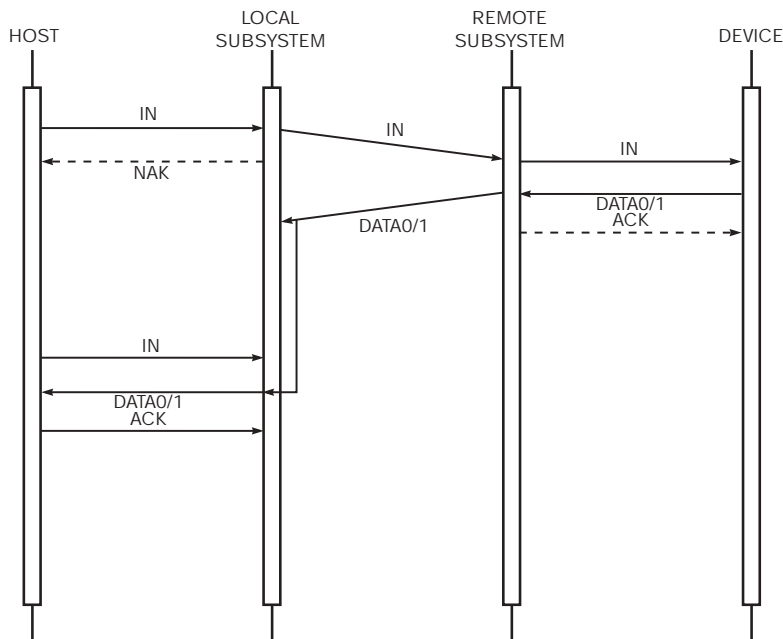


Figure 2 Performing a USB transaction over a wireless link requires that intermediate subsystems work to prevent the USB turnaround timer from creating problems (courtesy Icron Technologies).

## A TALE OF TWO RADIOS

The clash of the wireless-USB standards began as competition for IEEE standardization of personal-area-network-radio technology. To achieve high bandwidth over short distances without creating interference in an already-crowded spectrum, developers turned to UWB (ultrawideband) radio. The conflicts arose in the definition of modulation schemes for the UWB signal.

The UWB radio generates signals that are short bursts—only a few cycles long—of a carrier frequency. The frequency spectrum that results from these short bursts contains many harmonics of similar magnitudes spread out over a bandwidth of several gigahertz. Because the signal energy is distributed across numerous harmonics, the energy at any one frequency is relatively small. This dilution of energy allows a UWB signal to share radio spectrum with more conventional narrow-band communications without generating significant interference.

Two modulation schemes for UWB signals arose as contenders for IEEE standardization: DS-UWB (direct-sequence UWB) and OFDM-UWB (orthogonal-frequency-division-multiplexing UWB). Proponents of DS-UWB formed the UWB Forum to refine and promote their approach. The supporters of OFDM-UWB created the WiMedia Alliance. For several years, both groups engaged in fierce lobbying within the IEEE-standards process,

ending in a stalemate.

The DS-UWB approach has the advantage of simplicity. As Figure A shows, the scheme works on only two frequency bands. A given network uses one band or the other to avoid interference from other networks. Working with only two carriers simplifies the transmitter design.

DS-UWB also employs a simpler modulation scheme. The data stream directly controls the transmitter, turning it on and off with BPSK (binary-phase-shift keying). To prevent repeating data patterns from disturbing the signal's power spectrum, the data stream is first encoded into tokens to prevent such repetitions.

The OFDM-UWB approach is more elaborate, using frequency hopping over multiple channels to avoid interference (Figure B). The scheme allows the transmitter to eliminate noisy channels from the hopping sequence. This scheme also allows multiple networks to operate in

close proximity with minimal interference, but the penalty is a more complex and costly transmitter. Proponents of DS-UWB also contend that OFDM performs poorly in the presence of multipath propagation and requires channel manipulation rather than simple pulse shaping to control the output spectrum.

Unable to resolve these conflicting approaches, both camps have now turned to the marketplace for a decision. CableFree USB uses the DS-UWB approach, and the OFDM-UWB approach has its home in Certified Wireless USB. Both sides are hoping that their combination of cost, performance, and utility will win the market over.

Recent developments are favoring the OFDM-UWB approach, however. The WiMedia Alliance has seen the selection of its scheme by the USB Implementers Forum. In addition, the Bluetooth SIG (Special Interest

Group) has now chosen the WiMedia UWB radio as the successor to its current radio scheme. The Alliance has begun to define the behavior of a common radio platform for inclusion in next-generation PCs. With the right combination of protocol-adaptation layers, a single WiMedia radio transceiver can function as a Bluetooth, Certified Wireless USB, FireWire, and TCP/IP (Transfer Control Protocol/Internet Protocol) channel.

The Alliance is also vigorously pursuing worldwide regulatory acceptance of its UWB scheme. The United States allows full use of the WiMedia radio's 14 frequency channels, and other countries are expected to follow suit for many of the channels. In situations in which local regulations restrict channels, however, the WiMedia radio simply removes those channels from the hopping scheme. Thus, a single OFDM-UWB radio design has the potential of achieving worldwide regulatory acceptance. The two-channel DS-UWB scheme now has regulatory approval in only the United States.

Although the outcome of this competition seems to be stacked in favor of the WiMedia approach, it is too early to discount the impact of the design simplicity and early market entry that DS-UWB enjoys. As the market makes its choices over the next few years, it will be the best of times or the worst of times for the two camps. Who will enjoy which is still up in the air.

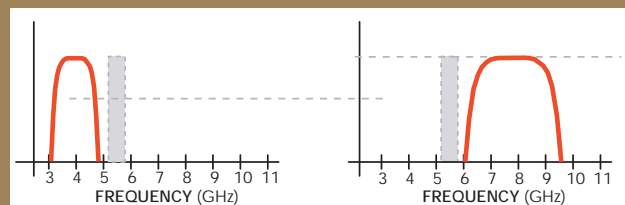


Figure A The direct-sequence ultrawideband radio uses low- and high-frequency bands (left and right, respectively) to avoid interference from adjacent networks.

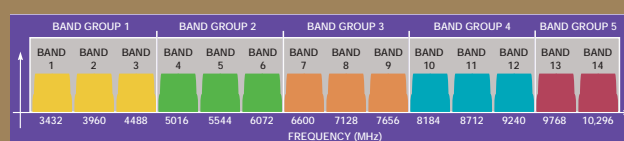


Figure B The WiMedia ultrawideband radio employs 14 channels and uses frequency hopping to mitigate interference.

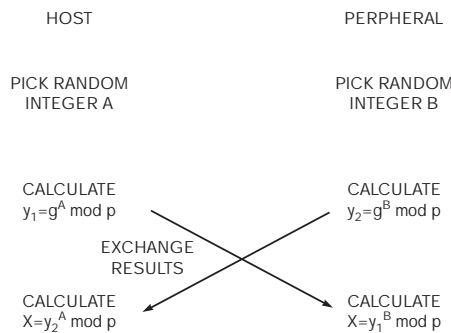
USB address these issues in different ways. CableFree USB exactly mimics USB 2.0 in its interfaces to host and peripheral devices, handling the wireless issues within device adapters. Certified Wireless USB employs a new communications protocol, similar but not identical to USB, to address the wireless issues.

This first difference in the two approaches could significantly impact their market acceptance. The Cable-Free approach of retaining the USB 2.0 protocol means that developers can quickly offer products that users can simply plug in without making any system changes. CableFree products, such as the Belkin four-port hub in **Figure 1**, appeared at the Consumer Electronics Show in January. The system offers a hub that connects to the peripheral devices and wirelessly communicates with an adapter, or “dongle,” that plugs into the USB port of a laptop computer.

The Certified Wireless approach, on the other hand, required the definition of a new specification. The initial specification, which its developers released in May 2005, received a supplement defining the association’s methods in March 2006. The specifications are now under the control of the USB-IF.

Waiting for a new specification has made Certified Wireless USB lag behind CableFree USB in its market introduction, giving CableFree a chance to establish itself as a de facto standard. In addition, introducing a protocol means that implementing Certified Wireless USB involves a software change. This need to change software may further delay implementation, as well as present a barrier to adoption by the market. Such software is beginning to appear, however. Windows XP drivers for Certified Wireless are now available from WiQuest Communications.

The flip side of having a new protocol is that it was developed for wireless communications. This situation has allowed the approach to provide extra value by optimizing data throughput over the radio link and providing power-management features for the radio. These additional attributes bode well for the long-term value of the Certified Wireless approach



**Figure 3** This Diffie-Hellman key agreement protocol is the basis for Certified Wireless USB’s unwired-association scheme.

if the CableFree approach does not first dominate the market.

### HANDLING SIGNAL DELAYS

The market impact of the two approaches may be important for companies seeking to develop peripherals and host computers, but developers who simply need to use an unwired USB connection will need to look at the technical details to choose the best approach for their application. One of the first places to look is at the signal-integrity issue and its impact on data throughput.

The Certified Wireless USB approach has built into its protocol the features to handle such wireless-channel attributes as noise, fading, and conversion delays. These features add to the protocol overhead, but the USB-IF claims that the protocol has a 75% efficiency in data transfers over a 480-Mbps link. Because USB 2.0 was designed for a wired connection, on the other hand, the CableFree approach requires that you make some accommodation to handle the problems that USB 2.0’s turnaround timer causes.

One such accommodation comes from Icron Technologies, developer of the ExtremeUSB extension (**Figure 2**). When the host device initiates a transaction, it expects to receive a response from the peripheral device within the turnaround time. To address that expectation, the ExtremeUSB extension inserts into the link a local and a remote subsystem to mimic the peripheral to the host and mimic the host to the peripheral. When the host initiates a transaction,

the local subsystem responds with an NAK (negative acknowledgment), so that the host does not wait for the peripheral’s response. The local subsystem then passes the transaction to the remote subsystem, which interacts with the peripheral. The remote subsystem returns the peripheral’s response to the local subsystem, which then waits for the host to make a second attempt at initiating the transaction. The local subsystem has the peripheral’s response in memory, allowing it to react immediately and complete the transaction.

This approach prevents the delays inherent in the wireless link from slowing the host system’s bus. The host need not wait for time-out of the turnaround timer before moving on to the next task. The approach does, however, require that the host make more than one attempt to initiate a transaction before obtaining the desired response. This need for multiple attempts can reduce the effective bandwidth available to the peripheral.

### ASSOCIATION METHODS

Another technical difference between the CableFree and the Certified Wireless approaches occurs in the way they handle association and security. CableFree devices have built-in association. The hub and dongle come as a matched pair, with internal registers that contain matching identity information. Communications between the hub and the dongle encapsulate the USB-data packet with a header that indicates the identity of the sender. By first validating the data-packet header, you can then configure the matched hub and dongle to respond only to one another’s signals.

This approach prevents outside devices from connecting to the host or the peripheral but does not prevent snooping. The hard-wired identity information, however, can also contain a private key for encryption of the data. Encryption makes the link more costly and complex but provides full data security. A Cable-Free USB implementation may not have built-in encryption.

The drawback of the hard-wired approach to association is that it prevents the interoperability of devices from different manufacturers. For the home-user

market that CableFree targets, this characteristic may not be a problem. Home users will adopt CableFree simply to eliminate the need for cables with their equipment. They will not purchase new CableFree peripherals for use with a pre-configured CableFree-ready PC.

The Certified Wireless approach, however, targets next-generation equipment, although, for the home user, vendors are developing a hub-and-dongle approach that can handle legacy USB 2.0. For this next generation, Certified Wireless has adopted association features that will ensure multivendor interoperability and data security. These association approaches allow Certified Wireless to go well beyond legacy installations.

Two methods of association are available in Certified Wireless: wired and unwired. In the wired approach, the peripheral must physically connect through a cable to its target host for first use. Once the devices connect, the user initiates association between them. The host and the peripheral exchange encryption keys and other information across the cable, and then store that information in their internal memories. The two can thereafter automatically establish a secure wireless link without physically reconnecting. The host keeps a record of all peripherals that it has associated with. The peripheral must retain association data on at least one host but may have enough memory to remember several hosts.

### UNWIRED-DISPLAY NEEDS

The unwired-association method, or numeric model, uses the Diffie-Hellman key agreement protocol to establish a secure channel. The method depends on a user's reading a two-digit display on each device to verify that the association is correct and then signaling each device to accept the association. This display requirement adds cost to the devices, but, because the approach targets devices that may have displays, such as printers and cameras, this constraint may not matter.

The Diffie-Hellman protocol has three elements (Figure 3). The first element is a pair of numbers,  $g$  and  $p$ , that are publicly known. The number  $p$  is a large prime, and  $g$  is an integer less than  $p$ . The

## THE UNWIRED-ASSOCIATION METHOD, OR NUMERIC MODEL, USES THE DIFFIE-HELLMAN KEY AGREEMENT PROTOCOL TO ESTABLISH A SECURE CHANNEL.

second element is the ability for the host and peripheral to independently develop random numbers. The third element is the ability of the host and peripheral to perform calculations of the type  $y=g^x \text{ mod } p$ , where mod means to use modulo arithmetic.

The protocol offers a secure way of exchanging keys. When the two devices attempt to associate, each generates a random number:  $A$  for the host and  $B$  for the peripheral. The host then calculates:  $y_1=g^A \text{ mod } p$ , and the peripheral calculates:  $y_2=g^B \text{ mod } p$ .

The devices exchange their results, and then use them to calculate  $X=y_1^B \text{ mod } p$  (peripheral) or  $X=y_2^A \text{ mod } p$  (host). This calculation yields the same number in each device,  $X=g^{AB} \text{ mod } p$  without revealing the random numbers.

To complete the association process, the user must verify that the two devices have reached an agreement. The devices each display a two-digit contraction of the result for  $X$ , which the user compares and verifies. The value  $g^{AB}$  becomes a shared secret key for the two to use in further communications. Because the system chooses a new random number each time it makes an association, only the two devices involved have possession of their private key. As with the wired approach, the host and peripheral must keep track of the keys and other data generated during the association.

The advantage of the Certified Wire-

less association method is that it allows devices from different manufacturers to associate at will, which, in turn, allows computers and other devices to build in support for Certified Wireless without knowing which devices it is will associate with. Certified Wireless thus becomes a cable-free replacement for USB functions rather than a simple replacement for a single USB cable.

All of the complexity associated with the new protocols of Certified Wireless USB may make the approach unsuitable for some applications. For those applications, the simpler and less expensive approach that CableFree USB offers can be compelling. Still, the long-term fate of the two approaches remains uncertain.

History has shown that being first in the market, like CableFree USB, can be a compelling advantage regardless of technical attributes. At the same time, the Certified Wireless approach has the backing of the USB-IF as well as industry powerhouses, and it promises both high performance and multivendor interoperability. One set of advantages may overwhelm the other, or both approaches may find a home in noncompeting applications. Deciding which approach to adopt will determine the outcome in this clash of the wireless-USB standards.EDN

### FOR MORE INFORMATION

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