Taking the Wires out of USB – Wireless USB Solutions

>> Whitepaper

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Wireless USB

>> Benefits and Limitations

Since its introduction in the late 1990s, USB has become an enormous success, creating an industry that has delivered billions of devices into the marketplace. With the vast majority of computing peripherals supporting the USB protocol, and the benefits of high bandwidth connectivity provided by the USB 2.0 standard, the development focus for next generation USB technologies has firmly entrenched itself in the wireless domain. With the widespread benefit and appeal of wireless technologies such as 802.11 and Bluetooth, the benefits of a wireless USB solution are vast. However, when looking at available and possible solutions, one should remember that the path to success is not always a simple one. Many of the benefits of a wired USB connection become serious hurdles to overcome in the quest to take the wires off the desktop.

This whitepaper addresses some of the misconceptions of wireless USB technologies and provides an overview of the current landscape of available and future solutions.

USB Adapters

>> Transports a non-USB protocol.

It is useful to note in a discussion regarding Wireless USB is that the end goal of the solution is to provide a cable replacement for a pure USB connection. Many Wireless USB adapters exist today, but these adapters do not perform the function required of a true Wireless USB solution.

A USB adapter, devices such as USB-to-Serial, USB-to-Ethernet, USB-to-802.11 and USB modems (USB-to-Telco or USB-to-Cable TV), provides an external connection and protocol conversion that just happens to connect to the PC via USB. The USB device itself is the dongle or adapter unit directly connected to the host. The remote side is not a USB device, and the connection is not USB. The goal of a true Wireless

USB solution is to enable connectivity of any USB device, and provide the same convenience of a simple wired USB connection.

Cable Replacement

>> Requirements for backwards compatibility

The simplest concept for a working Wireless USB solution is to envision the solution as a cable replacement for an existing USB 2.0 wired connection. Removing the wires should not change the available functionality. If anything, greater flexibility should be available to the user, in terms of connection models, and ease of use.

A cable replacement solution should support the following functional requirements:

- Backwards compatibility
  - It must support all three USB speeds – LS, FS and HS.
  - It must support all four USB transfer types – Control, Bulk, Interrupt and Isochronous.
- The system must accommodate the long and somewhat unpredictable delays that can occur in RF communications.
- The system must provide a robust transmission system that approaches the reliability of a wired solution.
- The system must provide the option to offer data security similar to a wired environment.

The functional requirements listed above derive directly from the USB specification. Further requirements and options available to the RF portions of a Wireless USB implementation are discussed in the following sections.

USB in Time and Space

>> Solutions for RF limitations

The largest limitation to USB extension beyond the wired desktop is the Turnaround Timer (TT). This parameter limits the time that any host or device may take to respond to a request or to acknowledge data reception. It is introduced into the design of USB to prevent an errant device from consuming a disproportionate amount of time on the shared bus. The TT helps maintain high occupancy of the bus by limiting the time that the bus sits idle waiting for a response that may never arrive.

In wired USB, the TT budget is allocated to the various hubs, cables and devices that constitute the worst case (greatest delay) topology. In wireless USB, there are additional factors that can push the turnaround time beyond the allowed limits. These factors include:

- Some half-duplex radios require a significant period to switch between transmit and receive modes.
- Restricted RF bandwidth forces longer transmission times.

- Lost packets equate to an infinite TT.
- Adding error correction, scrambling and encryption functions increases latency and consumes additional bandwidth.

Higher bit error rates and variable bandwidth over the wireless link can contribute to performance that in a worst case would eliminate the possibility of maintaining a USB host to device connection. Since the wired USB standard was designed to function over a medium without variable bandwidth or excessive BER, additional mechanisms need to be implemented at the physical and protocol layers to ensure reliable communications for a wireless system.

To address the issues with taking USB into the wireless world, the USB Implementers Forum, the standards body that governs all USB compliance, developed a new USB standard: Certified Wireless USB (WUSB). Essentially, WUSB is a replacement to the USB 2.0 standard to enable reliable wireless communications. Tightly tied to the selected physical layer implementation standardized by the WiMedia Alliance, WUSB is a whole new USB standard that requires enhancements and new drivers for both the PC host controllers, and the USB devices. All new host controller and device level software, along with development and commercialization of the WiMedia radio subsystem must be supported and installed to support a Certified Wireless USB solution.

Instead of creating a whole new standard, the ExtremeUSB® protocol developed by Icron Technologies to extend wired USB connections, is applicable to cable replacement in wireless systems over any physical media. ExtremeUSB enables a wireless USB 2.0 implementation that is transparent and driverless. The mechanisms behind ExtremeUSB are discussed in more detail below.

ExtremeUSB® Wireless

>> An industrial strength solution

ExtremeUSB was developed to enable USB devices in industrial and commercial environments where operational requirements often exceed those of the desktop for which USB was designed. To achieve long reach USB connectivity, ExtremeUSB overcomes the limitations imposed by the Turnaround Timer. Removing this limitation enables conventional RF techniques such as error correction to be employed. (For more details on how ExtremeUSB operates, see the How ExtremeUSB Overcomes Delay section.)

Referring back to the requirements discussed in the section on cable replacement, ExtremeUSB supports all three USB speeds – LS, FS and HS. ExtremeUSB also contains unique features that enable each of the four USB transfer types to be handled. Any particular implementation can combine support for speed and transfer type variants as required. Just like standard USB, devices with different speed and transfer type attributes can be attached to and detached from the system at random. ExtremeUSB recognises each device automatically and provides the appropriate protocol handling. For the host controller, no additional software installations are required to support the ExtremeUSB system. The ExtremeUSB core simply enumerates as a generic hub, allowing transparent connectivity of any device on the host controller.

Throughput on the link is independent of the ExtremeUSB protocol, and is determined by simple performance characteristics of the physical medium that include the maximum available bandwidth, and the round trip latency of the link.

Operating at the USB protocol layer, ExtremeUSB is independent of the physical media used for data transmission. ExtremeUSB has been implemented over both copper and fibre media providing wired extension up to 100s of meters over standard Category-5 UTP cabling and kilometres over fibre optics. In the wireless medium, ExtremeUSB has been combined with a standard 802.11g radio to enable a four port wireless hub, dubbed WiRanger.

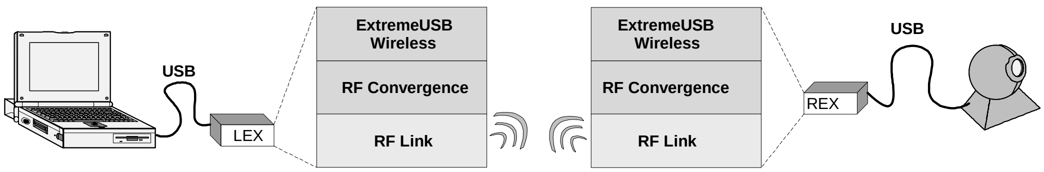

Figure 1. ExtremeUSB for Wireless System Model.

The structure of the local (LEX) and remote (REX) dongles is very similar. Each can be logically partitioned into three distinct functional layers. The top layer is the ExtremeUSB protocol layer that compensates for the effects of delay. The RF Convergence layer formats USB packets in a manner that is more suitable for transmission over RF. It is here that features such as encryption and error correction are added if required. The bottom layer represents the actual RF transceiver (or any physical layer transceiver) hardware and associated baseband modems. This architecture provides a flexible system in which the RF convergence layer can be tailored to suit the requirements of the chosen RF Link technology.

A wide variety of other physical media, wired or wireless, can be connected to an ExtremeUSB core to provide USB connectivity: 802.11, UWB, Broadband over Powerline transceivers, Gigabit Ethernet transceivers, etc.

Survey of Wireless Protocols

The following is a brief survey of wireless protocols that address the variety of performance requirements in today's wireless infrastructure. As noted previously, ExtremeUSB is agnostic to the physical layer upon which it is implemented, and any of these radio protocols could be integrated with an ExtremeUSB core to provide a Wireless USB solution.

Protocol	Data Rate	Reach	Comment
ZigBee – 802.15.4	250kbps	70m maximum	Low data rate mesh networking solution for sensing applications
Bluetooth – 802.15.1	3Mbps	10m typical	Killer application in wireless headset and HID applications. Is looking at UWB for high data rate radio enhancement.
UWB	Potential for Gbps Examples: WiMedia ~ 480Mbps C-Wave ~ 1.3Gbps	3-10m	Various implementations offering similar performance are available. WiMedia provides radio core for Certified Wireless USB. Throughput strongly tied to reach. Standard calls for 480Mbps at 3m.
802.11a/b/g	Up to 54Mbps	Up to 100m	Ubiquitous wireless Ethernet radio. Commercially available and well understood by user.
802.11n	540Mbps	Up to 125m	Next generation WiFi standard. Imminent ratification and implementation. Ideal for high bandwidth applications such as video distribution over Wireless.
802.16 WiMAX	70Mbps	Kms	Long range metro broadband wireless technology.
WirelessHD	5Gbps+	3-10m	60Ghz technology that is looking to develop Wireless HD Video application (HDMI, DVI)

How ExtremeUSB Overcomes Delay

>> Managing the Turnaround Timer

The following sequence diagrams provide a simplified view of how ExtremeUSB works.

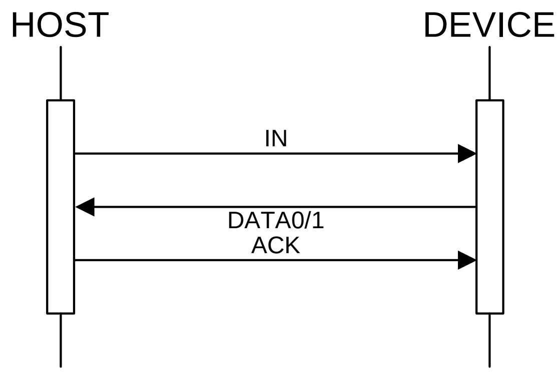

Figure 2 – A conventional IN transaction

Figure 2 shows the progress of an IN transaction between a USB host and a USB device. The host initiates the transaction by issuing an IN request to the device. The device responds with a DATA0 or DATA1 packet as appropriate and the host completes the transaction by sending an acknowledgement ACK to the device. For a successful transaction, the host must see the start of the data packet within a defined period after completing transmission of the IN request (the Turnaround Timer). Similarly, the device must see the start of the acknowledgement packet within a defined period after completing transmission of the data packet.

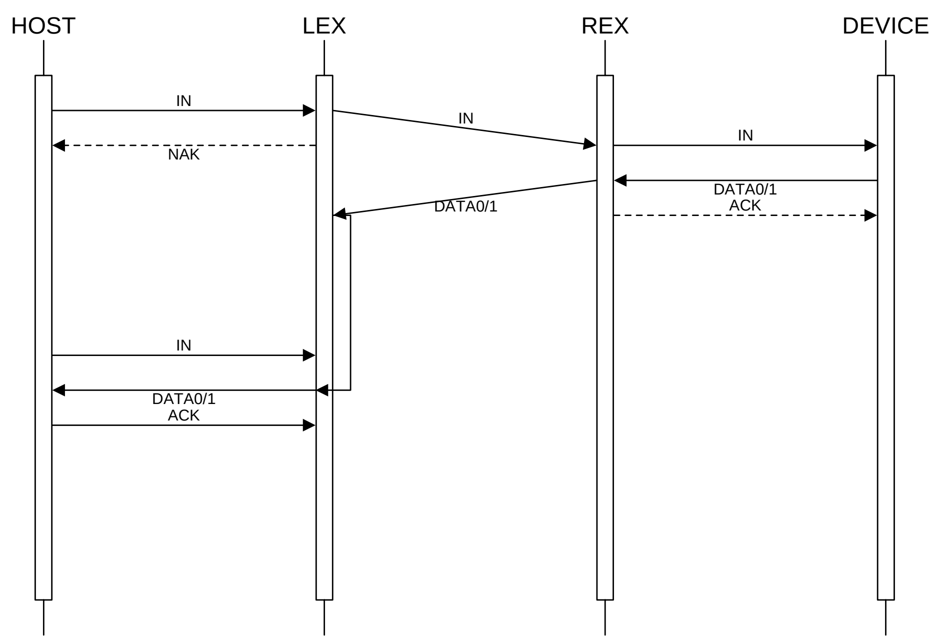

Figure 3 – An ExtremeUSB IN transaction

Figure 3 shows the same scenario with ExtremeUSB. In this case there are two additional subsystems involved. These subsystems are identified here as LEX (or Local ExtremeUSB subsystem) and REX (or Remote ExtremeUSB subsystem).

As before, the host initiates the transaction by issuing an IN request. The LEX subsystem recognises that the data packet cannot be returned within the allotted time and responds to the host with a negative acknowledgement (NAK). Concurrently, the LEX forwards the IN request to the REX unit and subsequently to the device itself.

The device responds to the IN request with a data packet, which is forwarded to the LEX and stored. Concurrently, the REX subsystem generates a local acknowledgement to the device.

At some later time (which is host dependent) the host issues a second IN request. This time, the LEX subsystem recognises that it has the desired data packet stored in memory and supplies it to the host.

In practice, each separate USB transfer type requires slightly different handling and additional algorithms are provided to deal with error situations such as when a complete packet is lost. However, the preceding does illustrate the general approach.

For more information

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