



Developers Conference 2007

Amsterdam, The Netherlands



Certified Wireless USB Architecture Overview

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Intel Corporation



Agenda

- Devcon goals
- Radio environment (common platform)
- High level architecture
- Compliance environment
- Industry Enabling

Devcon Goals



- Jumpstart Wireless USB product development
 - Get people thinking about Wireless USB product possibilities
 - Help people understand the architecture and features of Wireless USB
 - Improve product designs and timeline for development

Devcon Schedule



- Single track for first day
 - Basic topics that all attendees should hear
- Split track on second day in the morning
 - More focused topics that may not be of interest to everyone
 - Additional sessions focused on building and producing devices
- Introduction to USB 3.0



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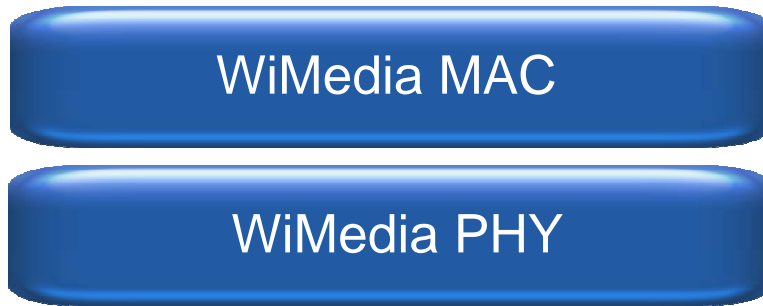
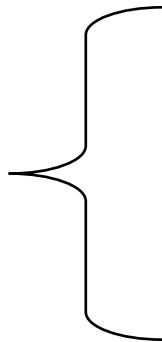
UWB Protocol Relationships



Protocol Abstraction Layer (PAL) - Various technology solutions running over the common platform

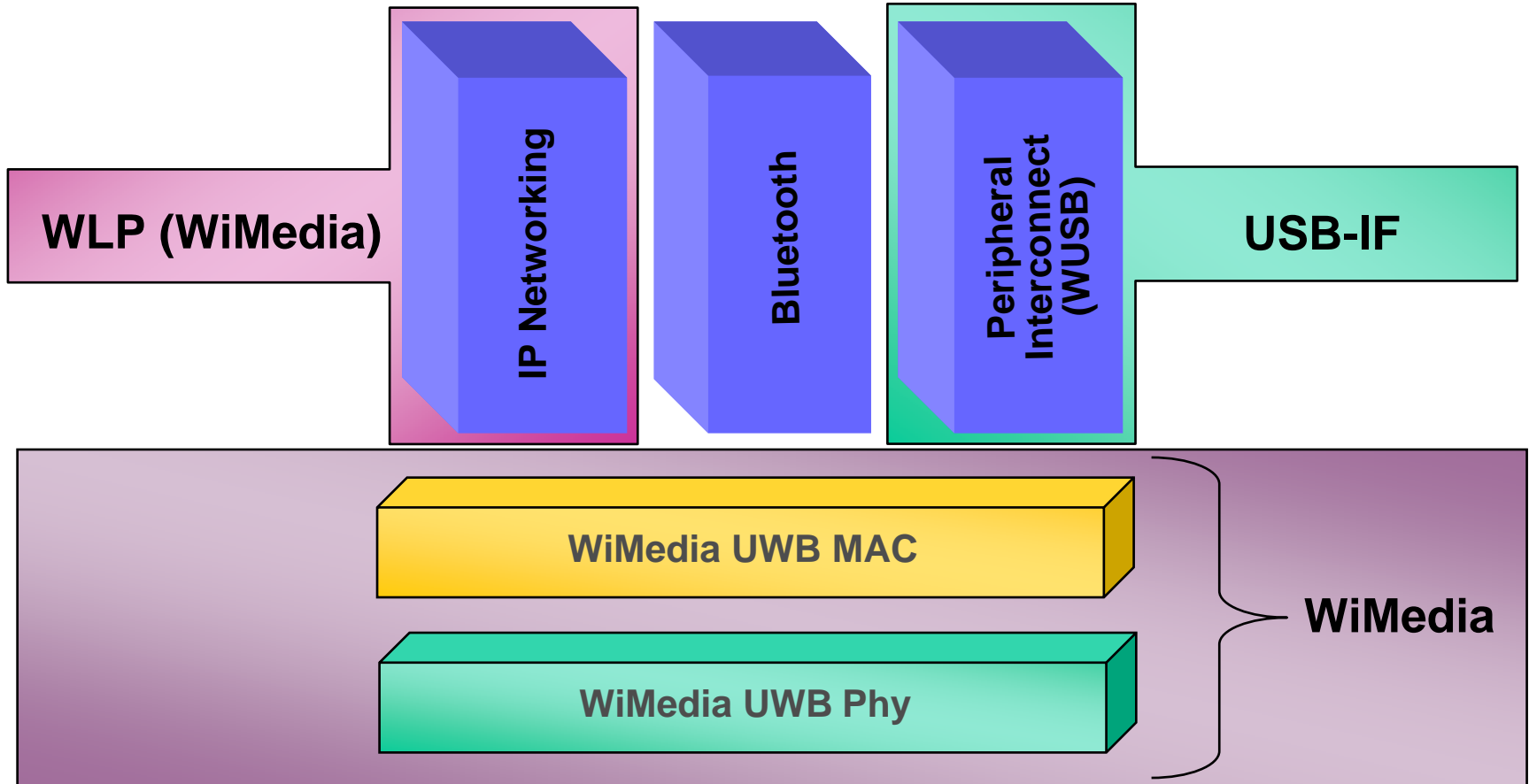


Common Ultra Wideband Radio Platform



Single Radio In Platform

Industry Group Structure





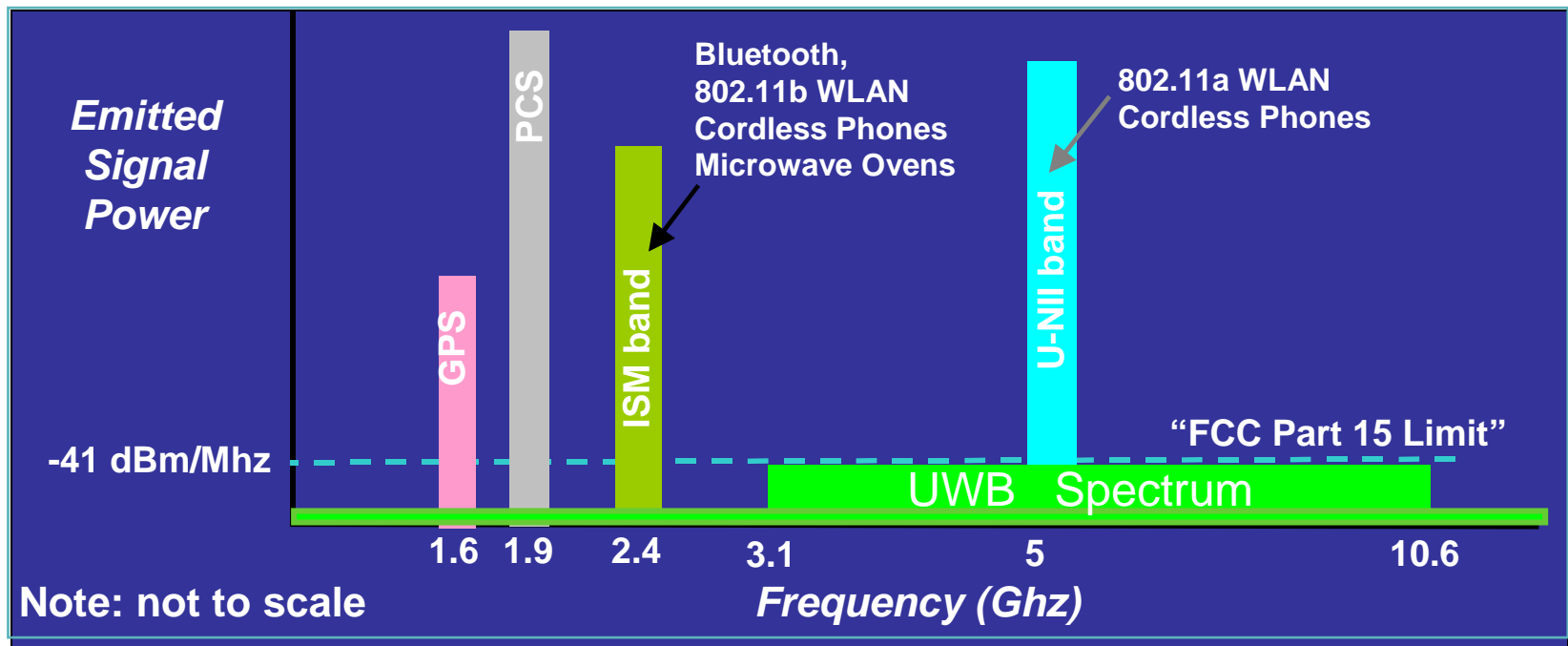
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 - WiMedia and MAC
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UWB Overview



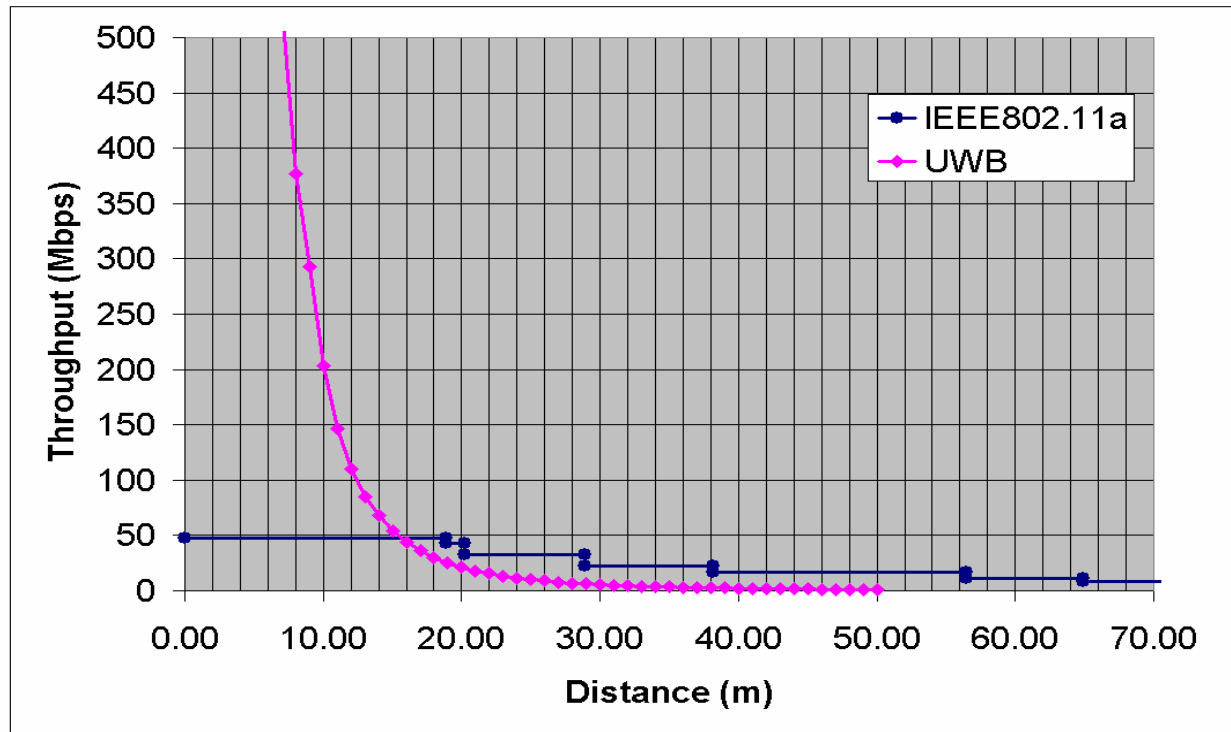
- UWB is presently legal in US, Japan, Korea, and Europe
 - Regulatory activity underway in China and Canada



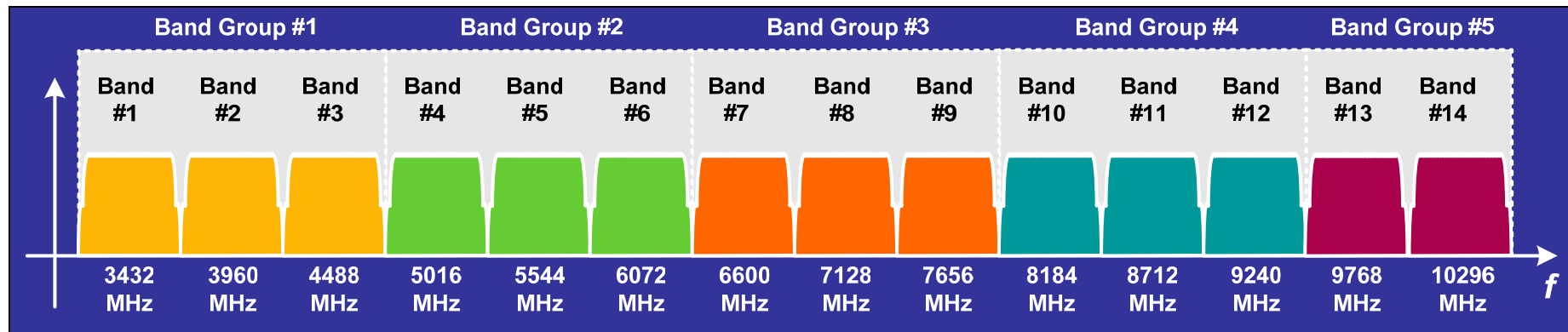
UWB Overview (con't)



- High speed at short range
 - 480 Mb/s at ~3m
- Scalable performance (Moore's Law radio)



Multi-band OFDM Bands



- Fourteen bands, grouped in five Band Groups
 - Each band is 528 MHz
- Each band is capable of 480 Mb/s
- First Wireless USB products use Band Group 1

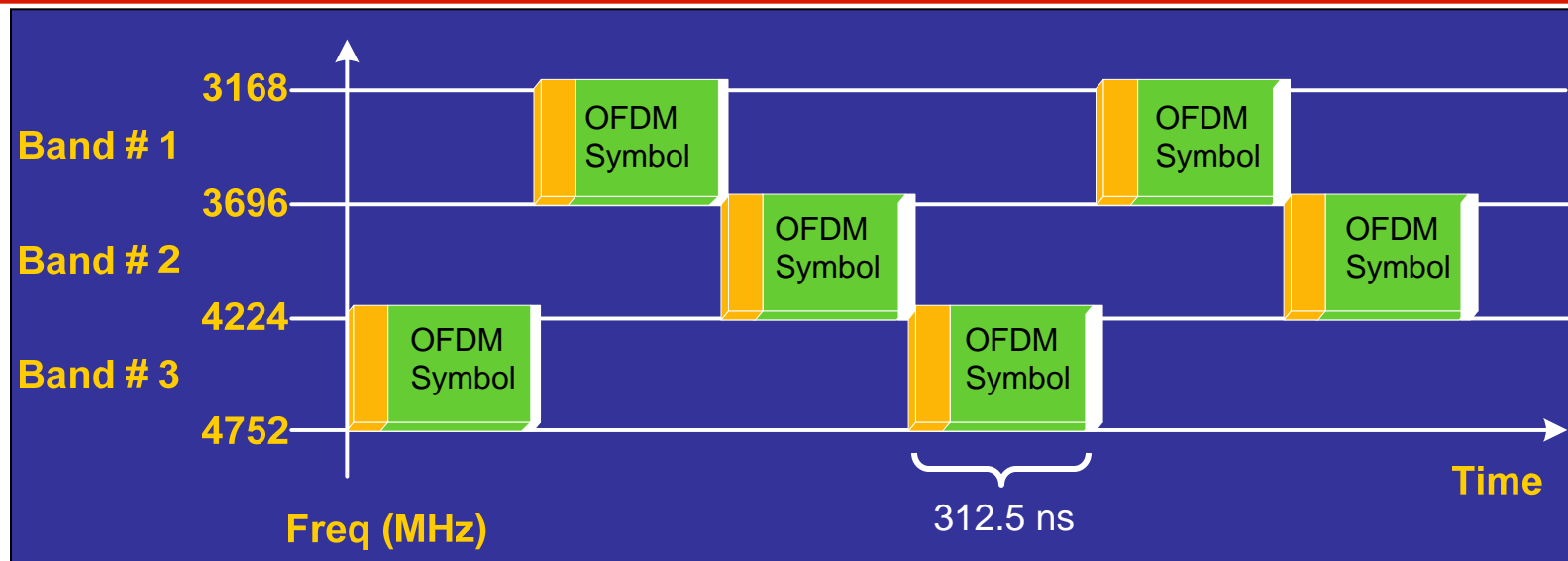
Regulatory Update



| | Band Group #1 | | | Band Group #2 | | | Band Group #3 | | Band Group #4 | | | Band Group #5 | | |
|---------------|---------------|--------------|--------------|---------------|--------------|--------------|---------------|--------------|---------------|--------------|--------------|---------------|--------------|----------------|
| Band | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 | #11 | #12 | #13 | #14 |
| United States | | | | | | | | | | | | | | |
| Europe | | | | | | | | | | | | | | |
| Japan | | | | | | | | | | | | | | |
| Korea | | | | | | | | | | | | | | |
| | 3168 3432 | 3696 3960 | 4224 4488 | 4752 5016 | 5280 5544 | 5808 6072 | 6336 6600 | 6864 7128 | 7392 7656 | 7920 8184 | 8448 8712 | 8976 9240 | 9504 9768 | 10032 10296 |

- Wireless USB 1.1 Spec update will address:
 - Upper band usage

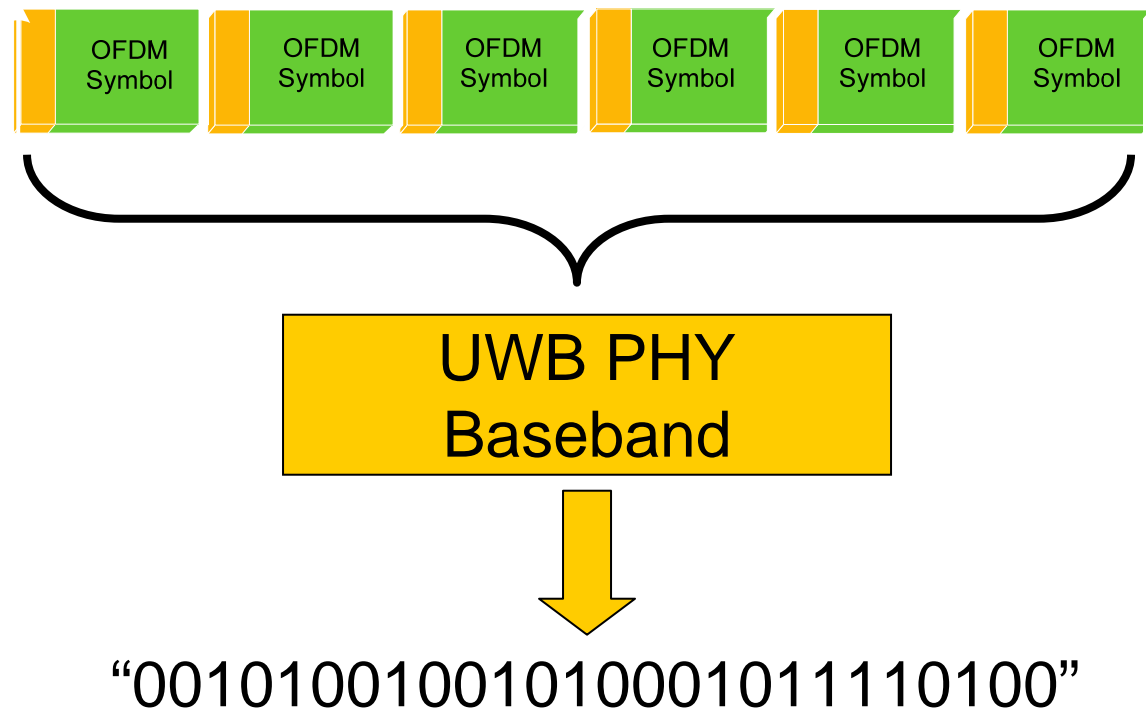
Multi-band OFDM Symbols



- OFDM symbol is basic quanta of UWB radio
- Symbol is 312.5ns long
- Each symbol has 100 data 'tones', each 4 MHz wide
- All data rates use same symbol
 - Different tone encodings within and between symbols provide different bit rates and different levels of robustness

Six Symbol Unit

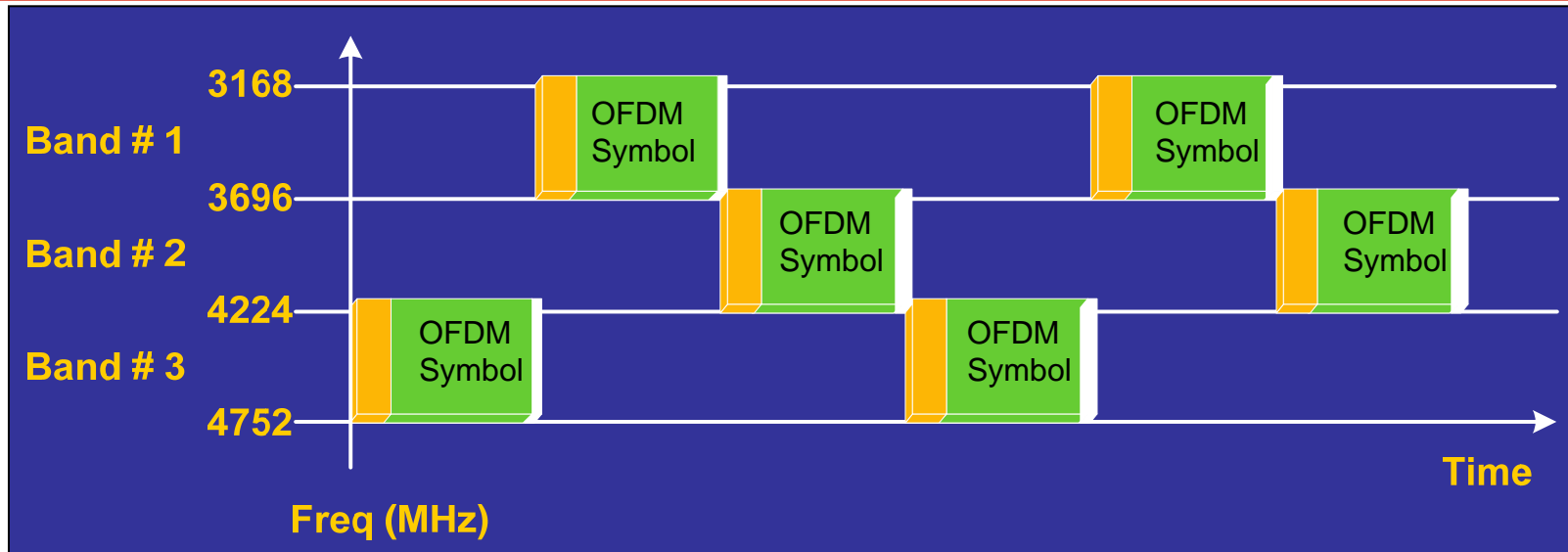
- Six consecutive symbols make base data unit
 - All packets are some integral number of six symbols in length (1.875us)
- PHY baseband converts to bits
 - Different tone codings and interleaving produce different bit rates



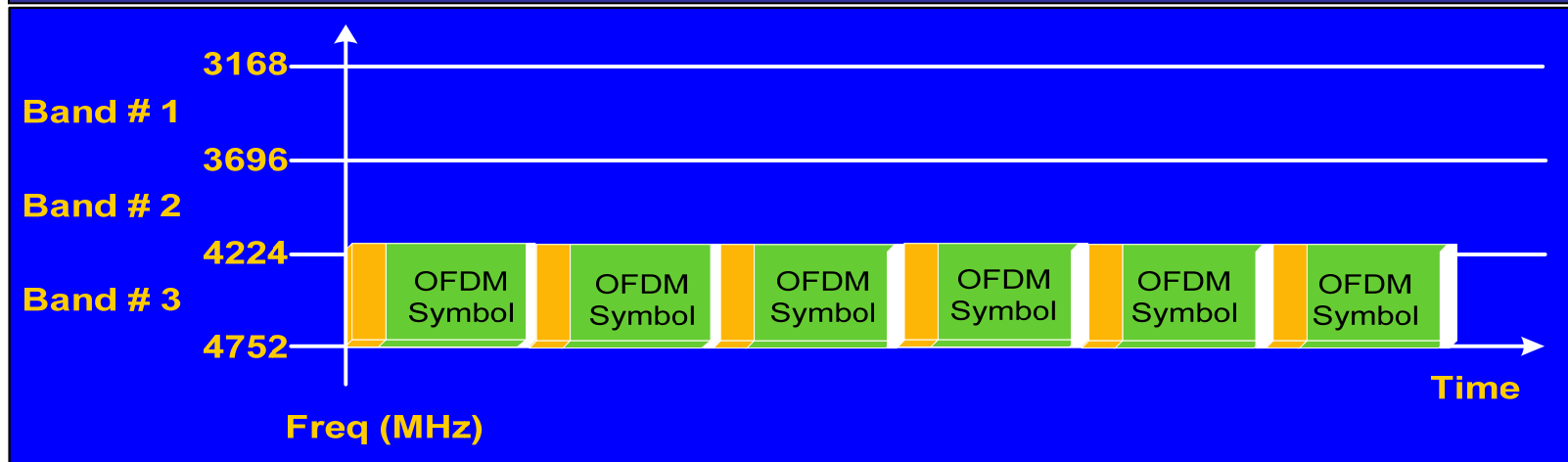


Time Frequency Codes (TFCs)

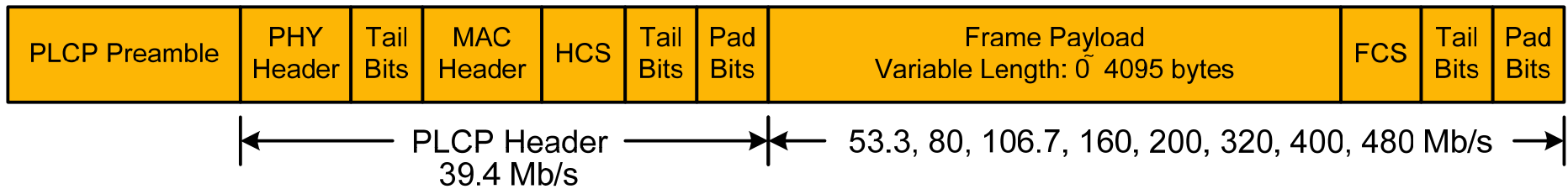
Time Frequency Interleaving (TFI)



Fixed Frequency Interleaving (FFI)



UWB Packets



- Standard preamble is 9.375 microseconds
 - 30 OFDM symbols
- Burst preamble is 5.625 microseconds
 - Only available for speeds above 200 Mb/s
 - 18 OFDM symbols
- PLCP header is 3.75 microseconds
 - 12 OFDM Symbols

Inter Packet Spacing



- Short Interframe Spacing (SIFS)
 - 10 microseconds
 - Used anytime there is Transmitter change
- Minimum Interframe Spacing (MIFS)
 - 1.875 microseconds
 - Only used when same transmitter



WiMedia PHY

- Required speeds
 - 53.3, 106.7, 200 Mbps
 - Other speeds (80, 160, 320, 400, and 480) are optional
- Band group 1 required
 - Three low bands
- TFI and FFI
 - PHY required to support both
 - How each will be used still to be decided



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 - [WiMedia and MAC](#)
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WiMedia MAC



- 64K microsecond superframes
- Supports TDMA capabilities
 - Wireless USB uses this feature
- All Wireless USB products need to be good WiMedia citizens
 - Primarily a responsibility of Wireless USB hosts



- Focused on making sure multiple devices can coexist
- Fairness policies
 - How much bandwidth can devices use
 - When/how bandwidth given up
- Policies are implemented by Wireless USB hosts
 - Devices generally don't have to worry about them



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Technology Features

- **Bandwidth**
 - 480Mbps @ ~3 meters
 - Scalable architecture & protocol (up to 1Gbps and beyond)
- **Power management (battery preservation)**
 - Sleep/Listen/Wake, conserve under operation
 - Tx/Rx power management
- **Security (secure connection)**
 - Device secure association & authentication
 - Low overhead, minimize performance impact
 - Encryption through application
- **Ease of Use (similar to wired USB)**
 - Easy installation & setup
 - Backward compatible to wired USB
 - Low cost implementation

Certified Wireless USB Topology



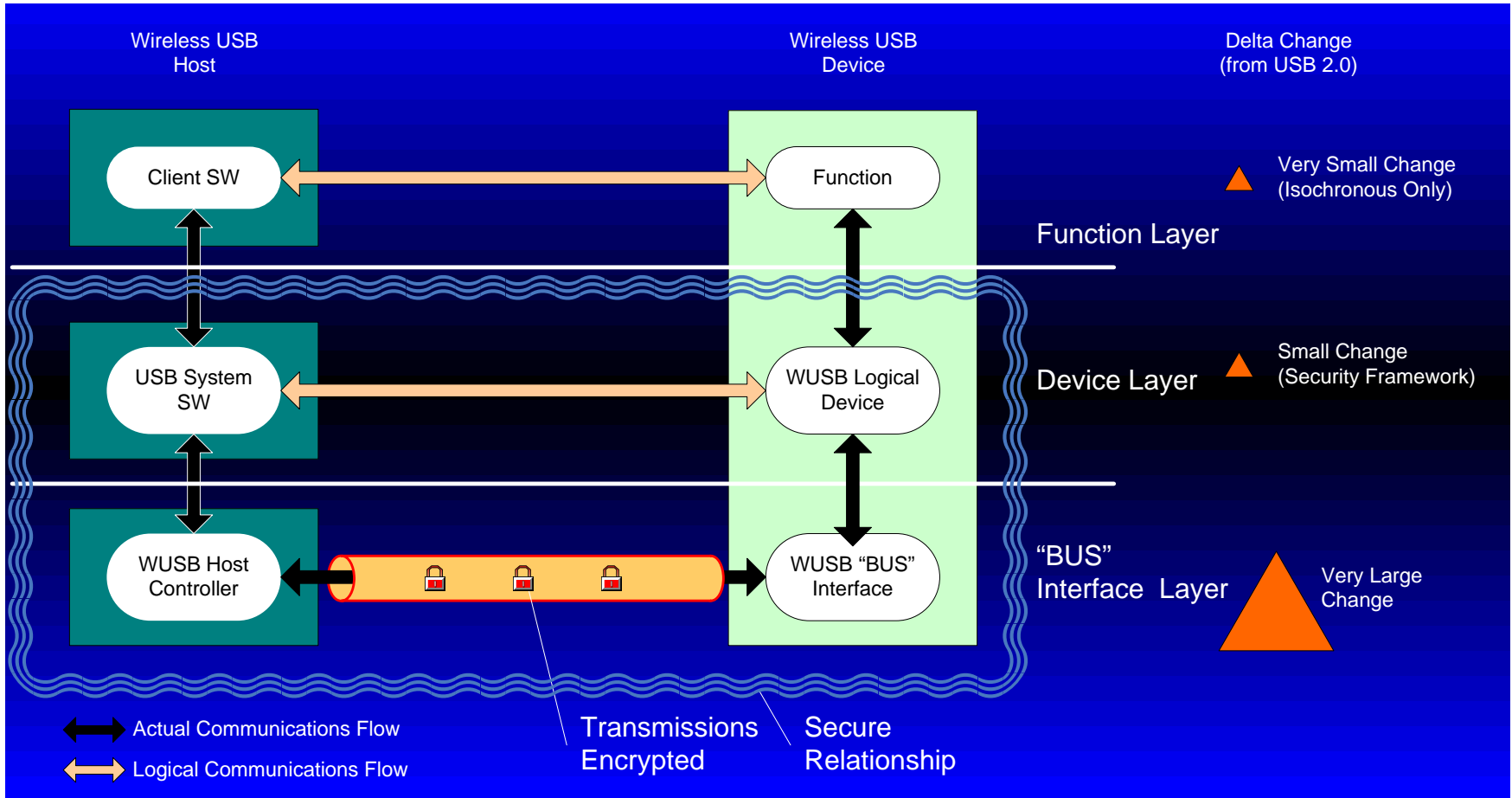
- Hub-and-spoke connection relationship
- Connection model is a wire replacement
 - Point-to-point connections
 - Between WUSB host & peripheral
- Wireless USB Cluster
 - Wireless USB Host with one or more peripherals (up to 127)
- Wireless USB Clusters may co-exist within an overlapping spatial environment



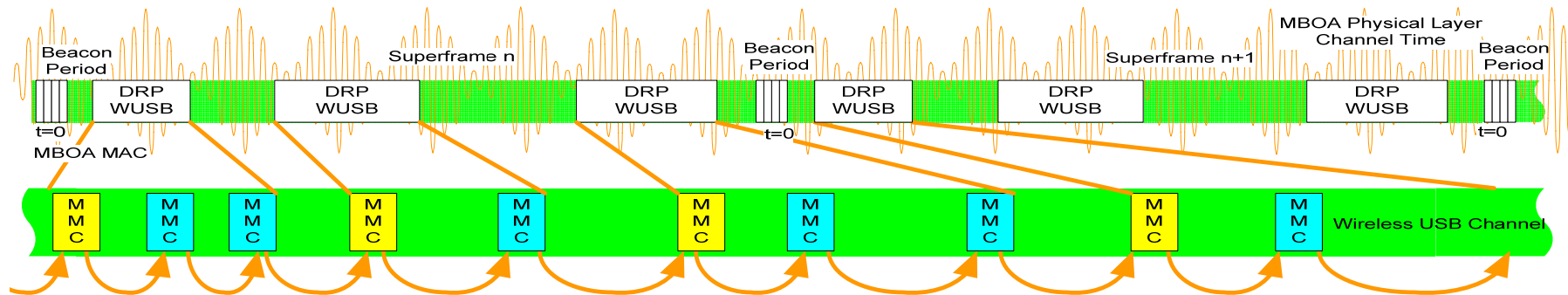
Dual Role Device connectivity



Communication Topology

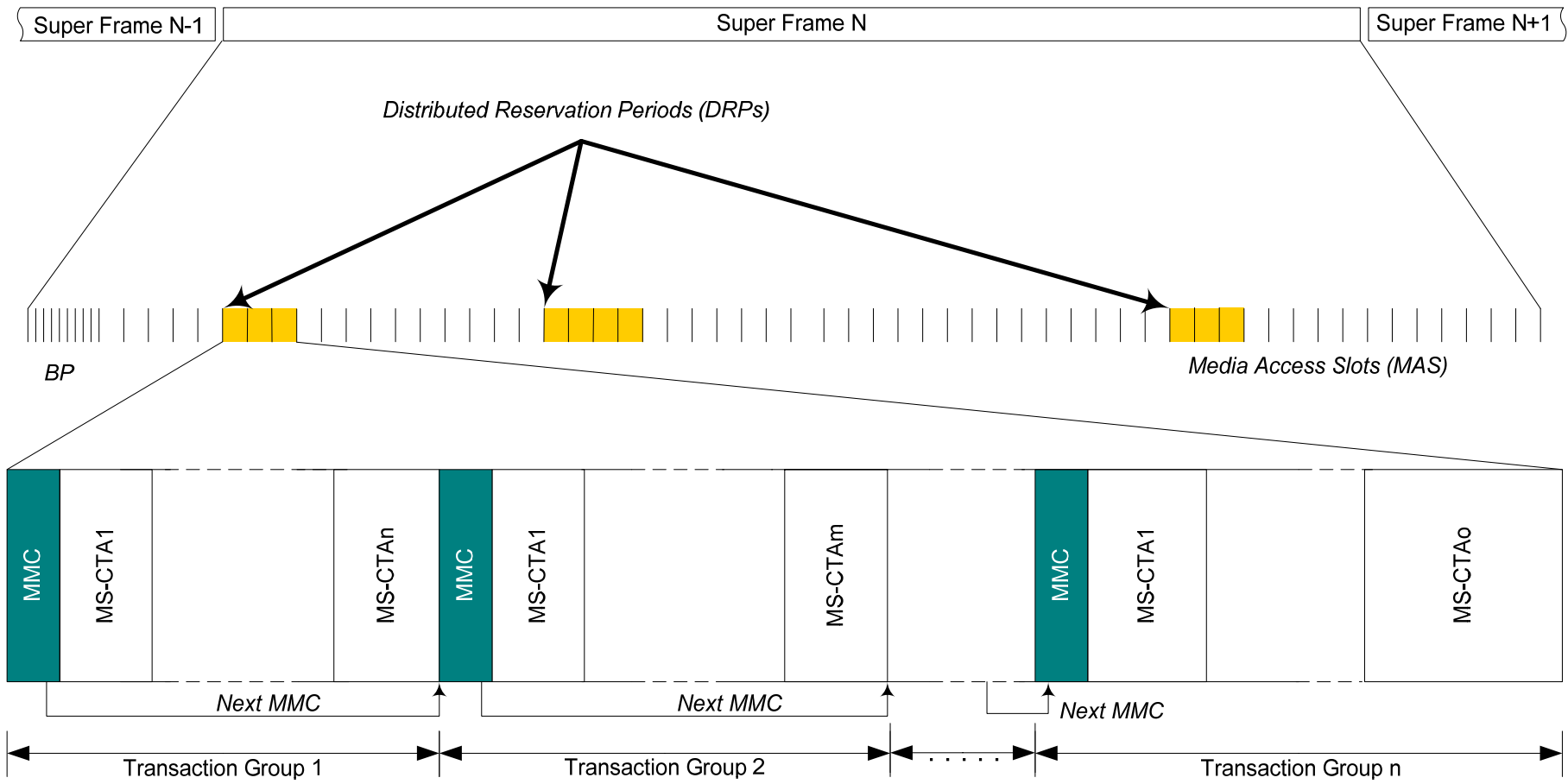
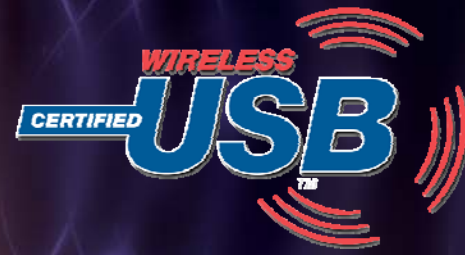


Wireless USB Channel

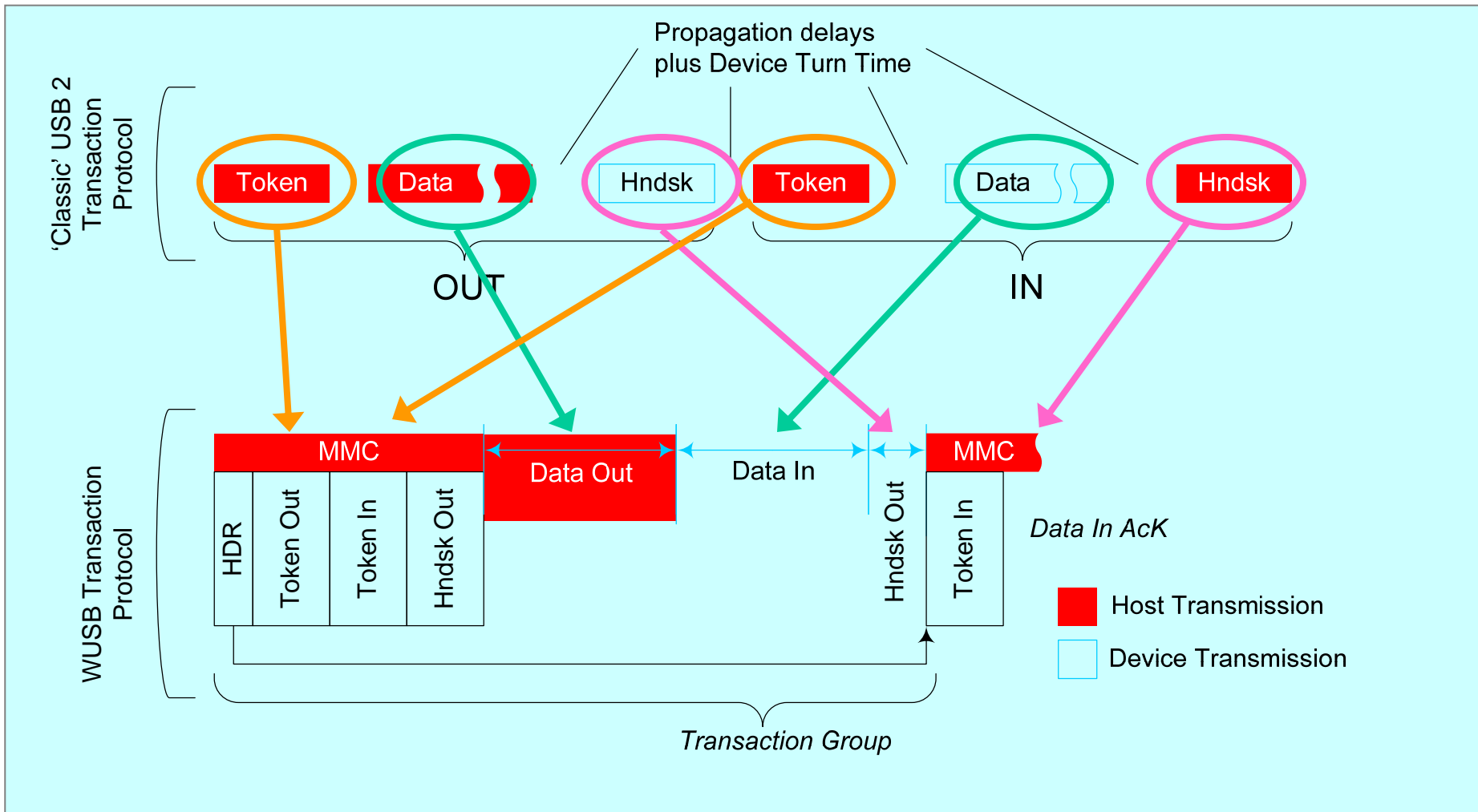


- The Wireless USB Channel is encapsulated by the WiMedia channel
- Uses WiMedia PHY/MAC compliant components
 - WiMedia PHY signaling and frames
 - MAC Headers, Security Encapsulation, etc.
- Wireless USB channel is a continuous sequence of linked control packets transmitted by the Host during reserved time
 - WUSB time is reserved from WiMedia channel time (DRPs)
 - Called MMCs – Micro-schedule Management Commands
- All Wireless USB Data communications are over Wireless USB Channel

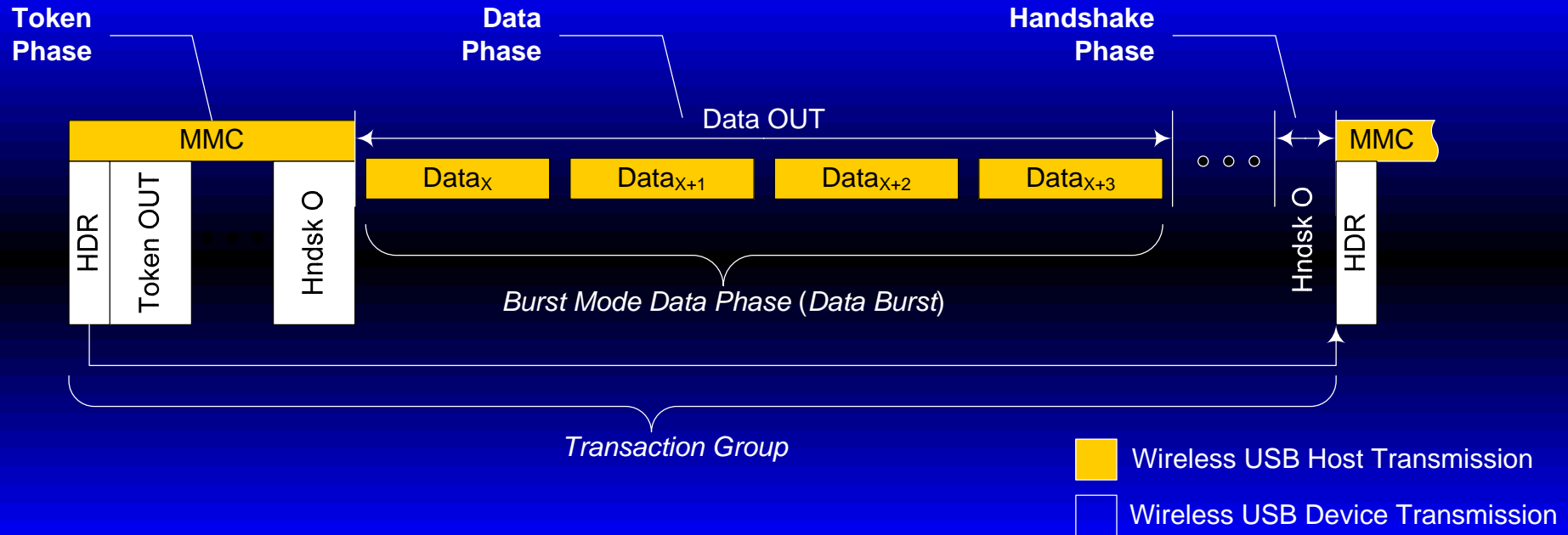
TDMA-based Protocol



Transaction Group

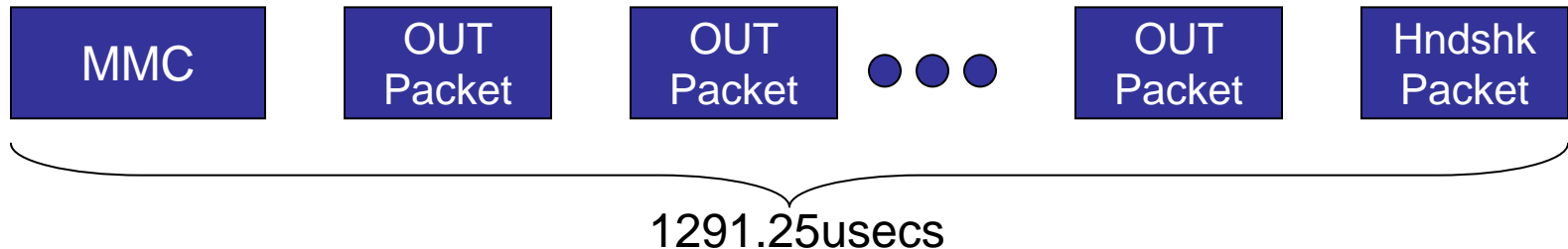


Data Burst



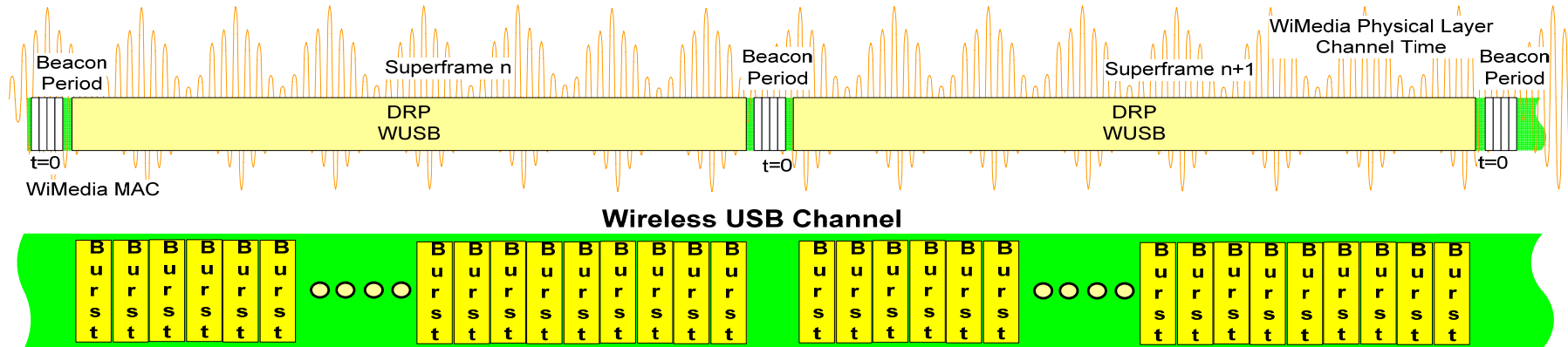
- Allows multiple data packets per data phase
 - Up to 16 packets in a burst
- Extends Efficiency of Transaction

Burst OUT



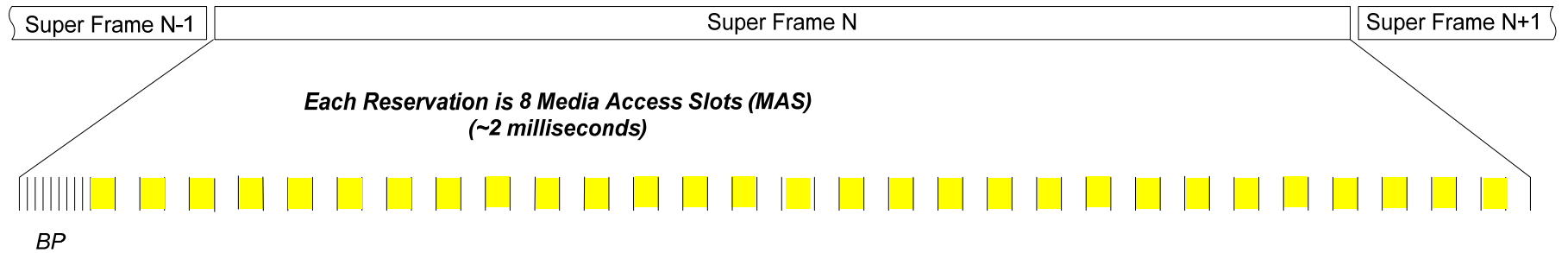
- Total transaction group duration
 - MMC duration (22.500usecs)
 - MIFS to first OUT packet (1.875usecs)
 - OUT packets with MIFS in between
 - OUT packet 3584 bytes (75.000 usecs)
 - SIFS (10usecs) after last OUT
 - Handshake IN packet (18.750usecs)
 - SIFS at end (before next MMC can start)

Max Performance in Superframe



- Beacon Period in Superframe is 2 MAS's (512 usecs)
- If WUSB Channel is operating the rest of the superframe
 - 352Mb/s or 44MB/sec (compared to 355Mb/s without BP)
 - Accomplished with 50 bursts of 16 and one burst of 6

Performance in Shared Superframe



- Equally shared with another Wireless USB host
- Reservation policy provides alternating 2ms time chunks
- During 2ms allocation WUSB host does 1 burst of 16, 1 burst of 9: total of 25 packets
- 15 2ms chunks in whole superframe yields 375 packets or 1344000 bytes
- Resulting throughput: 164 Mb/s or 20 MB/s

Performance



- ~75% efficient (44MB/s) in dedicated environment
- 66% efficient (20MB/s out of 30MB/s) in shared environment

**Wireless USB
Delivers Excellent Performance**

Isochronous



- Wireless medium requires retries and buffering
- Host will allocate retry time to meet fixed PER (10^{-3})
- Vendors choose amount of buffering
 - More buffering gives more reliable stream
- USB timebase (1ms) is preserved
- Day 2 presentation (Periodic Transfer Models) provides more details

Power Management



- Effective Power Management was important design goal
 - Portable (i.e. battery powered) devices are very popular
 - No longer have a cable to deliver power
- Explicit host-controller transaction scheduling provides opportunities for power management
 - Host and device have explicit times when they are able to transmit and receive
 - Radios can be 'power managed' at all other times

Interference Mitigation



- Wireless is not as reliable as a Wire
- Host has several controls to manage reliability
 - Transmit Power Control (TPC)
 - Bit Rate
 - Adjustable Packet Payload
 - Change PHY Channel
 - Dynamic Bandwidth Endpoints (Isochronous)



Transmit Power Control

- A host can make TPC level adjustments for device transmissions on the WUSB channel
 - These adjustments don't effect other applications that may be implemented on the device
- Wireless USB Host TPC level controls provided for:
 - Device level management
 - Transaction level management
- Wireless USB Host will use lowest TPC level required to sustain acceptable PER for data stream
 - Best Neighbor behavior; allows better spatial re-use

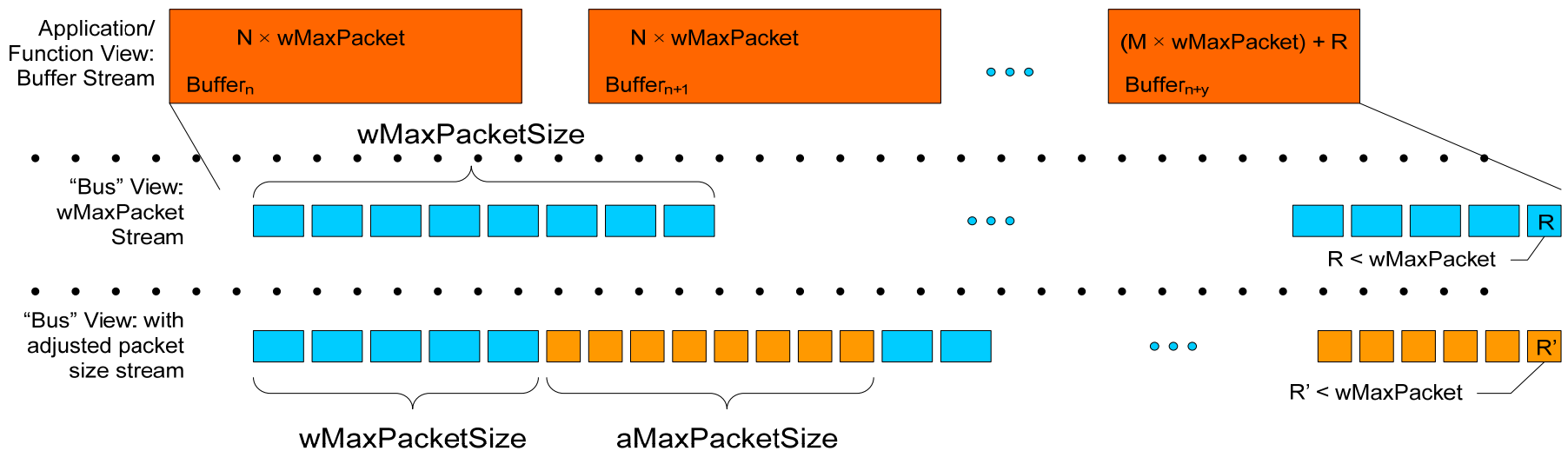


Transmit Bit Rate

- Host provides the TBR for all device transmitted packets in a data or handshake protocol time slot
 - Host must ONLY use values supported by device
 - Device capabilities reported in Wireless USB Device Capabilities on UWB descriptor (wPHYRates)
 - Device must use TBR indicated by host for all packet transmission during the time slot
 - Host may change TBR on every WDTCTA
- Host also varies bit rate on packets it transmits
 - Host must ONLY use values supported by device

Adjustable Max Packet Size

- Changes to data payload size can occur
 - On transaction boundaries
 - On contiguous-burst boundaries
- Host cannot adjust burst size if there are out-of-order data packets
 - Data packets that must be retried
- Note: this control motivated change in bus-level handling of short packets

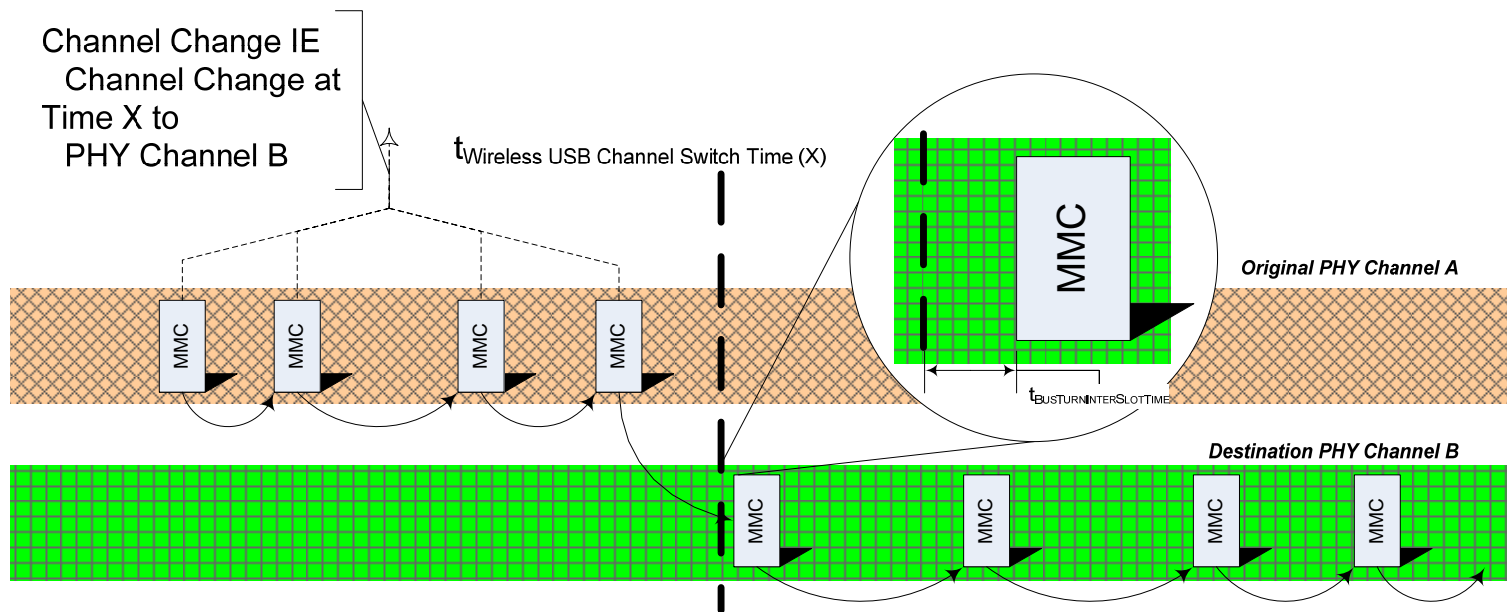


Change the PHY Channel

Example Mechanism



- Host keeps WUSB Channel active
- Host simply notifies cluster members when channel change will occur
 - Including destination channel
- Devices simply listen for 'next' MMC on new channel after the channel change time





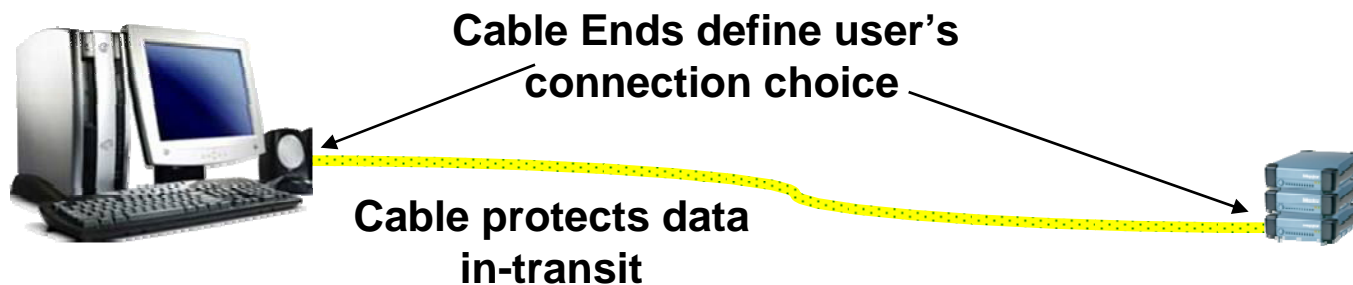
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Just as Easy and Secure* as the Wire



- Security's job:
 - Protect data in-transit
 - Encryption is used (AES-128 CCM)
- Association's job:
 - Connect the owner's devices the way the owner wants them connected



* Absolute security is not guaranteed

Sample Device Connect



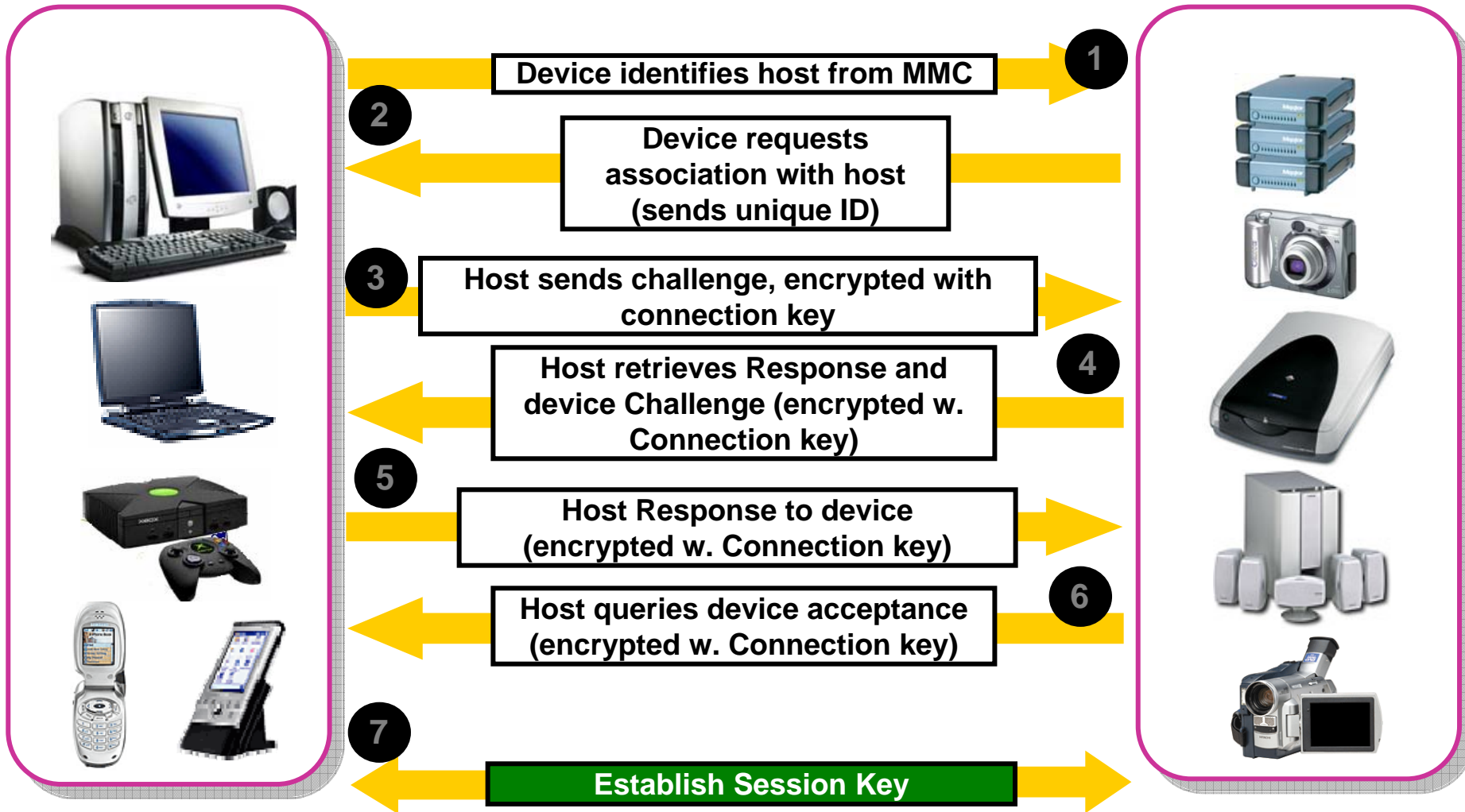
IDENTIFY

AUTHENTICATE

AUTHORIZE

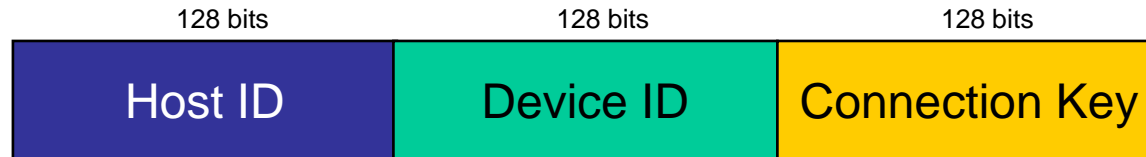


Sample Device Connect





The Connection Context



- Contains everything needed to set up secure* communication
- Unique for each host-device pairing

Association establishes CC on host and device

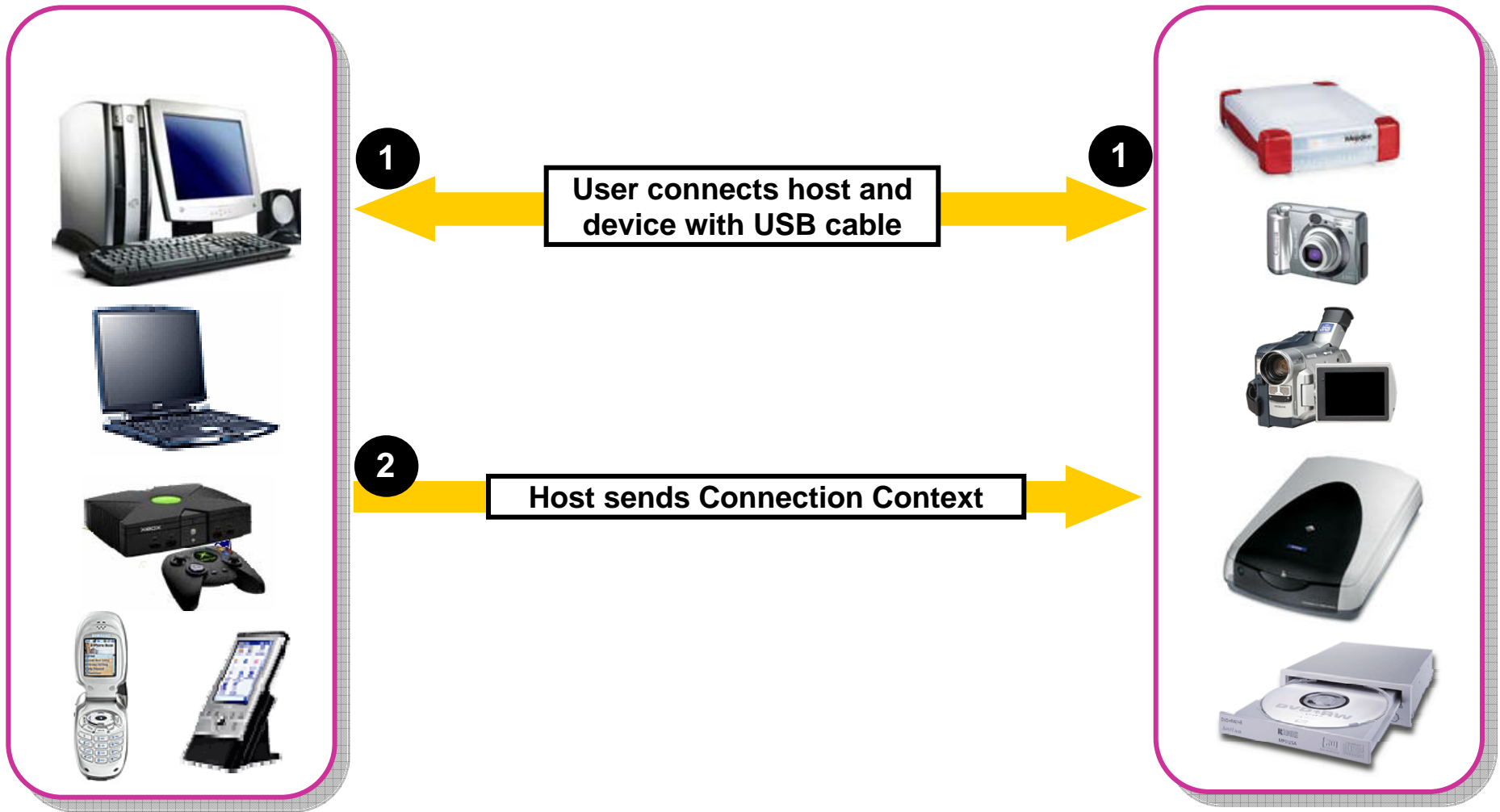
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Establishing the Connection Context

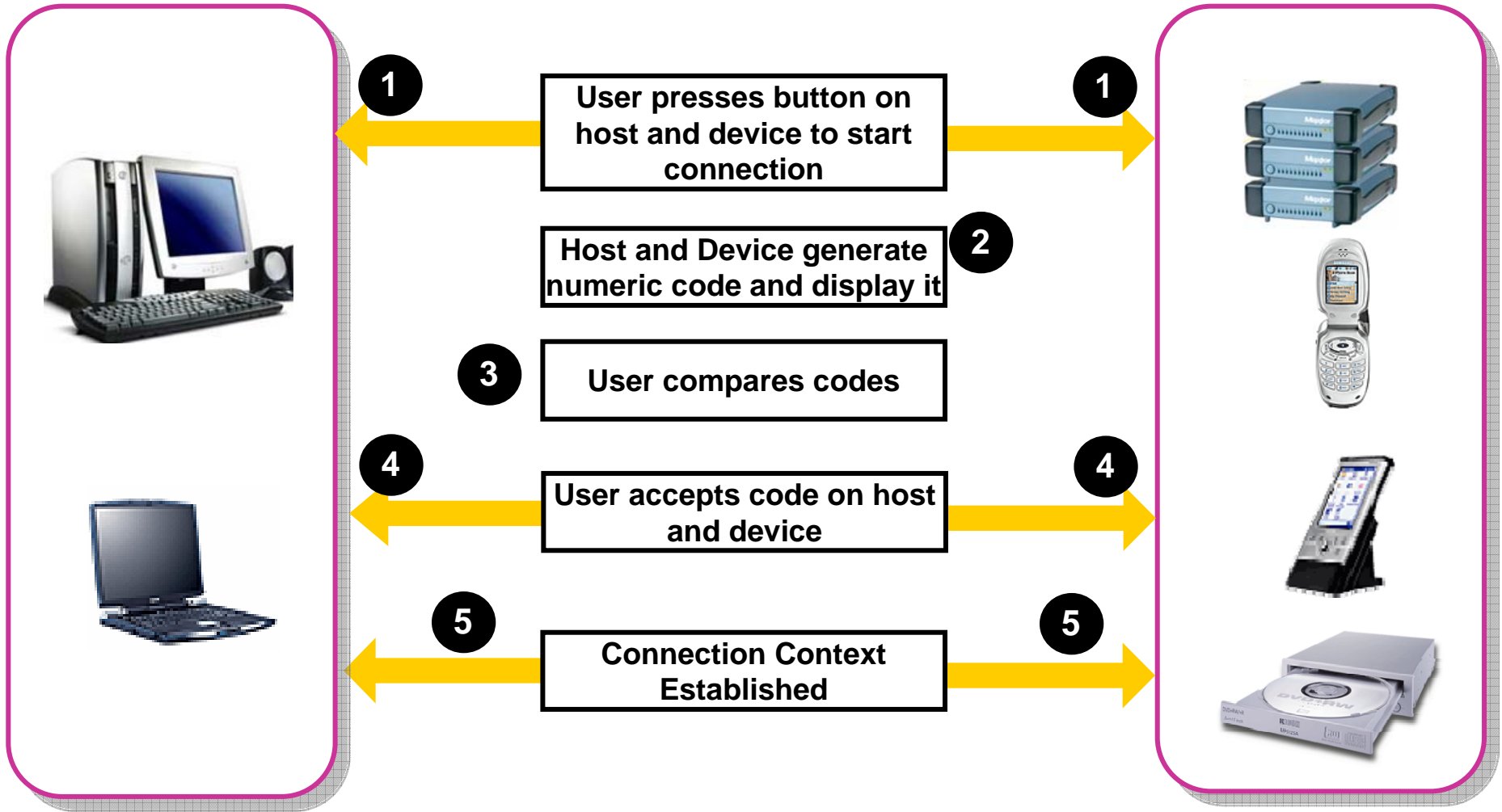


- Must be a secure mechanism
- Two mechanisms are defined
 - Use a USB cable
 - Use WiMedia UWB radios with PK technology and user authorization

Cable Model



PK Technology



Association Model Spec



- Spec is released at Rev 1.0
 - Available on www.usb.org/wusb
- Contains all the details on host and device requirements for association

**Associating Wireless USB
Devices is Easy and Secure***

Association Model Spec is Available

* Absolute security is not guaranteed



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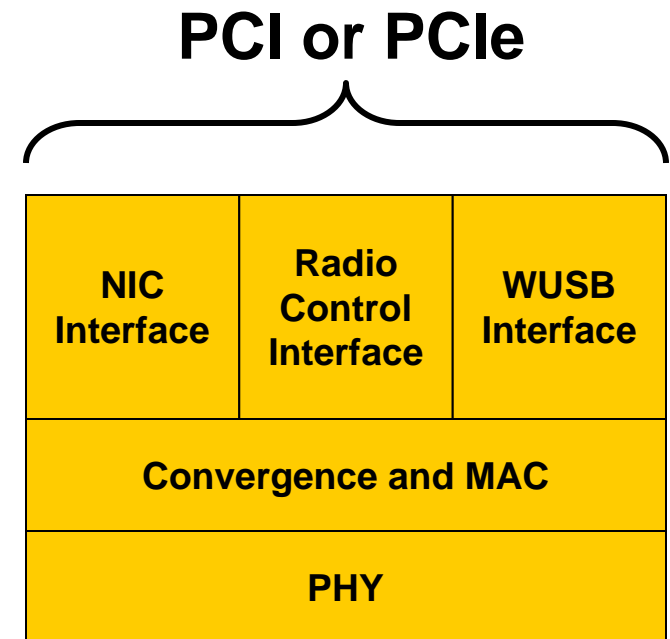
Host Radio Solutions

- PCI (or PCIe) based solution
 - Can go in addin card slot
 - Cardbus or ExpressCard solutions
- Wired USB dongle
 - Cabled 'base station' variety
 - Small 'key' solutions

PCI Host Architecture



- Supports both Wireless USB and IP
- Has a common radio control interface
- Enumerates as single PCI function
 - Bus driver will load appropriate other drivers



Wireless Host Controller Interface (WHCI)

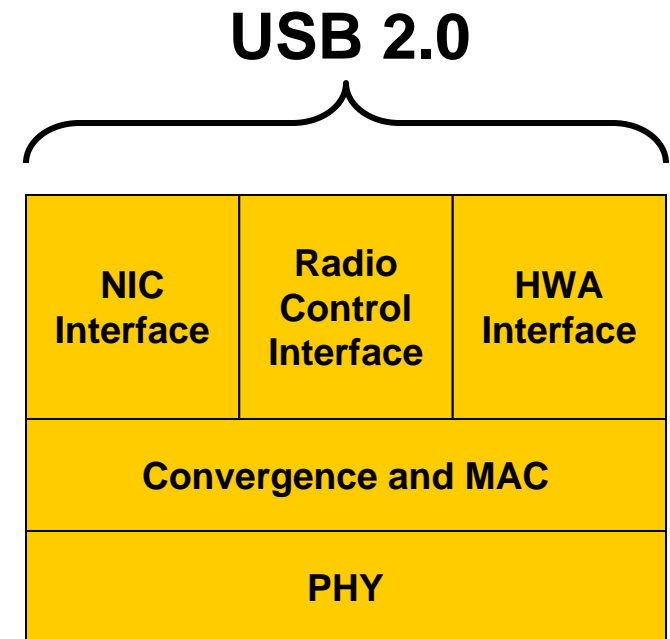


- Definition complete at Rev 0.95
 - Similar to EHCI
 - Special interface for radio control

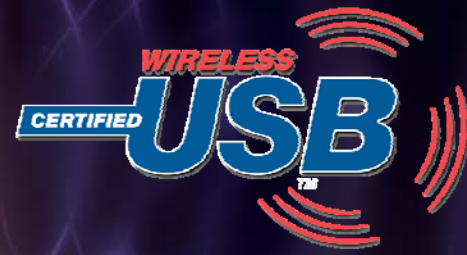
USB Host Architecture



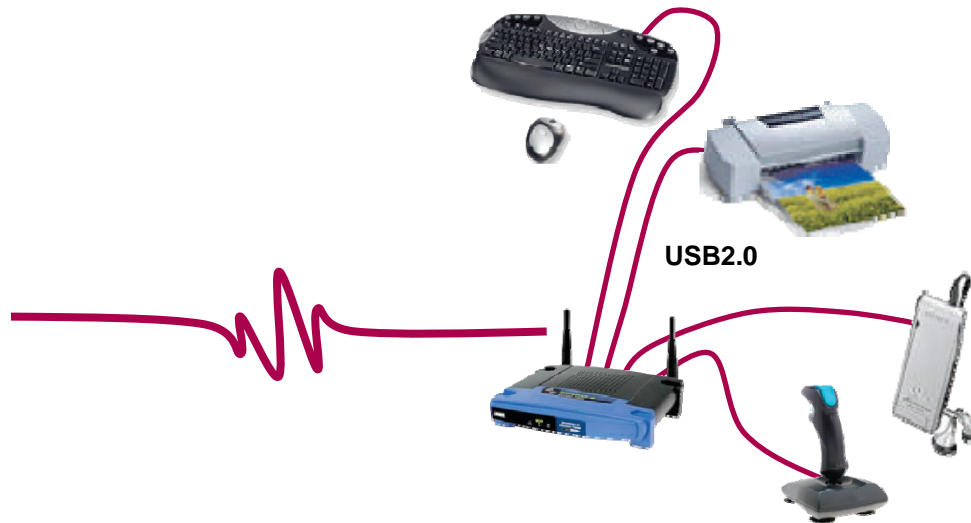
- Supports both Wireless USB and IP
- Has a common radio control interface
- Uses Interface Association Descriptor (IAD)
 - Single driver loads that will load other appropriate drivers



Device Wire Adapter



- Looks like a wireless hub
- Single chip implementations can be integrated directly into devices



Device Wire Adapter: DWA



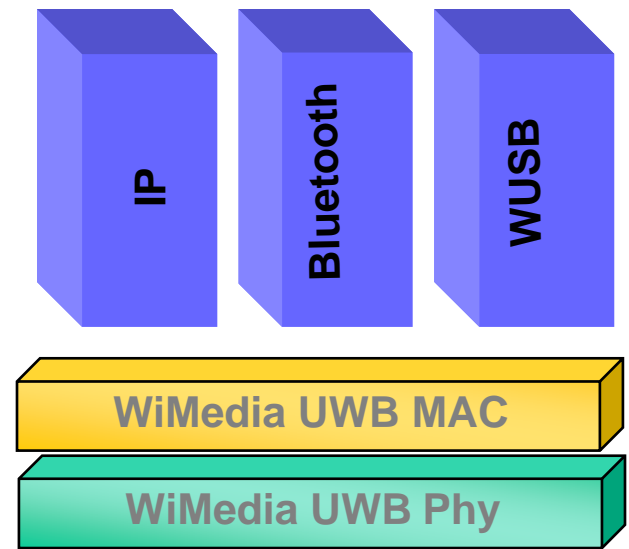
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Compliance Environment



- USB-IF owns tests for Wireless USB block
- WiMedia owns tests for MAC/PHY/Cooperation
 - Goal: Use WiMedia tests at USB-IF Compliance Workshops
- Complete testing (including WiMedia) for Wireless USB products will be done at Compliance Workshops
 - Or independent test houses
- Single logo for Wireless USB
 - Logo usage requires passing Wireless USB and WiMedia tests



Compliance Tests



- From USB-IF
 - Tests for all Wireless USB devices
 - WUSBCV, checks descriptors, commands, etc.
 - Tests for HWA
 - Checks command set and operation. Uses special WUSB compliance device
 - Tests for DWA
 - Checks command set and operation. Uses existing wired compliance devices
 - Test specs available on USB-IF website
 - Detailed session on Wireless USB Compliance at 4:15pm today
- From WiMedia
 - Tests for generic WiMedia MAC/PHY based products
 - Checks for proper beaconing and reservation
 - 'Platform' test spec available on WiMedia website

Compliance Timeline



- Silicon and end user products from 11 companies have been certified
 - Intel lab continues to do certification testing
- First Compliance Workshop where certification will be available
 - October 22-26 - Portland, OR (USA)
- External test labs operational Q1 2008



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Peripheral Developers Kit (PDK)



- Provides host radio and SW solution to enable early peripheral development
 - PCI add-in card or USB dongle
 - Software stacks from Microsoft and Stonestreet One
 - WUSBCV and DWACV available
- Available for purchase through the USB-IF e-Store <http://www.usb.org/developers/estoreinfo/>



- Provides early debug and interop help
 - Access to tools, other products, and experts
- Available to early developers
 - By appointment
 - For multiple days, if needed
- Hosted at Intel in Oregon
 - Contact WUSB-PIL@usb.org



Analysis Tools

- UWB/WUSB protocol analyzers
 - Lecroy, Ellisys
- Physical layer analysis tools
 - Tektronix, Lecroy, Agilent
- See demos at the showcase

Summary



- Certified Wireless USB uses WiMedia PHY and MAC layers
- Certified Wireless USB defines a new protocol
 - Delivers excellent performance
 - Enables great power management
- Association is easy and secure*
- Ecosystem pieces are in place for Wireless USB launch
 - Development tools, analysis tools, compliance tools

Learn as much as you can at the rest of the sessions
Go forth and build product!!



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