Developers Conference 2007

Amsterdam, The Netherlands

Certified Wireless USB Data Transfer and Protocol

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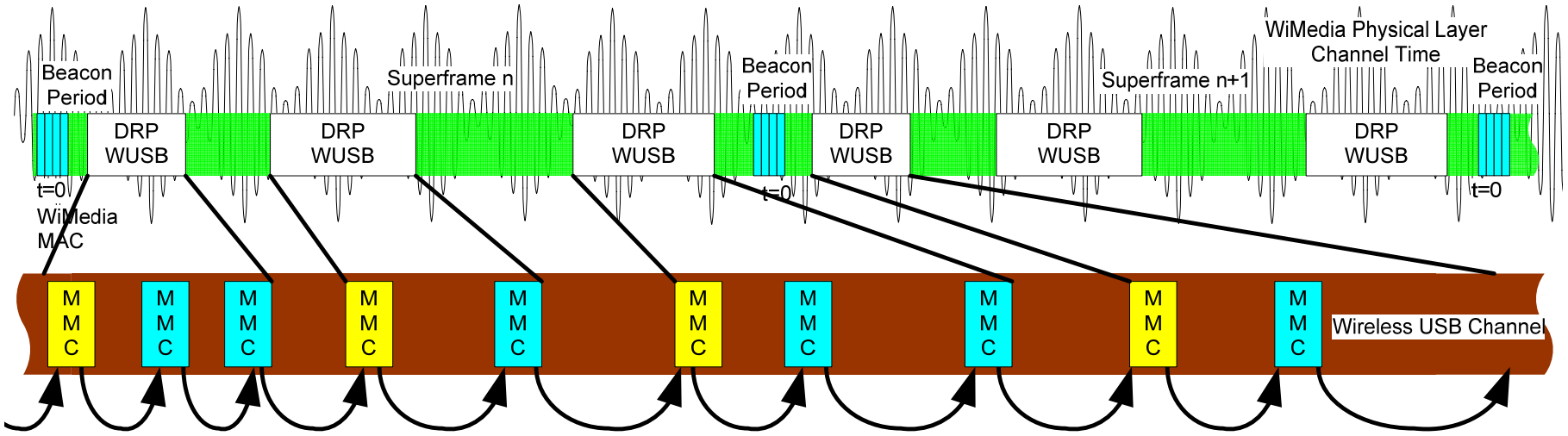
Agenda

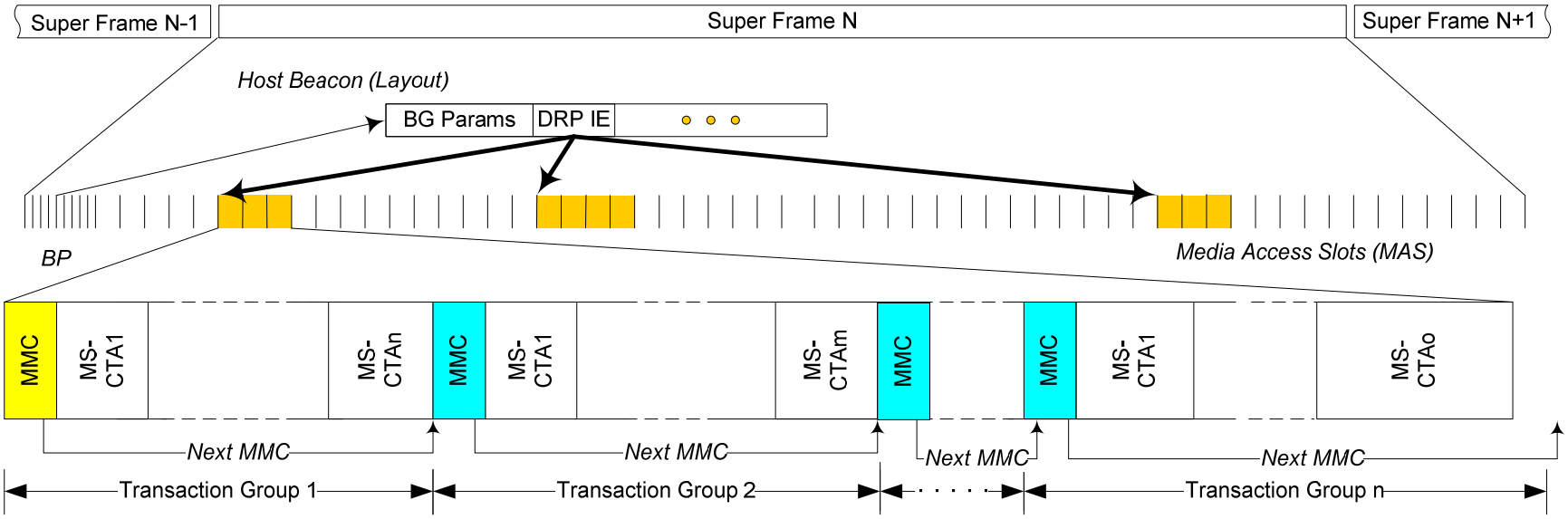
- Data Transfer Model Overview
  - Certified Wireless USB Channel
  - Device Types
  - Transfer Types/Constraints
- Protocol Components
- Data Transfers (general model)
- Device Notifications

Certified Wireless USB Channel



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

Certified Wireless USB Channel Control



- Continuous linked series of MMCs transmitted by Host
- Contain:
  - Certified Wireless USB Channel Time Stamp
  - Time to next MMC
  - General Channel Management Info (Host ID, etc.)
  - Certified Wireless USB channel time allocation declarations
- Transaction Group can not span multiple WiMedia reservation blocks

USB Time

- Wired USB hosts maintain USB channel time
  - In wired USB, HW has 11-bit SOF frame counter providing millisecond resolution or 1/8th millisecond resolution
  - Exported to client drivers through USBDI as 32-bit value
  - In wired USB, time values are primarily used for isochronous traffic
  - SOFs (Start Of Frame packets) pass time information to devices
- Certified Wireless USB hosts also maintain USB channel time
  - 17-bit 1/8th millisecond counter and 7 bit microsecond counter
  - Still exported to client drivers as 32-bit millisecond value
  - Timer used for isochronous and directed beaconing
  - MMCs used to pass time information

Certified Wireless USB Time vs. WiMedia Time

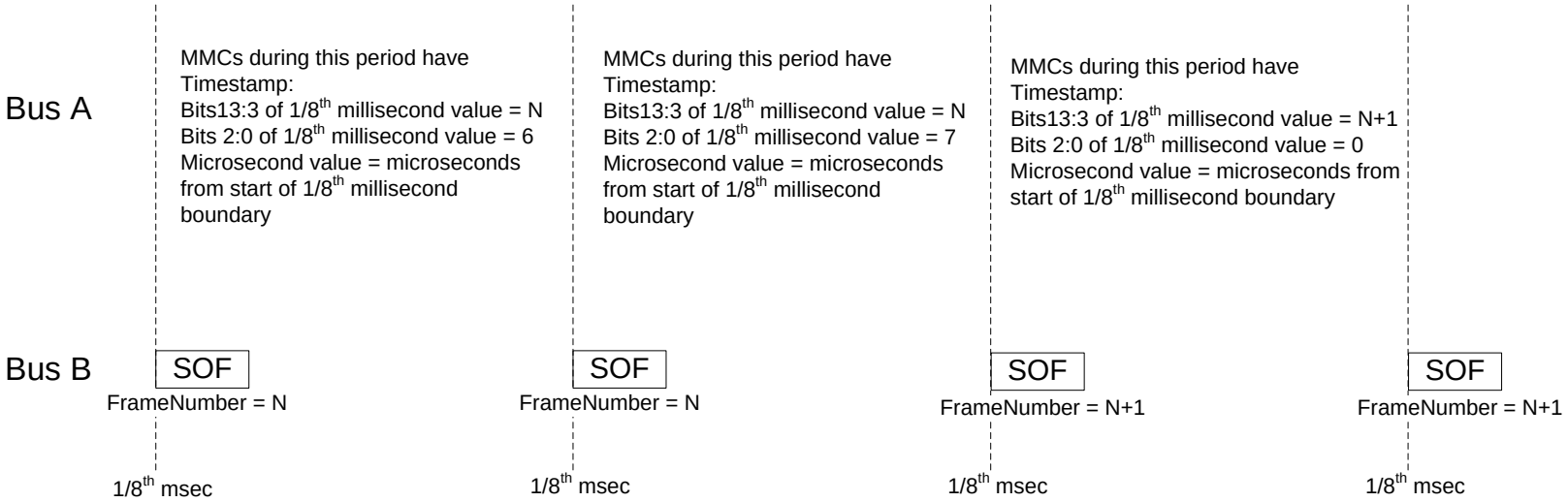
- Certified Wireless USB time is NOT slaved to WiMedia time
- WiMedia superframes will be some number of WUSB microseconds
  - If there is a slow beaconing WiMedia device, superframe may be a few more CWUSB usecs than 64K
- Devices use MMC timestamps to synchronize their internal usec clocks
  - Done on devices that need clocks (isochronous or DBD)
    - DBD must sync transmit packet repetition to WUSB channel time.
  - Device clocks must adjust to host rate

USB Time Across Hierarchy

Example Topology

Actual times in MMC and SOFs are the same

Bus Timings



- Device Wire Adapters synch to upstream USB time and propagate to downstream USB time

Certified Wireless USB Cluster

- Term used to refer to devices connected to and communicating via the same Certified Wireless USB Channel
- One Certified Wireless USB Host
- One (or more) Certified Wireless USB Devices
  - Maximum of 128 devices.
  - 128 Addresses used to manage unauthenticated/unassociated devices

Certified Wireless USB Device Types

- Self Beaconing Devices
  - Devices are full WiMedia MAC aware
  - Attend “Design Considerations for SBDs/DRDs and Multi-Pal Devices” for details
- Non Beaconing Devices
  - Limited transmit and receive range
  - Fully encompassed by hosts range
  - Not enough detail to be built (yet)

Transfer Type Constraints

- Same Transfer types as USB 2.0
  - Bulk
  - Control
  - Interrupt
  - Isochronous
- Different/new constraints to make more efficient for Wireless Media

Transfer Type Constraints
Bulk

- Retains many/most constraints and behavior of Wired USB
  - Reliable Delivery
  - “Good Effort” service
    - Host may restrict number of data packets (burst size) to provide some level of service in available channel time
  - Short-packet Semantics preserved
- Maximum Packet Size, one of
  - 512, 1024, 1536, 2048, 2560, 3072 and 3584 (only)
- Maximum burst size of 1 to 16
- Use any bit transfer rate supported by device
  - Host choice
- On Flow control event, taken from active list
  - Device must notify host when ‘ready’

Transfer Type Constraints
Control

- Retains many/most constraints and behavior of Wired USB
  - “Best Effort” service
  - Reliable data delivery
- Maximum Packet Size of 512 (only)
- Maximum burst size of 1 data packet per data phase
- Host must use PHY Base rate with Default Control Pipe (Standard Commands)
- On Flow control event, taken from active list
  - Device must notify host when ready

Transfer Type Constraints

Intterrupt and Isochronous

- Not more than 80% of Certified Wireless USB Channel (combined all periodic)
- Similar purpose and characteristics of Wired USB
- On Flow control event host MAY remove from active list
  - Host must resume service next interval.
- See Periodic Transfer models session/presentation for more details.

Agenda

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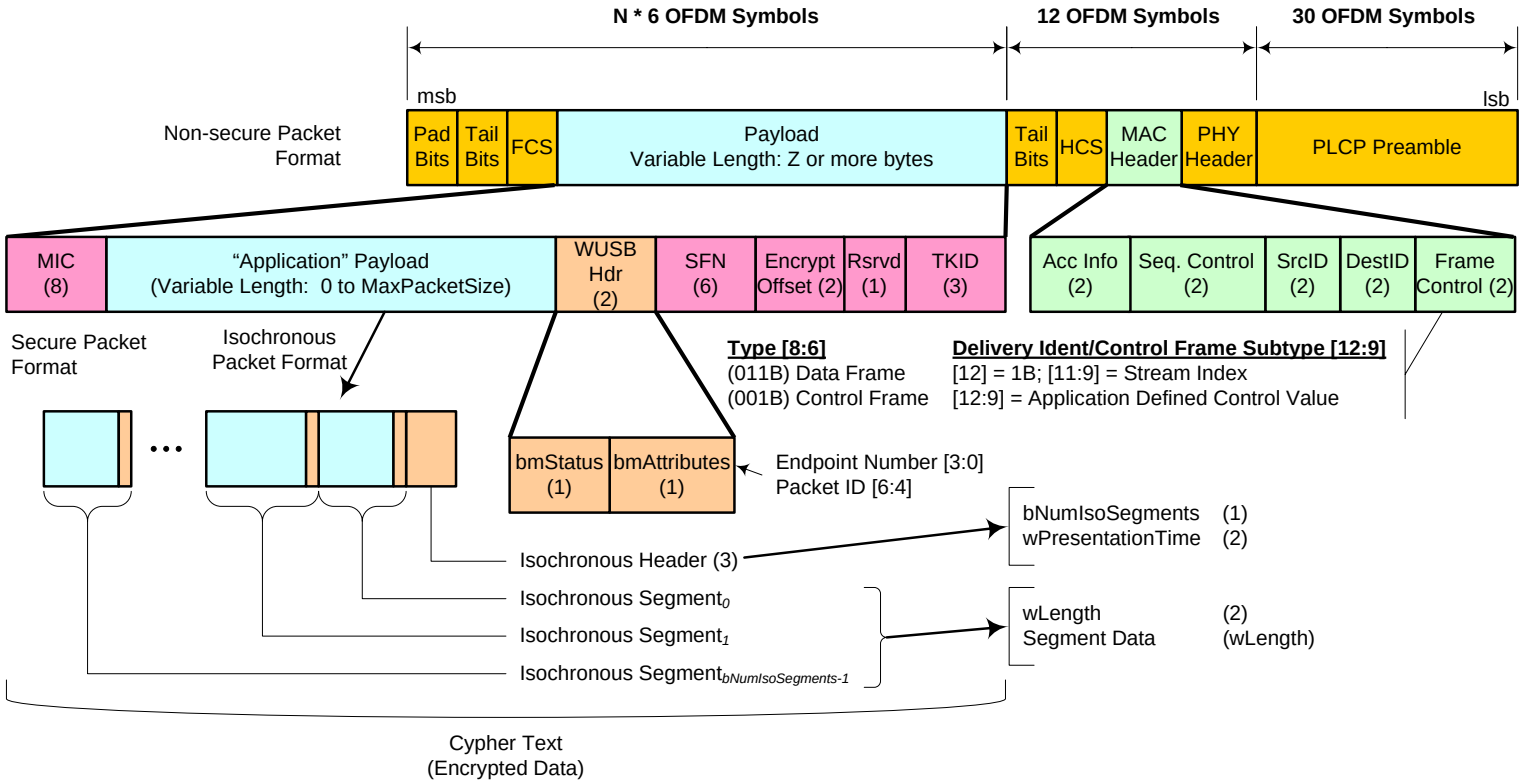
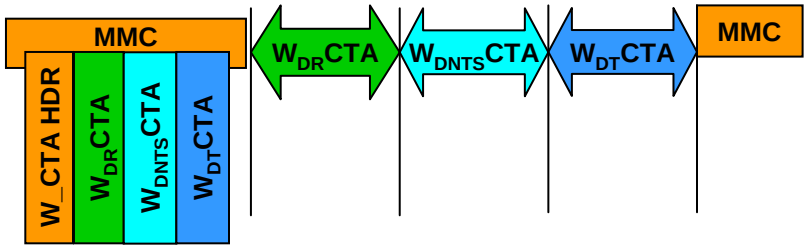
Packet Layout



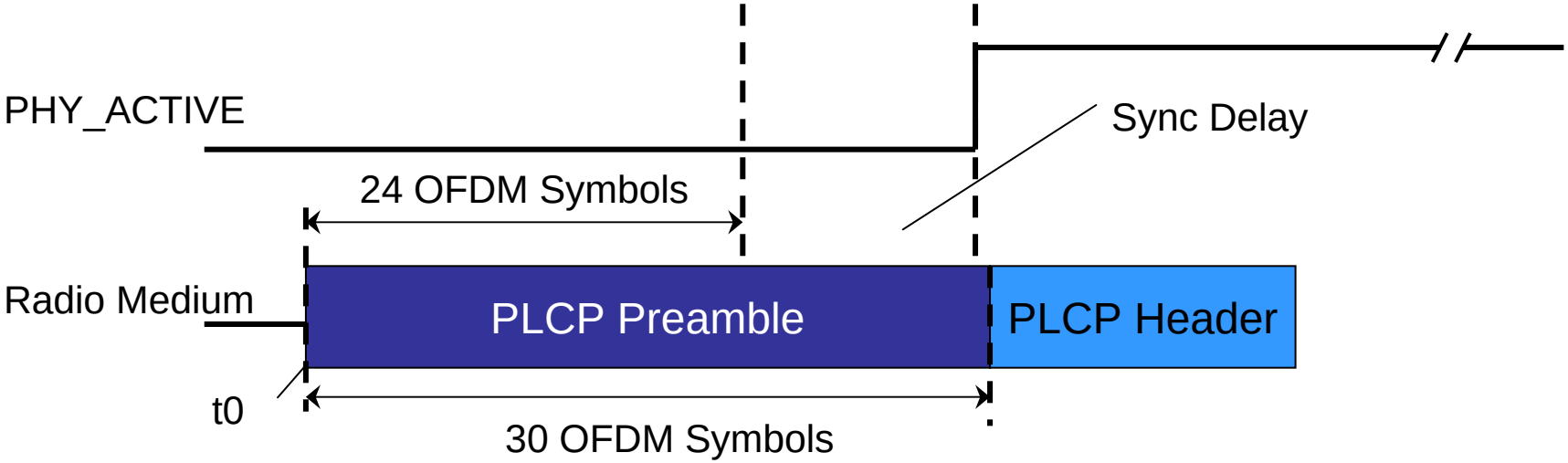
- WiMedia MAC Packet format
- Utilizes Secure 'frame' format

Time Slot Allocations



- Three basic slot types
  - W_{DR}CTA (Device Receive)
  - W_{DT}CTA (Device Transmit)
  - W_{DNTS}CTA (Device Notification Time Slot)
- W_{DR}CTA, W_{DT}CTAs are used for Transaction Protocol
  - Control, Bulk, Interrupt and Isochronous data streams
  - Access is : guaranteed time slot
  - Schedule based on client application data flow needs
- W_{DNTS}CTAs used to emulate USB signaling events
  - Connect, disconnect, etc.
  - Access is: contention based - Slotted Aloha
  - Host schedules sufficient number of slots to provide adequate service for the cluster

Transaction Group
Protocol Synchronization (cont.)

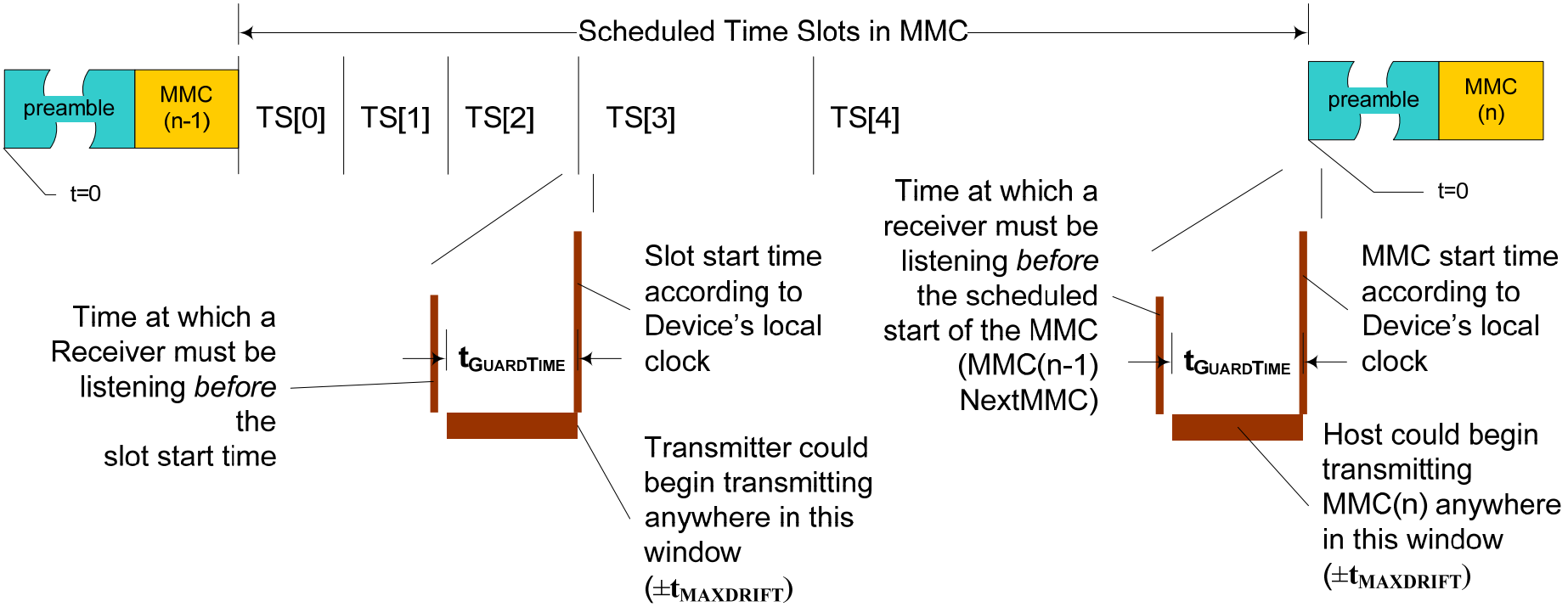


- t0 is the start time of the first symbol of the MMC's preamble
- Devices can 'calculate' this from the edge of PHY_ACTIVE

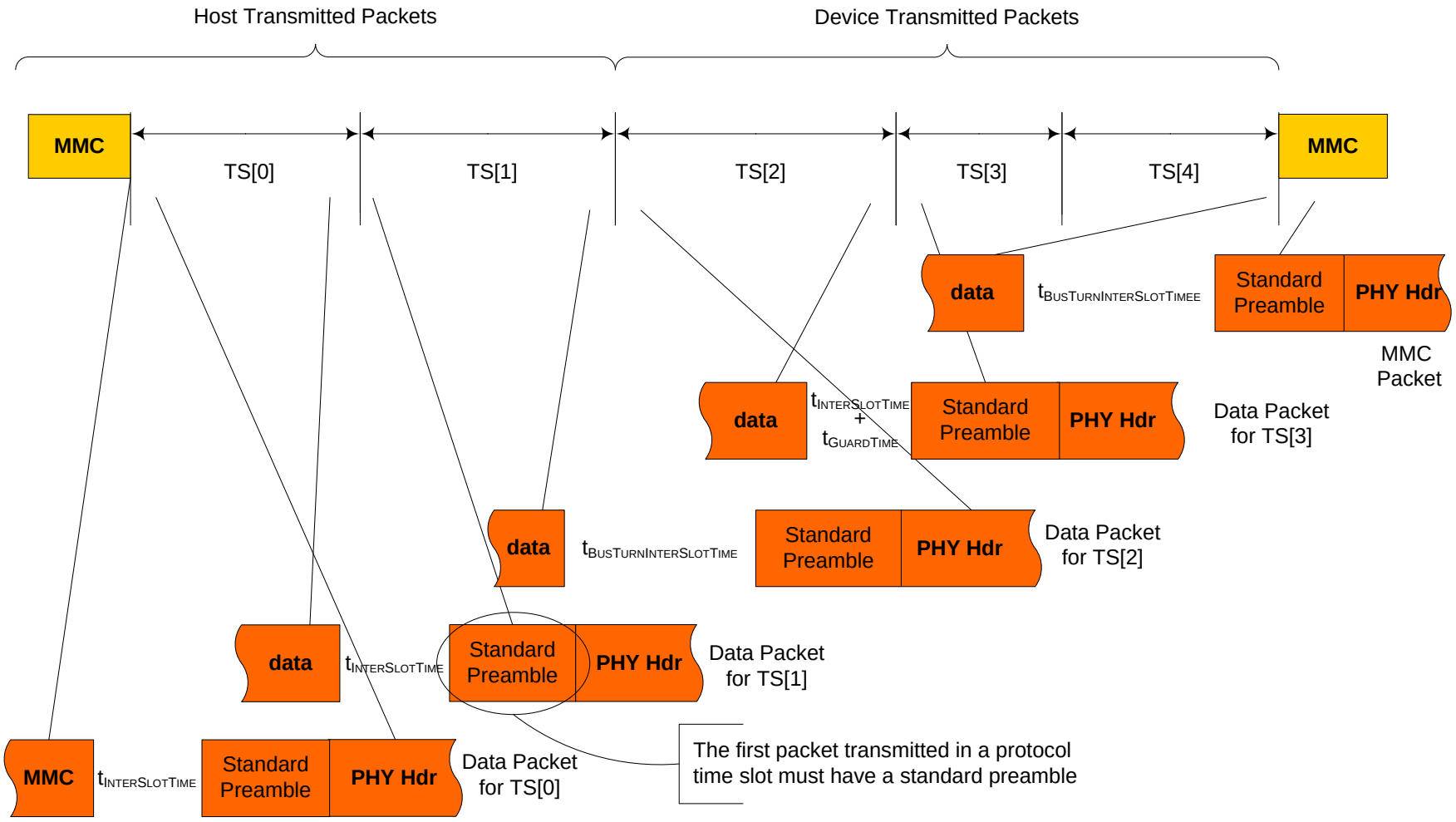
PLCP : Physical layer convergence protocol

OFDM : Orthogonal frequency division multiplexing

Transaction Group
Protocol Synchronization



Time Slot Scheduling Requirements



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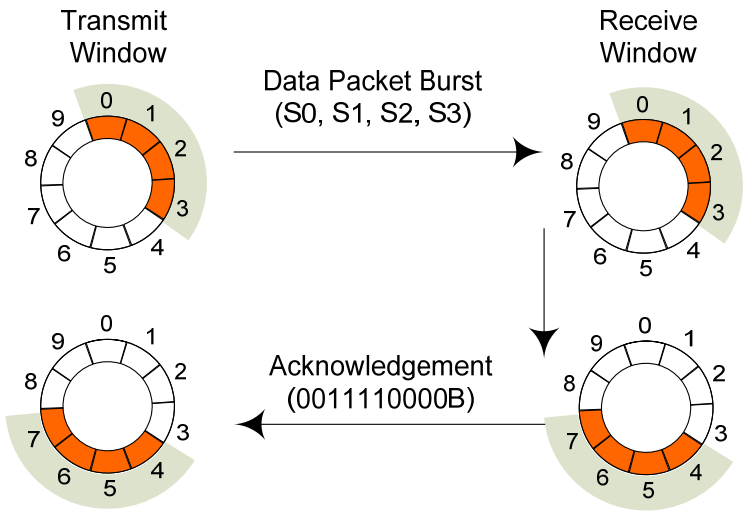
Data Stream Synchronization

Basic Model

- Protocol-level support for reliable data delivery
- Identifies:
  - Data ordering requirements
  - Guarantees advancement of data stream only after reliable data delivery
- Terms:
  - Maximum Burst Size
  - Maximum Sequence
  - Maximum Sequence Distance

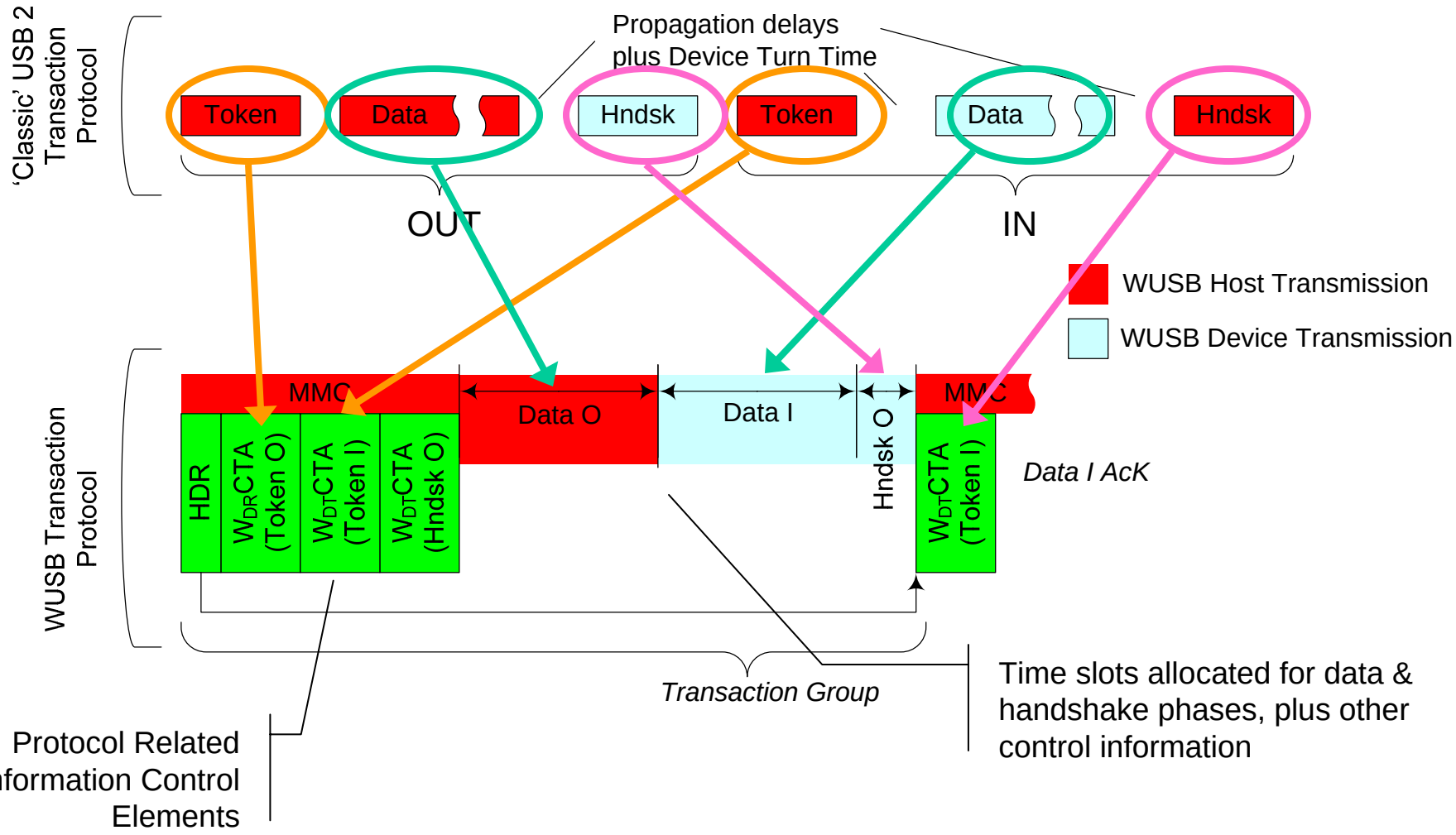


- Transmitter sends data packets associated with Transmit window Sequence numbers
- Receiver acknowledges with new receive window (what is available now)
- Protocol rules for recovering lost packets, avoiding sequence range wrap, etc.

Transaction Transmit Bit Rate

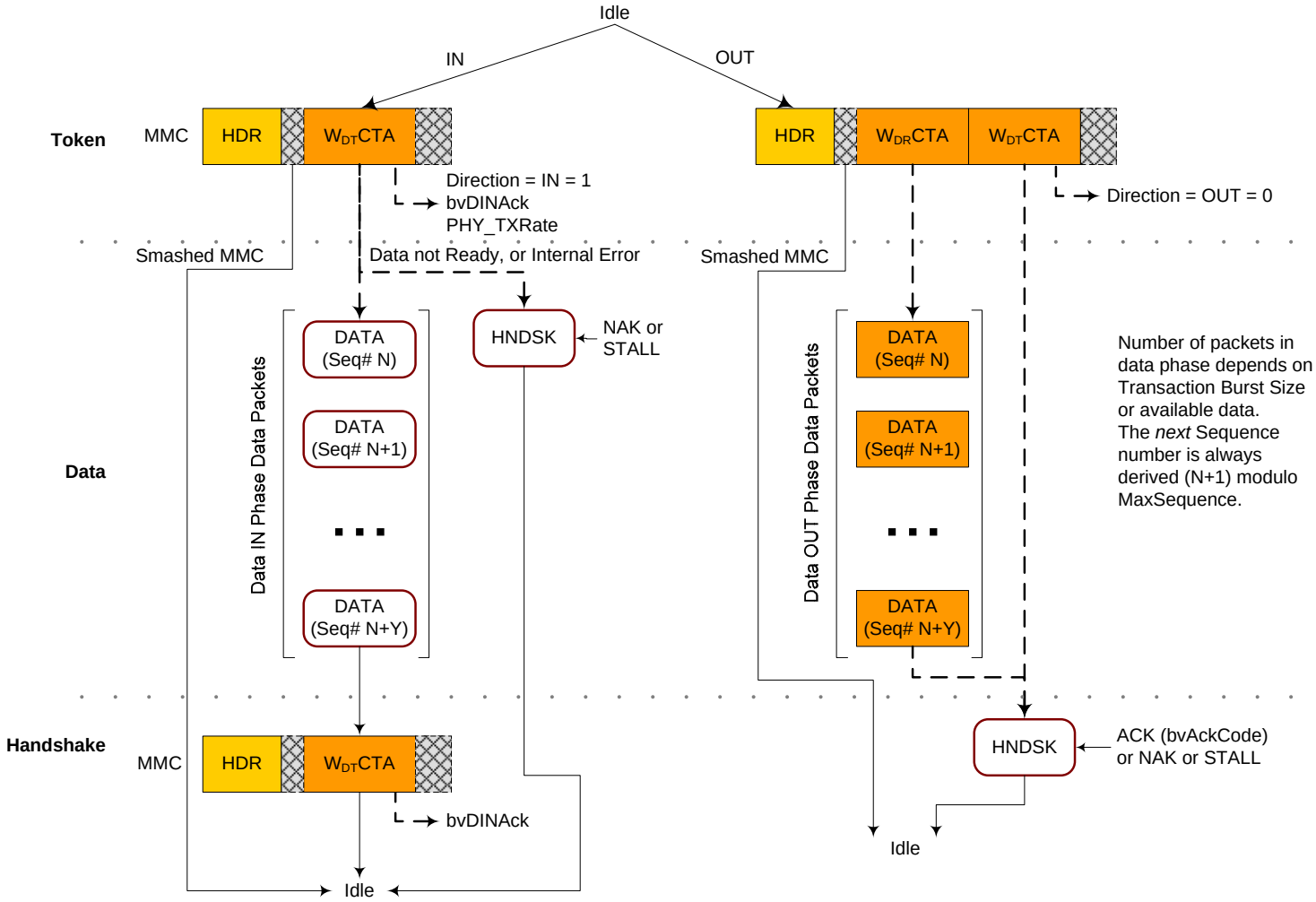
- MMCs are transmitted at ‘base’ signaling rate (53.3 Mb/s)
- Host dictates transmit bit rate for data and handshake phase transmissions
  - Transmit bit rate applies to entire phase
  - OUTs: host uses only TBRs supported by device (assumes Tx/Rx symmetry)
  - INs: W_{DT}CTA.PHY_TXRate directs which TBR device must use during protocol time slot
- Handshakes:
  - Host must use ‘base’ signaling rate for a handshake time slot (OUTs)
  - Host must ensure a data phase time slot is always large enough to accommodate a handshake transmitted at ‘base’ signaling rate

Certified Wireless USB Transactions



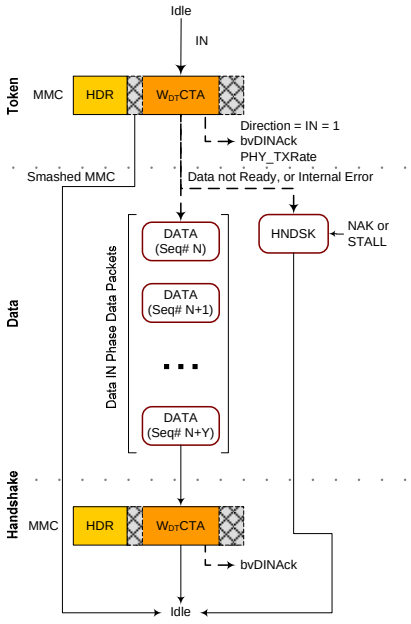
Transaction Format

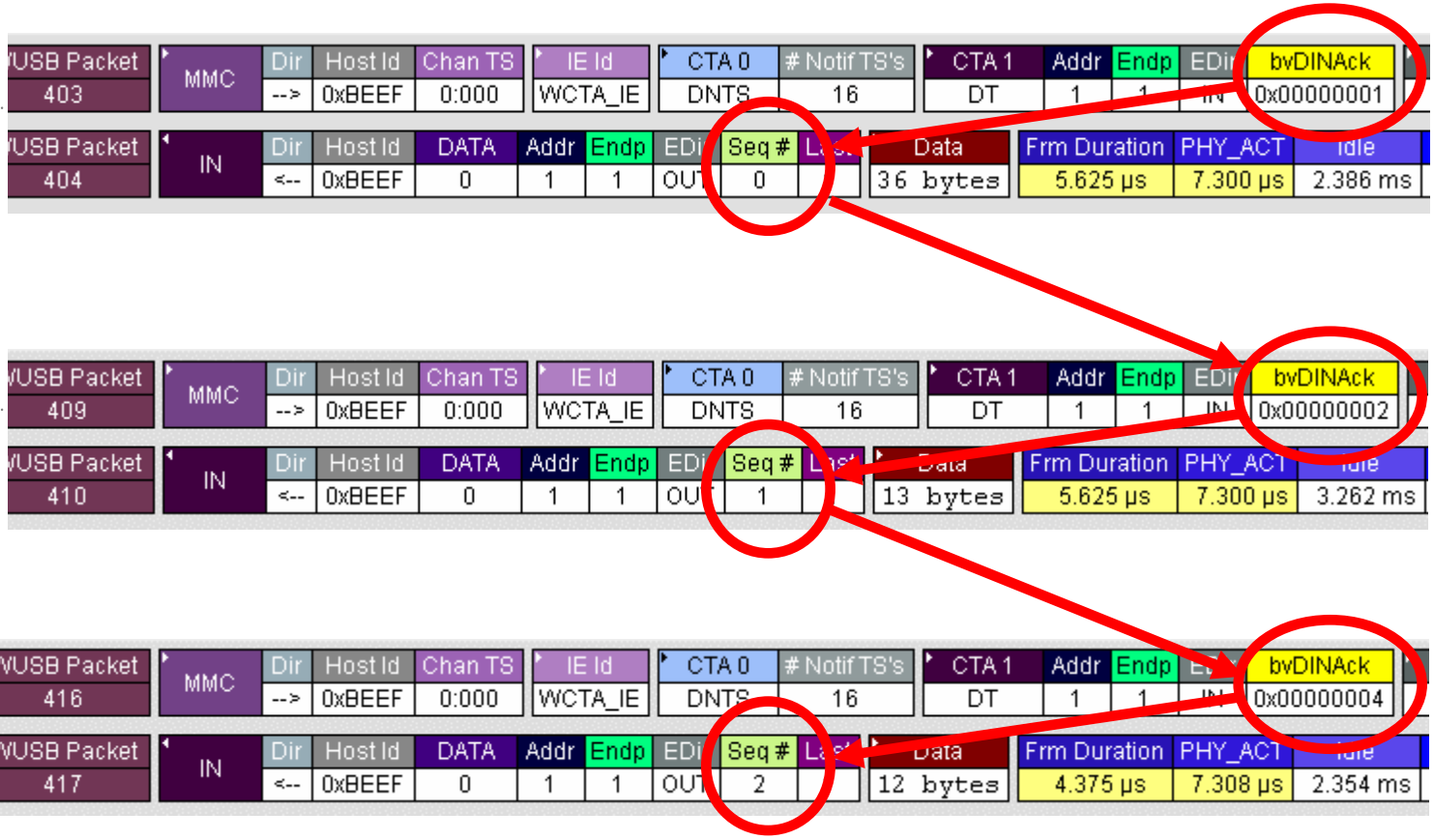
General Model



Data IN Transfer

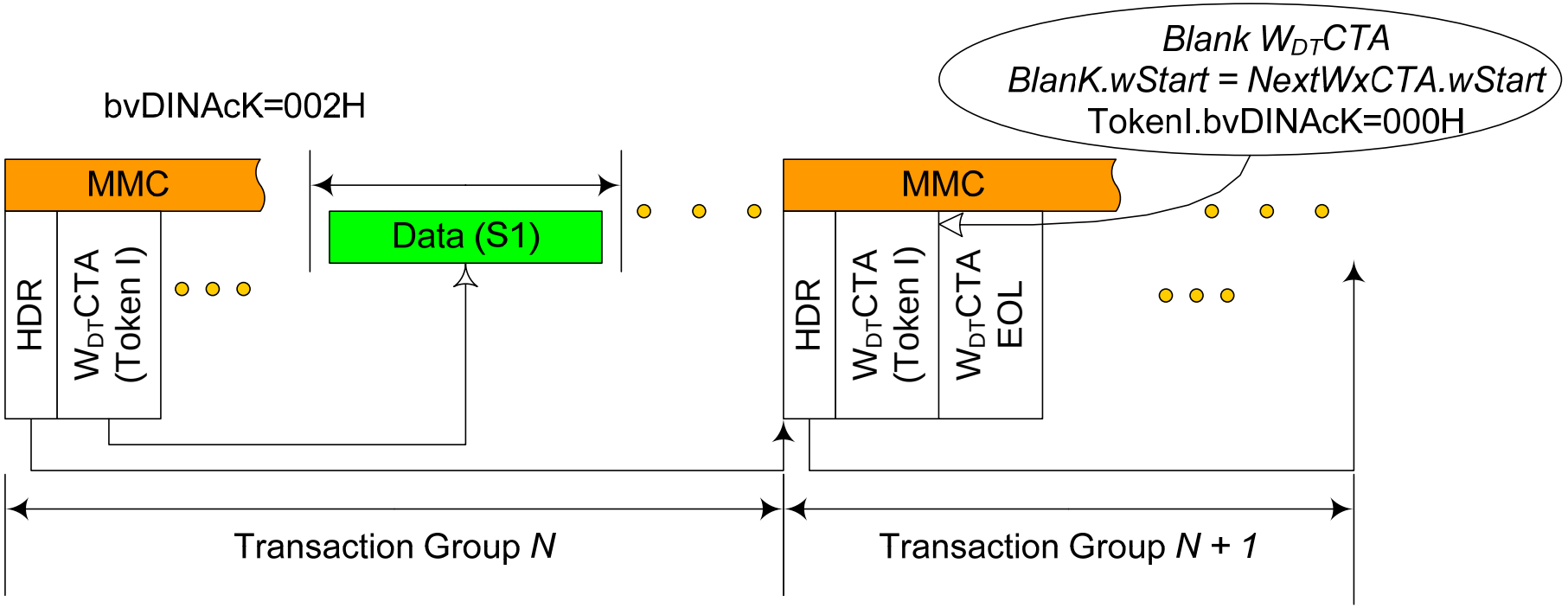
Streaming Example





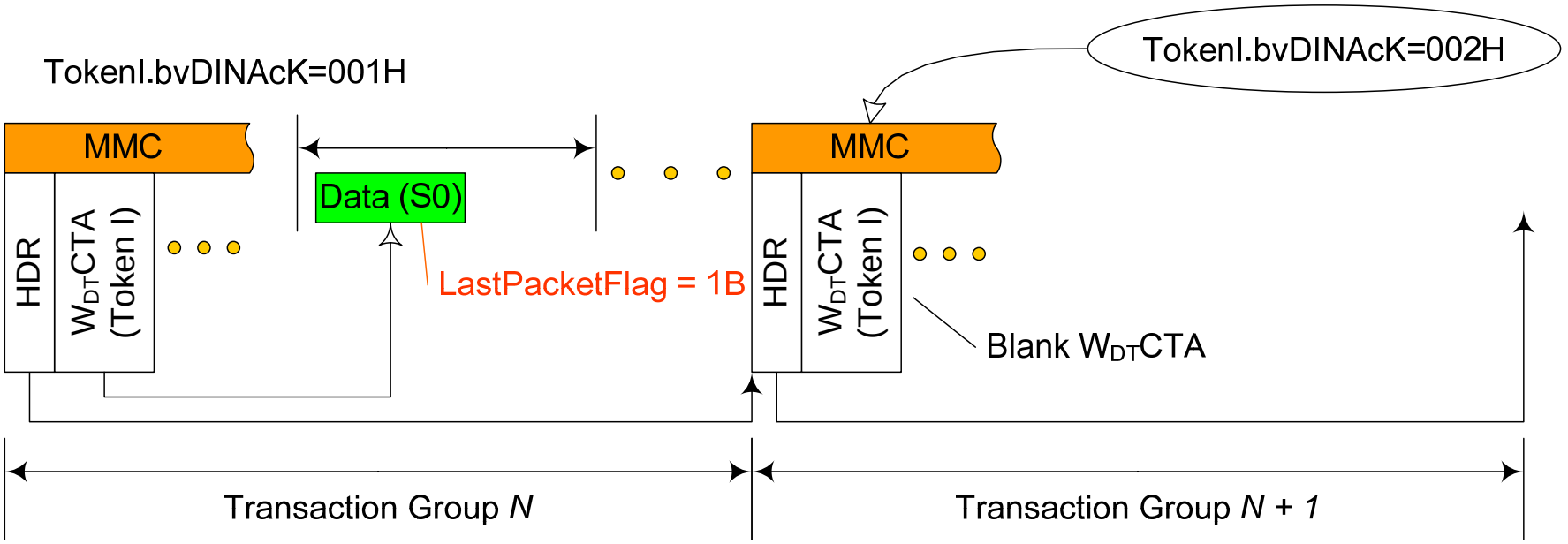
Disclaimer : early prototype host and devices used for traffic capture

Data IN Transfer
End Of Transfer Example



- At end of Transfer, need to acknowledge last data phase
- Uses ‘Blank’ IN Token (W_{DT}CTA)

Data IN Transfer
Short Packet Example



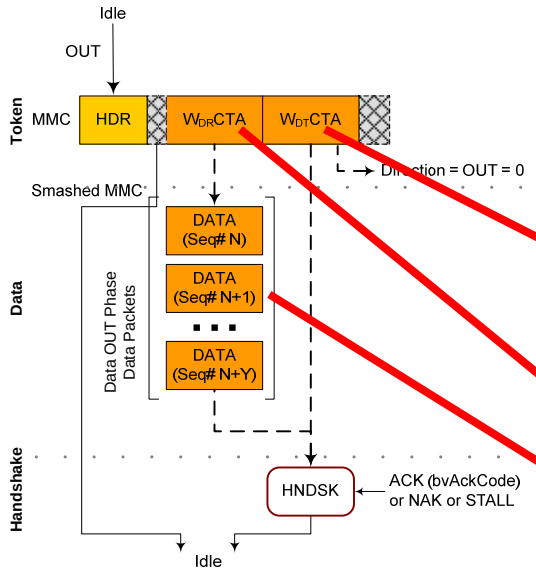
Host may commence next transfer immediately (if buffer available)

Last Packet Flag may only be set on last packet in a burst

Blank W_XCTA contains start time for next CTA.

Data OUT Transfers

Streaming Example



Initial Condition:
Out Endpoint Window (0x0000FFFF)

Data Phase CTA

Handshake Phase CTA

WUSB Packet		Dir	Host Id	Chan TS	IE Id	CTA 0	Addr	Endp	CTA 1	# Notif TS's	CTA 2	Addr	Endp	EDir	bvDINAck
398	MMC	-->	0xBEEF	0:000	WCTA_IE	DR	1	1	DNTS	16	DT (Hnd)	1	1	OUT	0x00000000

WUSB Packet		Dir	Host Id	DATA	Addr	Endp	EDir	Seq #	Last	Data	Frm Duration	PHY_ACT	Idle	Time Stamp
399	OUT	-->	0xBEEF	0	1	1	OUT	0	1	31 bytes	15.000 µs	10.714 µs	479.668 µs	7.466400520

WUSB Packet		Dir	Host Id	ACK	Addr	Endp	EDir	bvAckCode	Frm Duration	PHY_ACT	Idle	Time Stamp
400	Hand	<--	0xBEEF	1	1	1	OUT	0x0001FFFE	1.875 µs	7.308 µs	2.630 ms	7.466890902

Handshake Acks the Seq # (0) by advancing (by one) receive window : 0x0000FFFF<<1 = 0x0001FFFE

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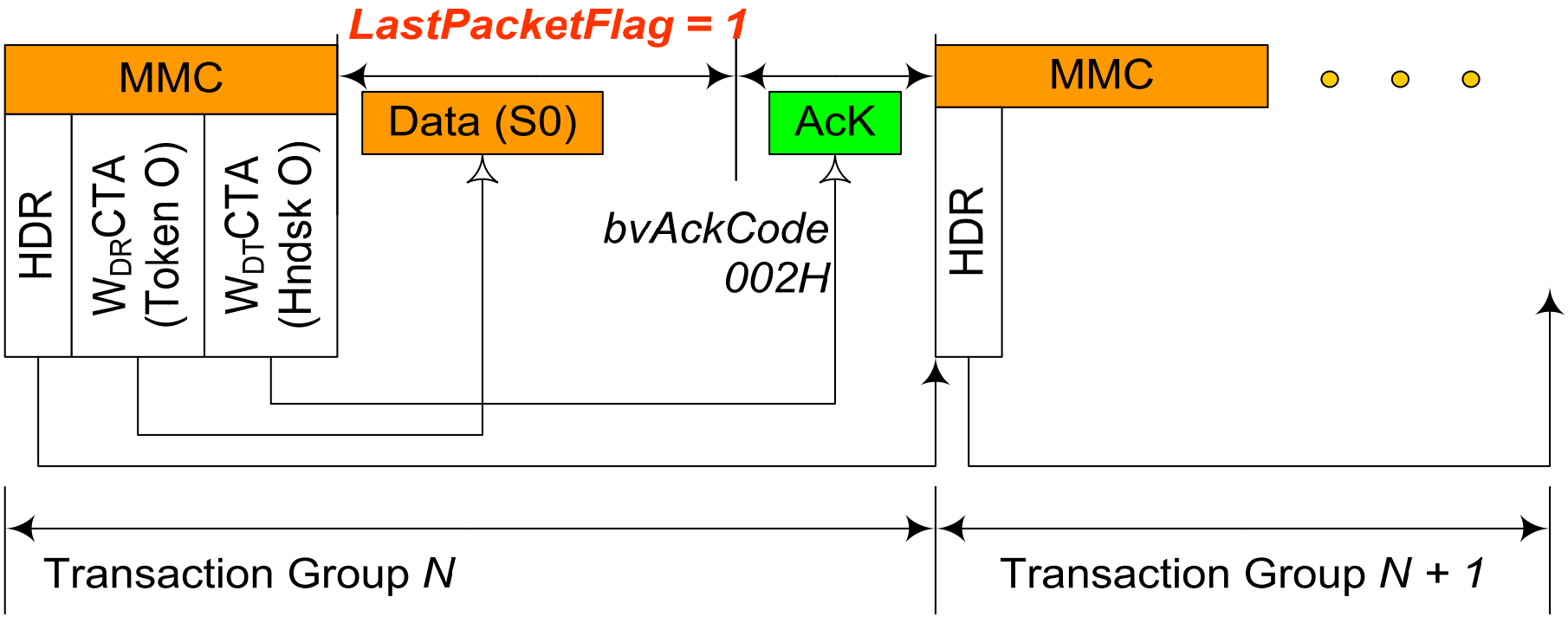
Data OUT Transfers

Short Packet Example

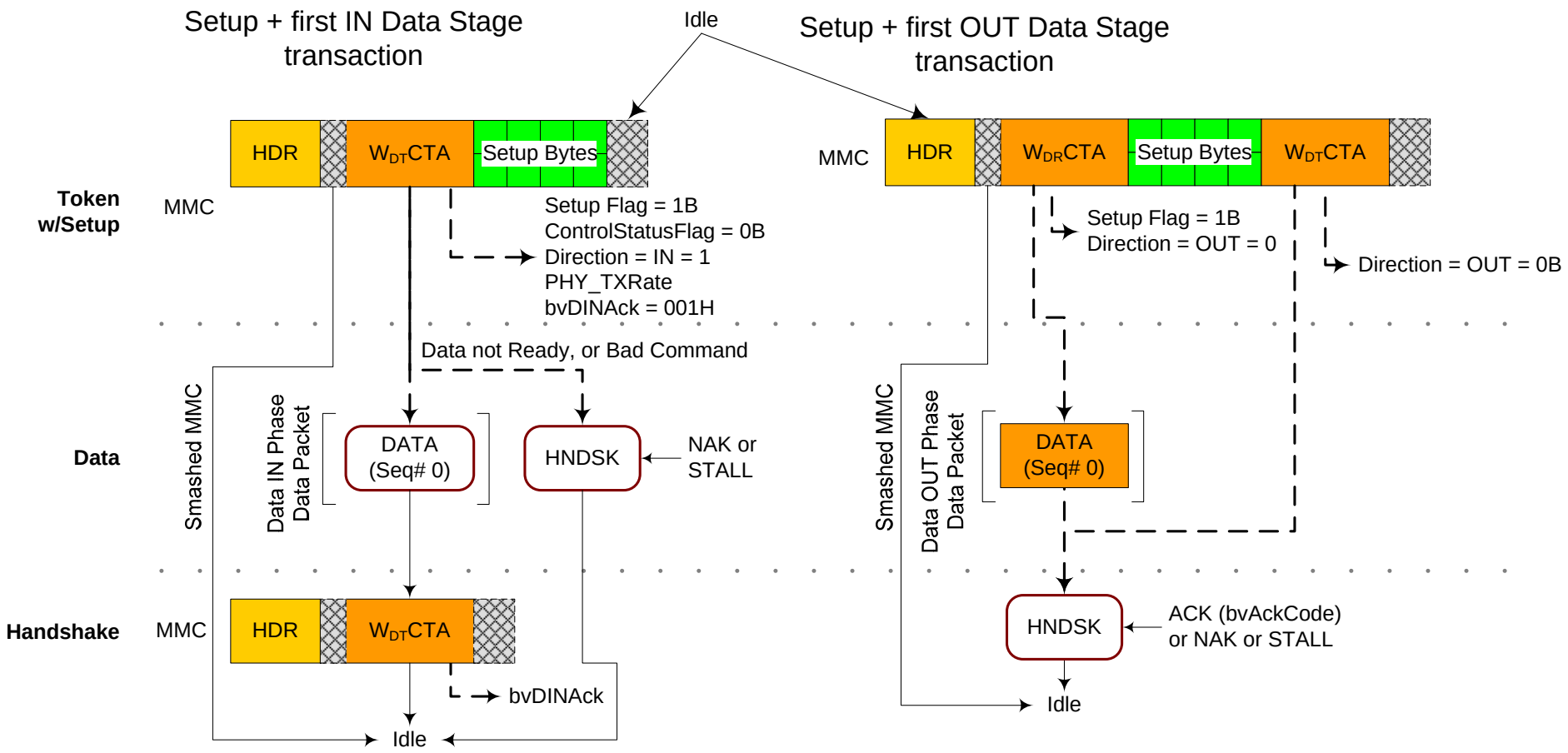


Host may commence next transfer immediately (if data available)

Last Packet Flag may only be set on last packet in a burst

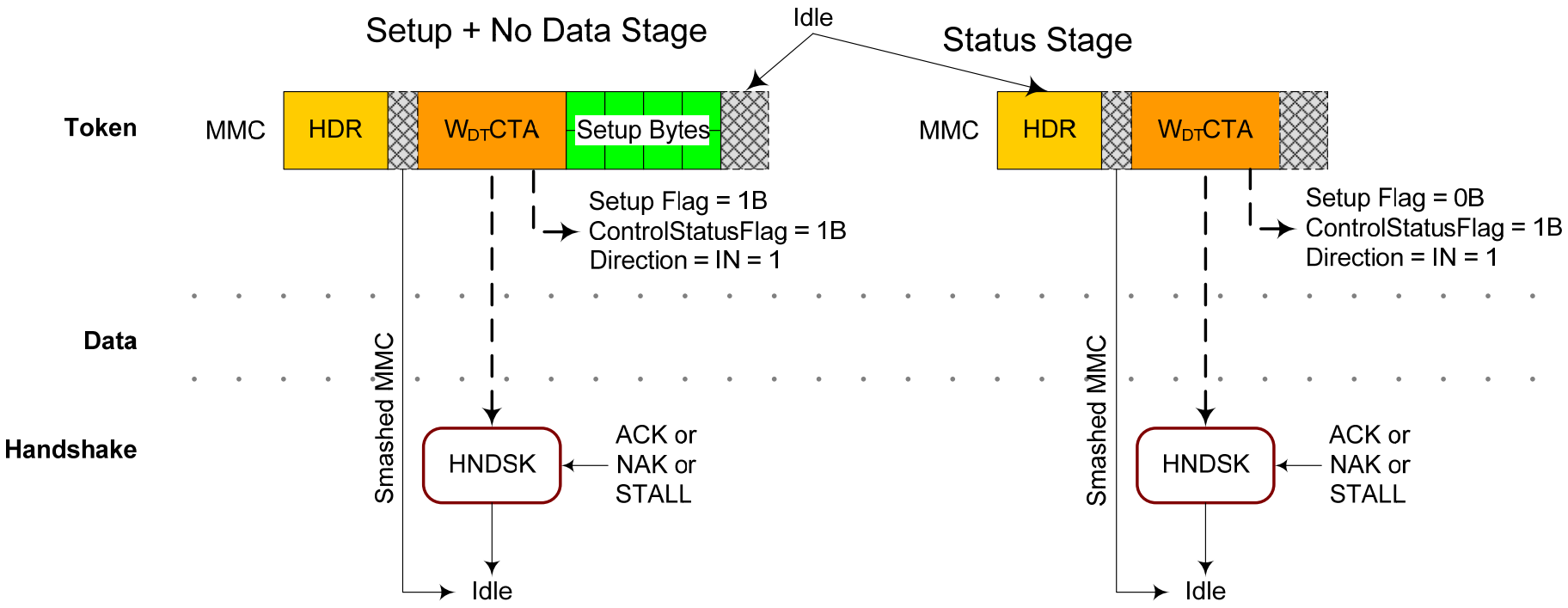
Control Transaction Format

Setup Stage w/Data Stage



Control Transaction Format

Setup w/No Data Stage; Bare Status Stage



Control Transfer

Example (Set Address - No Data Stage)

Setup Stage

Status Stage

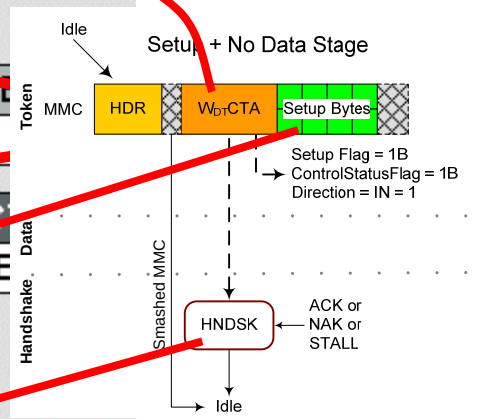
WUSB Packet	MMC	Dir	Host Id	Chan TS	CTA 0	# Notif TS's
249		-->	0xBEEF	0:000	DNTS	16

CTA 1	Addr	Endp	EDir	Setup	TX Sz	CtlStat	Rate	Pwr
DT (Hnd)	128	0	OUT	1	0	1	53M	0

Policy	bvDINAck	Data
Std only	0x00000000	00 05 00 00 00 00 00 00

Addr	Endp
224	0

WUSB Packet	Hand	Dir	Host Id	ACK	Addr	Endp	EDir	bvAckCode
250		<--	0xBEEF	1	128	0	OUT	0x00000000



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Control Transfer

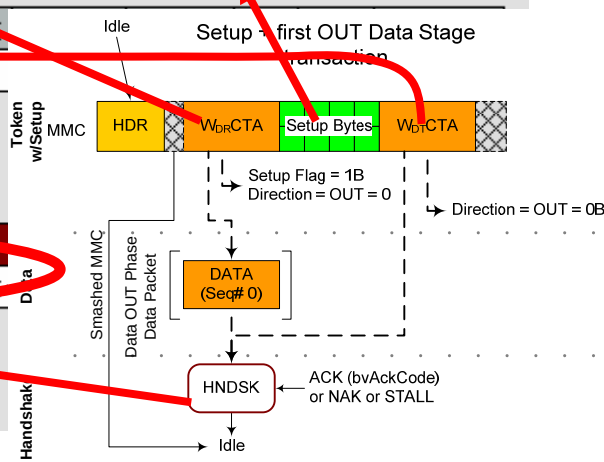
Example (Control Write - SetKey)

Setup Stage

Packet	MMC	Dir	Host Id	Chan TS	CTA 0	Addr	Endp	Setup	Start	Data
313		-->	0xBEEF	0:000	DR	1	0	1	150µs	25 07 00 22 00 00 1C 00

CTA 1	Start	# Notif TS's	CTA 2	Addr	Endp	EDir	Start	TX Sz
DNTS	259µs	16	DT (Hnd)	1	0	OUT	643µs	0

bvDINAck	CTA 3	Addr	Endp	Start
0x00000000	EOL	224	0	716µs



Data Stage

Packet	OUT	Dir	Host Id	DATA	Addr	Endp	EDir	Seq #	Last	Data
314		-->	0xBEEF	0	1	0	OUT	0	1	28 byt

Packet	Hand	Dir	Host Id	ACK	Addr	Endp	EDir	bvAckCode
315		<--	0xBEEF	1	1	0	OUT	0x00000000

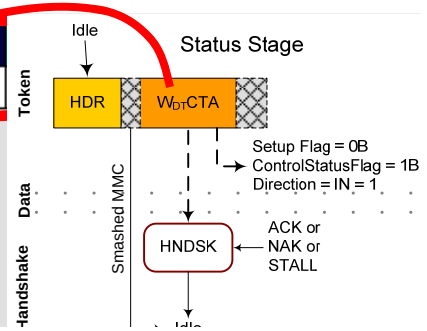
In a subsequent transaction group… the status stage

Status Stage

Packet	MMC	Dir	Host Id	Chan TS	CTA 0	Start	# Notif TS's	CTA 1	Addr
318		-->	0xBEEF	0:000	DNTS	212µs	16	DT (Hnd)	1

CtlStat	Rate	Pwr	Brst	Policy	bvDINAck	CTA 2	Addr	Endp	Start
1	53M	0	1	Std only	0x00000000	EOL	224	0	668µs

Packet	Hand	Dir	Host Id	ACK	Addr	Endp	EDir	bvAckCode
319		<--	0xBEEF	1	1	0	OUT	0x00000000



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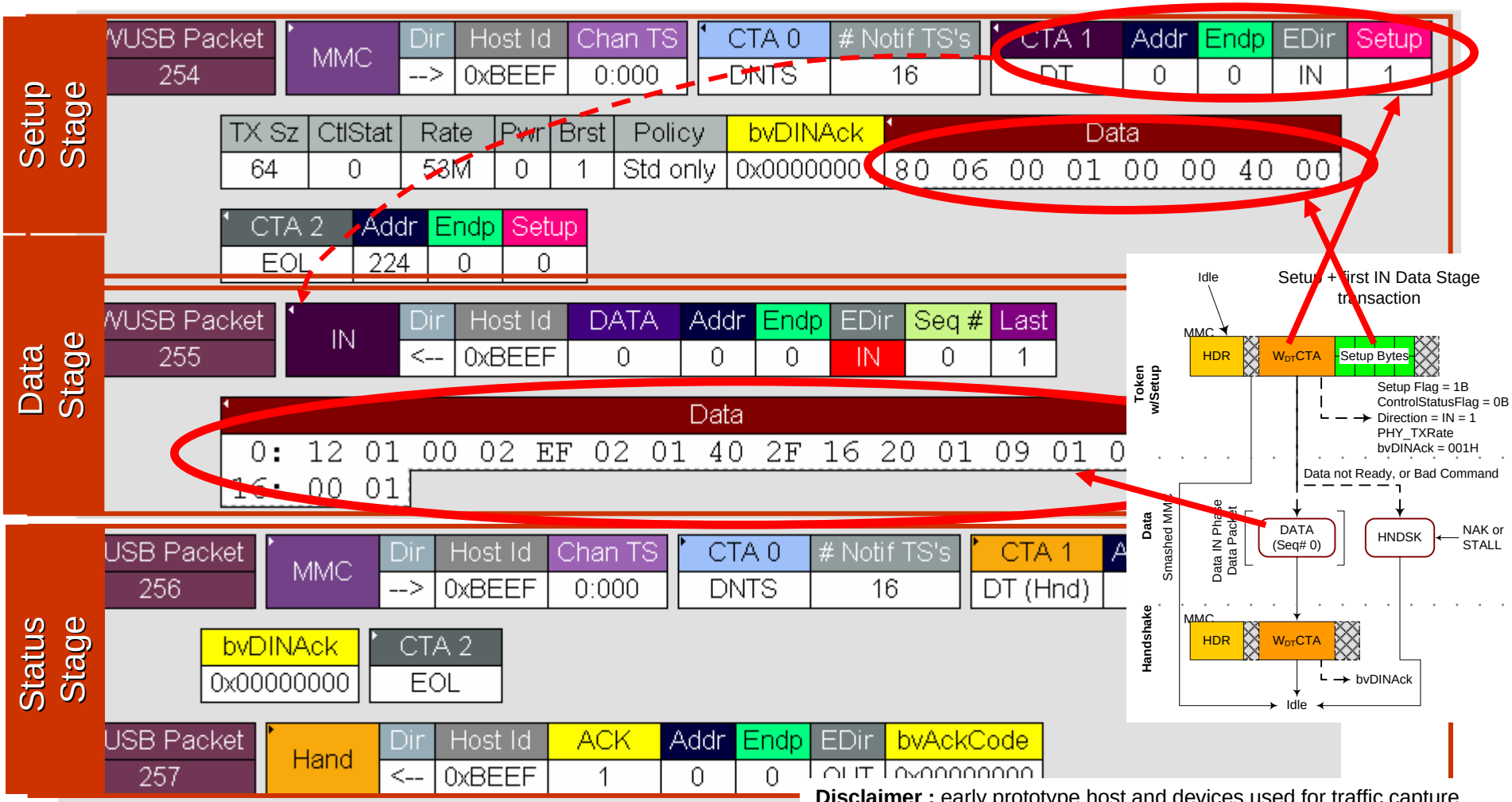
Control Transfer

Example (Control Read – Get Descriptor)



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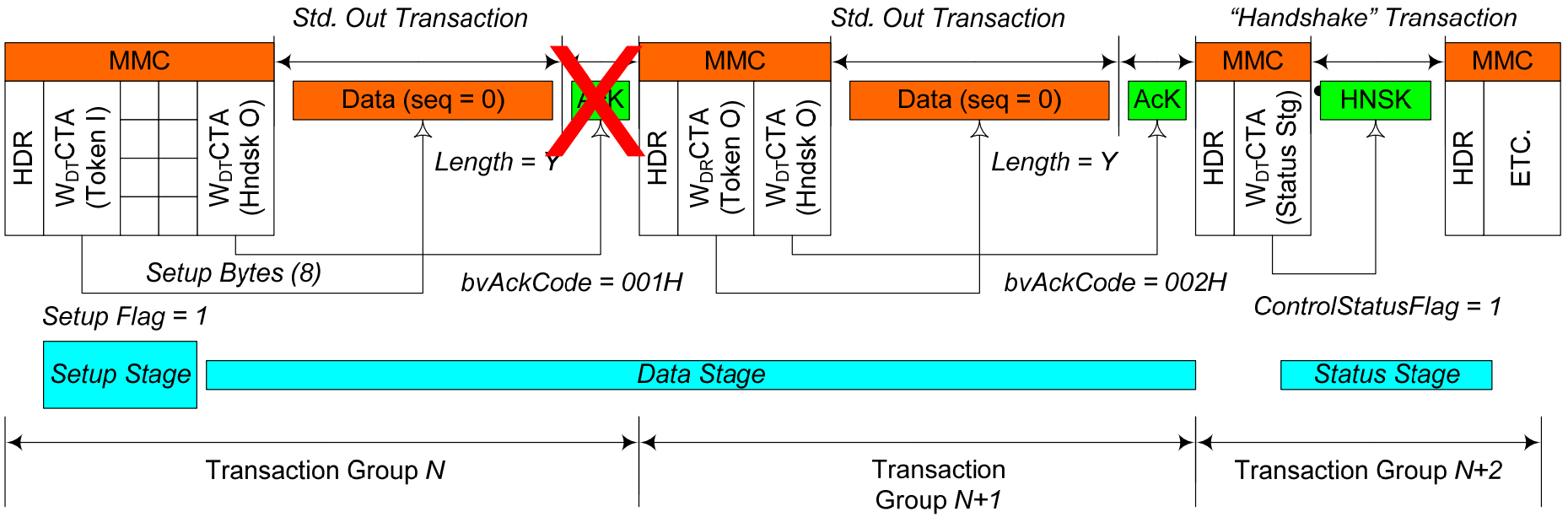
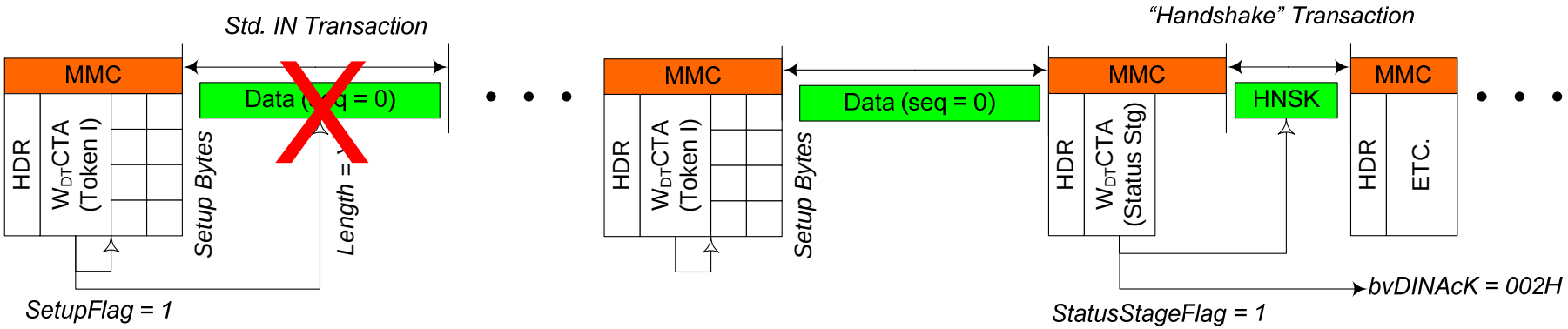
Control Transfer
Example (Control Write – Retry Policy)

- No response from device on Setup + OUT
- Retry only first OUT of Data Stage
  - Device response when missed SETUP is a STALL handshake

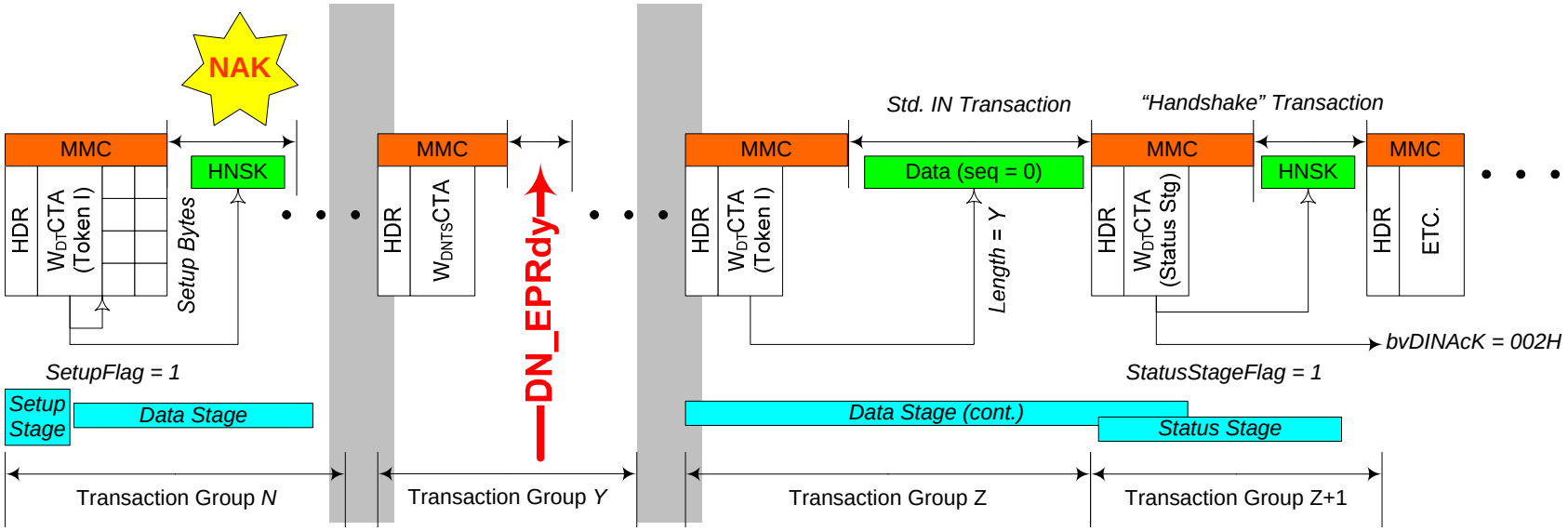


Control Transfer
Example (Control Read – Retry Policy)

- No response from device on Setup + IN
- Host will retry Setup Stage + IN



Control Transfer
Example (Control Read – Flow Control)



- Host stops polling endpoint on NAK
- Device notifies it is ready with DN_EPRdy
- Host resumes polling endpoint
  - Retries data phase transaction in this example

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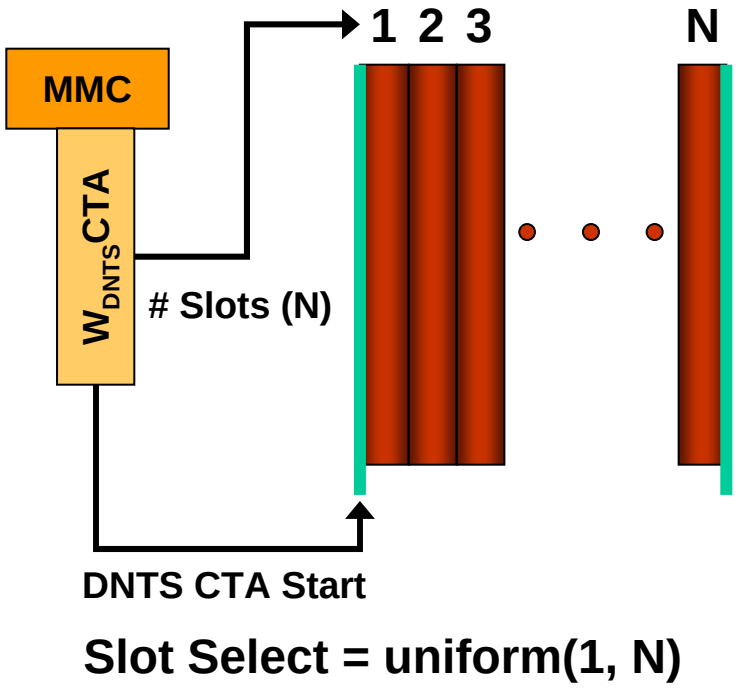
Device Notifications Time Slots
DNTS

- Devices are only allowed transmitters
- Device notification messages (to the WUSB Host) are only allowed data communications
- Nature of notification messages are that they are asynchronous and infrequent
- Fixed Maximum Size for notification messages
- Device policy for priority of notification messages
- Host policy to manage ‘efficiently’
  - Unused time is just lost to CWUSB data stream

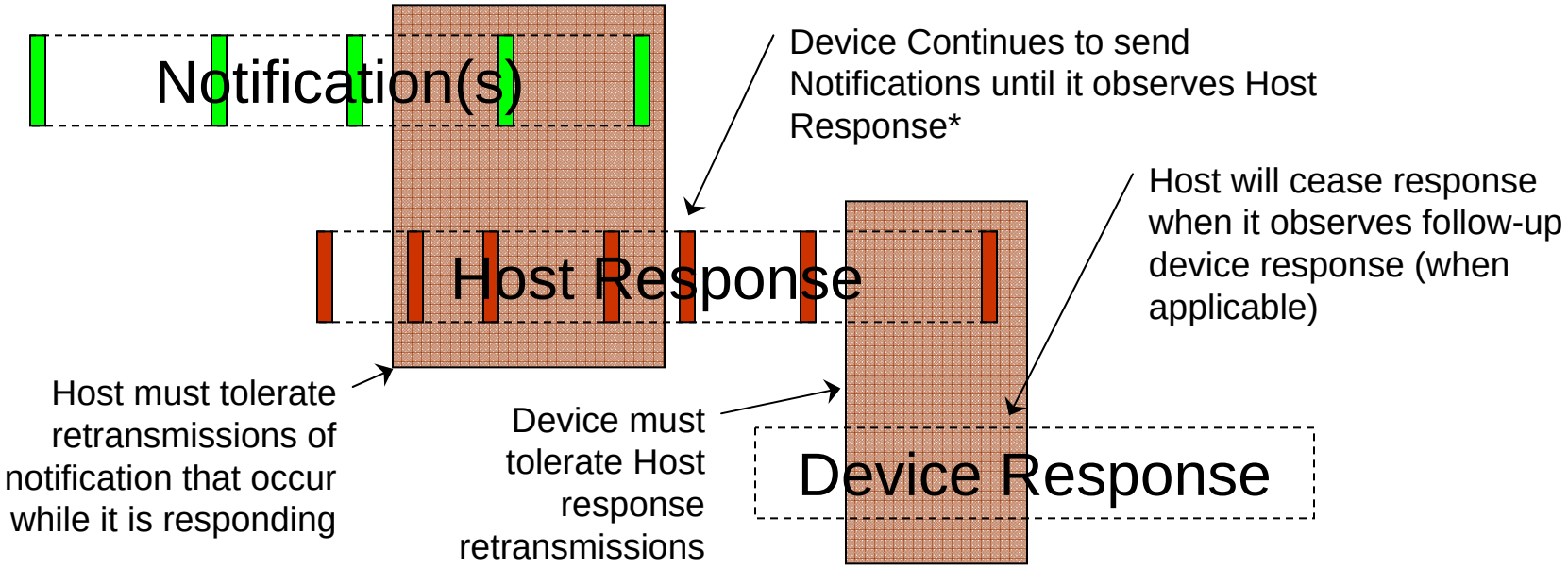
DNTS Access Method
Contention Based: Slotted Aloha

- Fixed (maximum) sized message
  - DNTS is a window of uniform sized message slots
- W_{DNTS}CTA indicates number of message slots
- Device selects a message slot using a uniformly distributed random integer value (in range 1 to N)
- Device transmits message a message slot start time
- Device uses only one slot per W_{DNTS}CTA



Device Notifications
Reliability

- Protocol for Device Notifications is designed for unreliability of channel



*For Endpoint Ready notifications there is 50 ms on/off cycle

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