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## Introduction

As the most successful interface in personal computer history, there is intense interest in moving USB into the wireless domain. According to Intel (<http://www.intel.com/labs/wusb/>)

a successful wireless USB technology must meet the following criteria:

- Compatibility with USB 2.0 standard
- Security at the same level as wired USB
- Connections to 127 (maximum) WUSB devices
- Performance providing the typical user with an experience equivalent to a wired user's experience

Icron adds that a successful wireless USB technology should also:

- work over potentially longer distances
- be available in a wide selection of form factors to satisfy diverse product requirements and channels to market



## Wireless USB

### >> *Benefits and Limitations*

Since its introduction in the late 1990s, USB has become an enormous success, creating an industry that has delivered hundreds of millions of devices into the marketplace. There is now strong pressure to build upon that success and make all of these USB devices “wireless”. In the rush towards a totally wireless desktop, there is a danger that the practical limitations of USB become lost in the marketing fervor.

This whitepaper will attempt to put wireless USB developments in the context of traditional USB to clarify the situations in which these technologies apply, and more importantly, when they do not. To that end, the first distinction to be made is whether or not the wireless technology is backwards compatible with the installed base of wired USB devices. We will first consider those technologies that are not backwards compatible.

## USB Adapters

### >> *Devices that masquerade as something else*

USB is so successful as a plug-and-play connectivity tool that it is frequently used to connect computers to devices that implement other communication technologies. Examples abound, and include devices such as USB-to-Serial, USB-to-Ethernet, USB-to-802.11 and USB modems (USB-to-Telco or USB-to-CableTV).

It is important to realise that these adapters do not extend the USB domain into the other technologies. The USB domain ends at the first “adapter” it meets. A USB mouse cannot be connected to a USB computer merely by connecting each unit to a “USB LAN adapter”.

In summary then, a USB adapter is a USB device that implements a specific function, such as RS-232 communications. One side of the adapter connects to the host computer over USB. The other side of the adapter connects to a non-USB device over a communication scheme that is also not USB.

The same rationale applies in the wireless domain. A wireless mouse that communicates over a proprietary RF channel with a USB HID adapter is not a USB mouse. It is the HID adapter that is the USB device – not the mouse. The mouse cannot be plugged into a USB host since it has neither a USB connector nor the capability to understand USB transactions. The underlying RF technology does not provide a mechanism that enables existing USB devices to become wireless. It is not a USB cable replacement solution. (See the table titled “*Cable Replacement Candidates*” for a summary of announced technologies that can be considered.)



### Cable Replacement Candidates

The table lists some of the technologies being promoted for connecting peripherals over wireless. Unfortunately, the known candidates are either not compatible with existing USB devices or are not available.

Technology	Data Bandwidth	Range	Frequency	USB Device Compatibility	Availability	Typical Peripherals
"27 MHz"	<100Kb/s	5m	27MHz	No BlueTooth or other	Now	HID
Cypress Wireless USB	32 - 64Kb/s	10m	2.4GHz	No	Now	HID
UWB Wireless USB	110 -480 Mb/s	2 - 10m	3-10GHz	Not Defined	N/A	Streaming multimedia

### Cable Replacement

>> *Requirements for backwards compatibility*

For backwards compatibility, a USB cable-replacement solution must support the following functional requirements:

- It must support all three USB speeds – LS, FS and HS
- It must support all four USB transfer types – Control, Bulk, Interrupt and Isochronous

In addition, the limitations of an RF environment raise the following concerns:

- 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. The requirements imposed by RF limitations

require further explanation, as discussed in the next section.

### USB in Time and Space

>> *Solutions for RF limitations*

If there is a single attribute of USB that limits the extension of its capabilities beyond the wired desktop, it 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. It 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

Another major difference between wired and wireless communications is the much higher error rate at the physical layer that must be expected. Compensating for this requires the use of error correction and scrambling functions that exacerbate the Turnaround Timer issue mentioned earlier. In the limiting case, when the error rate becomes very high, re-transmission of an entire packet may be required.

Standard USB was not designed with these issues in mind and does not accommodate them well, if at all. Fortunately, there is an existing solution for all of these issues that is ready to be applied to the wireless domain. Developed to permit USB to be used in large-scale commercial and industrial environments, Icron's ExtremeUSB<sup>®</sup> enables standard USB hosts, hubs and devices to be used in high delay situations.

### **ExtremeUSB Wireless**

*>> An industrial strength solution*

ExtremeUSB was developed to enable USB devices to be used in industrial and commercial environments where operational requirements often exceed those of the

desktop for which USB was designed. In particular, ExtremeUSB overcomes the limitations imposed by the Turnaround Timer. Removing this limitation enables conventional RF techniques such as error correction to be employed. (For a more detailed description of ExtremeUSB, see Appendix 3: "How ExtremeUSB overcomes delay".)

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 with a variant optimised for RF communications also designed.

Referring back to the requirements derived in the section on cable replacement, ExtremeUSB has been implemented to support 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.

### **Deployment Options**

*>> Flexible solutions for every need*

ExtremeUSB has been developed as a flexible set of modules that can be mixed and matched for each particular scenario.



Although ExtremeUSB operates at the protocol layer, it has been recognised that convergence functions between the protocol and physical layers is required. Since some USB companies may not have the expertise to develop the necessary technology, Icron ([www.icron.com](http://www.icron.com)) has developed a suite of RF convergence modules that support the ExtremeUSB layer.

ExtremeUSB and its convergence layer are implemented as a set of VHDL modules. These modules can be brought to market in a variety of form factors to suit the target application.

In its most fundamental form, ExtremeUSB will be available in VHDL for implementation in an FPGA. Icron is working with partners to facilitate the availability of specific feature sets in ASIC form. Icron is also developing relationships with RF transceiver vendors to bring a complete turnkey solution to market.

## Conclusions

The document illustrates the following points:

- There is intense interest in moving USB into the wireless domain.
- USB adapters do not provide a backwards-compatible solution.
- A cable replacement solution is backwards compatible.
- Cable replacement requires that a solution for the tight timing constraints of USB be found.

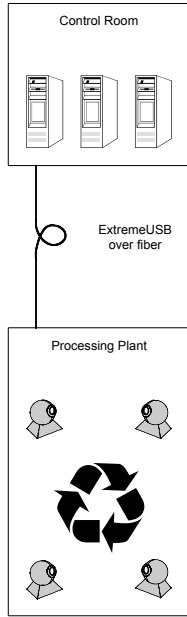
- ExtremeUSB Wireless provides a field-hardened solution to the timing problem.
- ExtremeUSB will be available in a wide selection of form factors to satisfy diverse product requirements and channels to market.

## Appendix 1: Real World Applications

ExtremeUSB is currently being used to extend USB to more than 25,000 peripheral devices over copper and fibre-optic media. ExtremeUSB technology has been deployed by such companies as Lockheed Martin and Silicon Graphics across applications ranging from submarines to super-computers.

The following diagram shows a current application of ExtremeUSB. In this installation, a group of USB cameras is set up to observe the workings of a mineral processing plant. Through ExtremeUSB, the plant managers are able to monitor its operation from a control room situated two kilometres away from the actual site.





## Appendix 2: How ExtremeUSB Overcomes Delay

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

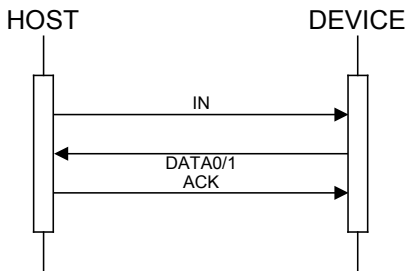


Figure 1 – A conventional IN transaction

Figure 1 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.

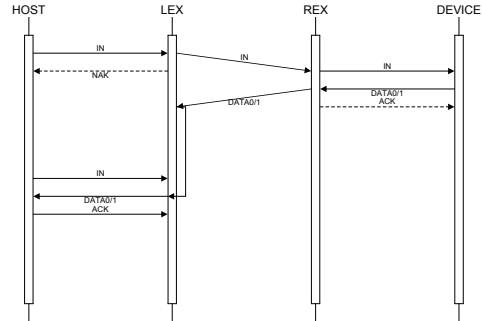


Figure 2 – An ExtremeUSB IN transaction

Figure 2 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).

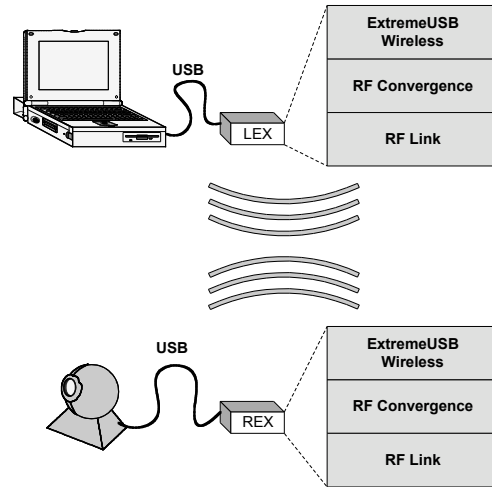
As before, the host initiates the transaction by issuing an IN request. The LEX subsystem recognises that the data packet cannot be returned within the allotted time and responds to the host with a negative acknowledgement (NAK). Concurrently, the LEX forwards the IN request to the REX unit and subsequently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



### Appendix 3: ExtremeUSB System Architecture

The following diagram shows the architecture of an ExtremeUSB Wireless system. NOTE: Other options would follow the same concept with the ExtremeUSB Wireless technology embedded in either the device and the Host, or both. The LEX and REX dongles take the place of a conventional USB cable. The host (laptop) and device (camera) represent any standard USB-enabled component.

The structure of the LEX and REX dongles is very similar. Each is composed of three 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 hardware and its 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.

USB Speed	Bandwidth	RF Band
LS	1.5 Mbps	900 MHz
FS	12 Mbps	2.4 GHz
HS	12-480 Mbps	3 – 10 GHz



Icron is actively seeking partners with RF Link technology who wish to add USB to their suite of supported applications. A typical – but not exclusive – tier of products is shown in the preceding table.

For more information on Icron's ExtremeUSB for Wireless solution, please contact:

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