



Radio Control Interface for Host Wire Adapter

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Outline

- Rationale
- Commands & Events
- Sample architectures
- Division of responsibilities between Host and Adapter
- Some examples



Introduction

Why a Dedicated Interface?

- A Host Wire Adapter (HWA) contains a WiMedia UWB radio
- The Radio Control Interface (RCI) allows the host software to control and configure the radio in a HWA.
- Some of the functionalities that must be implemented are common to any WiMedia node
- A WUSB HWA implements all mandatory and a subset of optional functionalities defined by WiMedia.
- A standard interface simplifies deployment of other application protocols running on the host and sharing the radio with Wireless USB.

Rationale



- Low Cost, Low Complexity
 - Only the functionalities with tightest timing requirements are embedded in the HWA
- Coexistence and Scalability
 - Expose common radio functionalities, enabling extensions for other protocols. → *Common WiMedia platform*
 - Compatible with WiMedia's MAC Convergence Layer
- High Flexibility
 - Enable early development of Wire Adapters while WiMedia specifications are finalized

Radio Control Interface: Principles of Operation

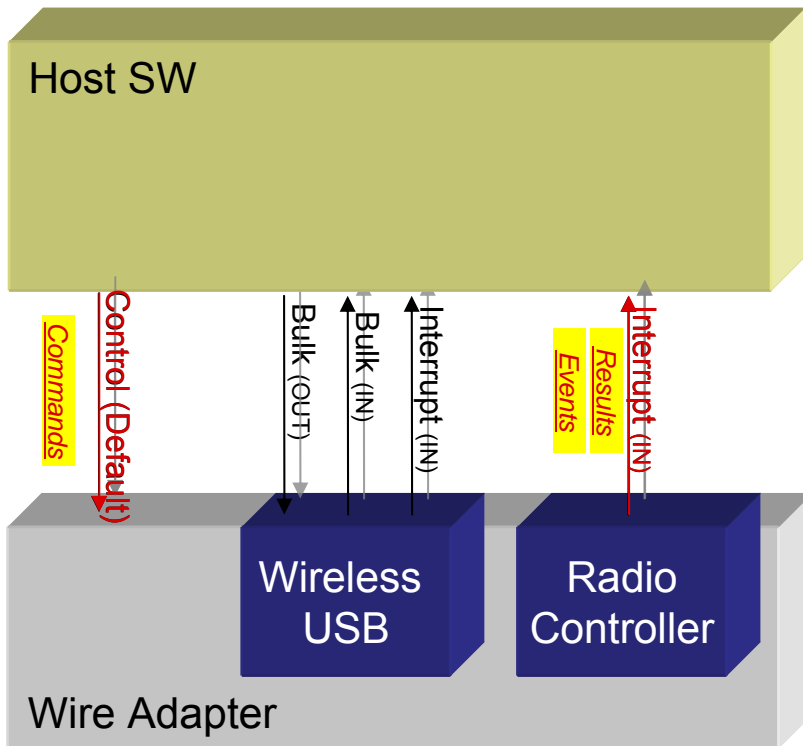


- Host → Radio

- Host sends commands to Radio Controller via the HWA's default control endpoint
- Radio Controller returns command status and results to host via its interrupt endpoint

- Radio → Host

- Radio Controller sends asynchronous notifications (events) to host through its interrupt endpoint
 - Notification filter should be set by host



Commands



Value	Command	Brief Description
16	Channel Change	Instruct the adapter to change operating channel after informing neighboring devices
17	Device Address	Query or set the 16-bit device address or EUI-64 address used by the adapter
18	Get IE	Retrieve Information Elements transmitted by the adapter
19	Reset	Reset the adapter's radio to the default power on state
20	Scan	Instruct the adapter to start or stop a scan operation
21	Set Beacon Filter	Enable/disable notifications of events related to neighboring devices' beacons.
22	Set DRP IE	Set the DRP IEs to be included in the adapter's beacon
23	Set IE	Set any of the host settable IEs to be included in the adapter's beacon
24	Set Notification Filter	Instruct the device to filter one or more notification
25	Set TX Power	Set the default power for transmissions by the adapter of packets (for which power level is not set by other means)
26	Sleep	Instruct the device to enter hibernation state after informing neighboring nodes (if remote wakeup is not enabled).
27	Start Beacons	Instruct the adapter to begin beacons on the selected channel and join the specified beacon period
28	Stop Beacons	Instruct the adapter to stop beacons

Events



Value	Command	Brief Description
0	AS Probe IE Received	Reception of an Application-specific Probe IE from another node
1	Beacon Received	Reception of a beacon (during scan operation or according to beacon notification filter)
2	Beacon Size Change	Change in the size of the beacon transmitted by the adapter (due to a modification of one or more of the IEs handled by the adapter).
3	BPOIE Change	Change of the BPOIE transmitted by the adapter
4	BP Slot Change	Change of the beacon slot in which the adapter is transmitting its beacon
5	BP Switch IE Received	Detection of a BP Switch IE in a neighboring node's beacon
6	Device Address Conflict	Detection of a device address conflict
7	DRP Availability Change	Change in own DRP availability
8	DRP	Detection of a request to create (or modify) a DRP - implicit or explicit destined to own device address or multicast address. Also detection of DRP conflict.

Radio Control Commands

- Sent using a Control Transfer Request via HWA's Default Control Endpoint
- Encapsulated within a Radio Control Command Block

bmRequestType	bRequest	wValue	wIndex	wLength	Data
00100001B	EXEC_RC_CMD (40)	Zero	Interface Number	Command Length	Radio Control Command Block

CHANNEL_CHANGE	16
DEV_ADDR	17
GET_IE	18
RESET	19
SCAN	20
SET_BEACON_FILTER	21
SET_DRP_IE	22
SET_IE	23
SET_NOTIFICATION_FILTER	24
SET_TX_POWER	25
SLEEP	26
START_BEACONING	27
STOP_BEACONING	28

bCommandType	wCommand	bCommandContext	Parameter0	...	ParameterN-1
GENERAL 0 VENDOR SP. F0-FFH	[16-28]	ID 1-FEH Response FFH	Size and data are specific to each command		

Radio Control Events

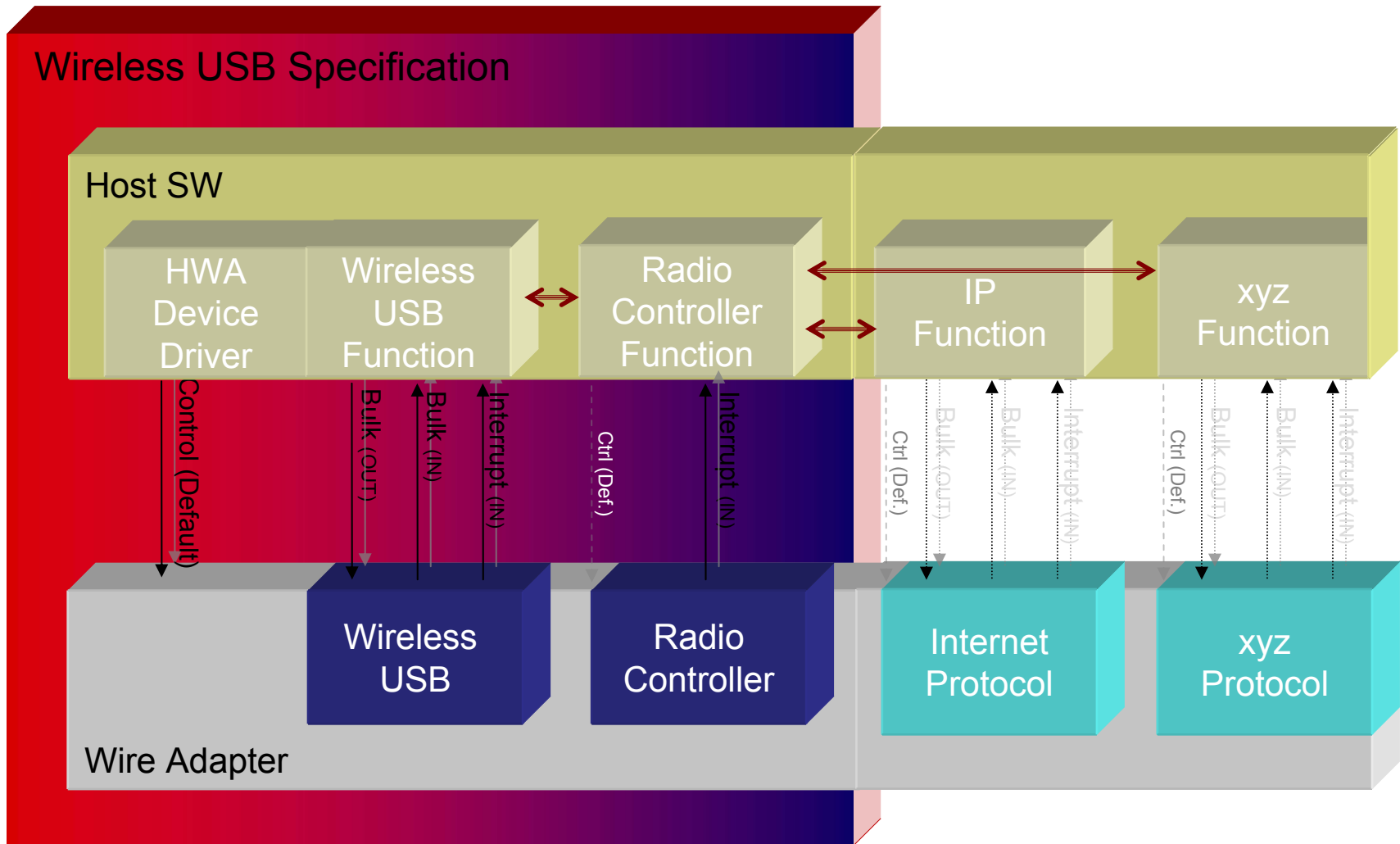
- All commands must be confirmed by the Adapter using an Event Block sent via the Interrupt endpoint.
- If asynchronous notifications are enabled, these are also sent using an Event Block sent via the Interrupt endpoint.

bEventType	wEvent	bEventContext	Parameter0	...	ParameterN-1
GENERAL 0 VENDOR SP. F0-FFH	NOTIFICATIONS [0-8] RESULTS [16-28]	EVENT 0 RESULT 1-FEH	Size and data are specific to each command		

AS_PROBE_IE_RECEIVE	0
BEACON_RECEIVED	1
BEACON_SIZE_CHANGE	2
BPOIE_CHANGE	3
BP_SLOT_CHANGE	4
BP_SWITCH_IE_RECEIVED	5
DEV_ADDR_CONFLICT	6
DRP_AVAILABILITY_CHANGE	7
DRP	8

CHANNEL_CHANGE	16
DEV_ADDR	17
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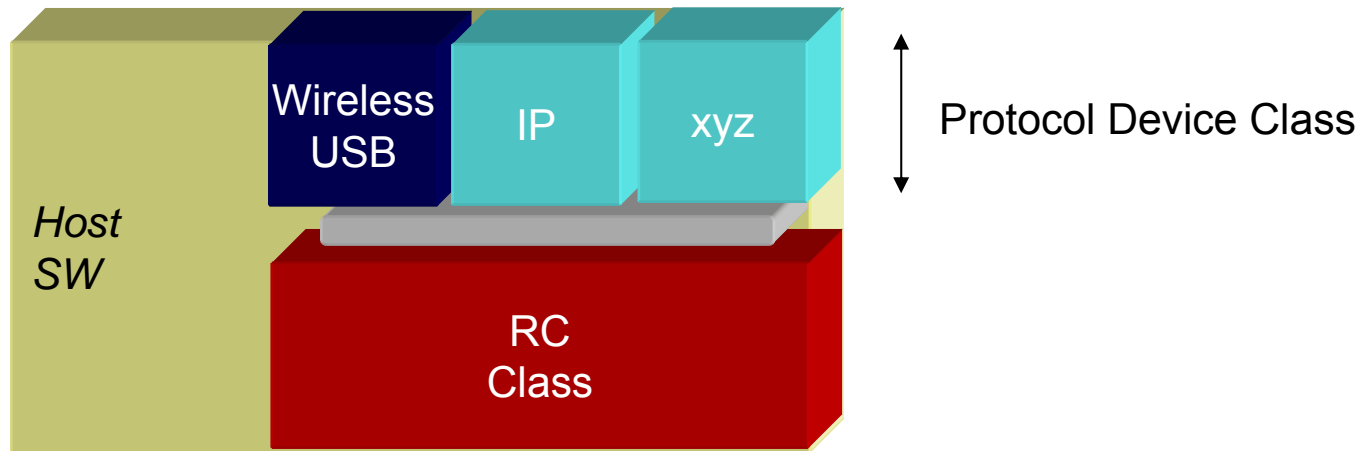
Architecture & Scope



Radio Controller & Protocol Function Drivers



- Different Protocol Function Drivers interact with the Radio Controller Function Driver in the Host
- The Radio Controller Function Driver manages all individual requests to the Radio
- Each Protocol Function Driver is responsible for properly configuring and operating its associated block in the HWA

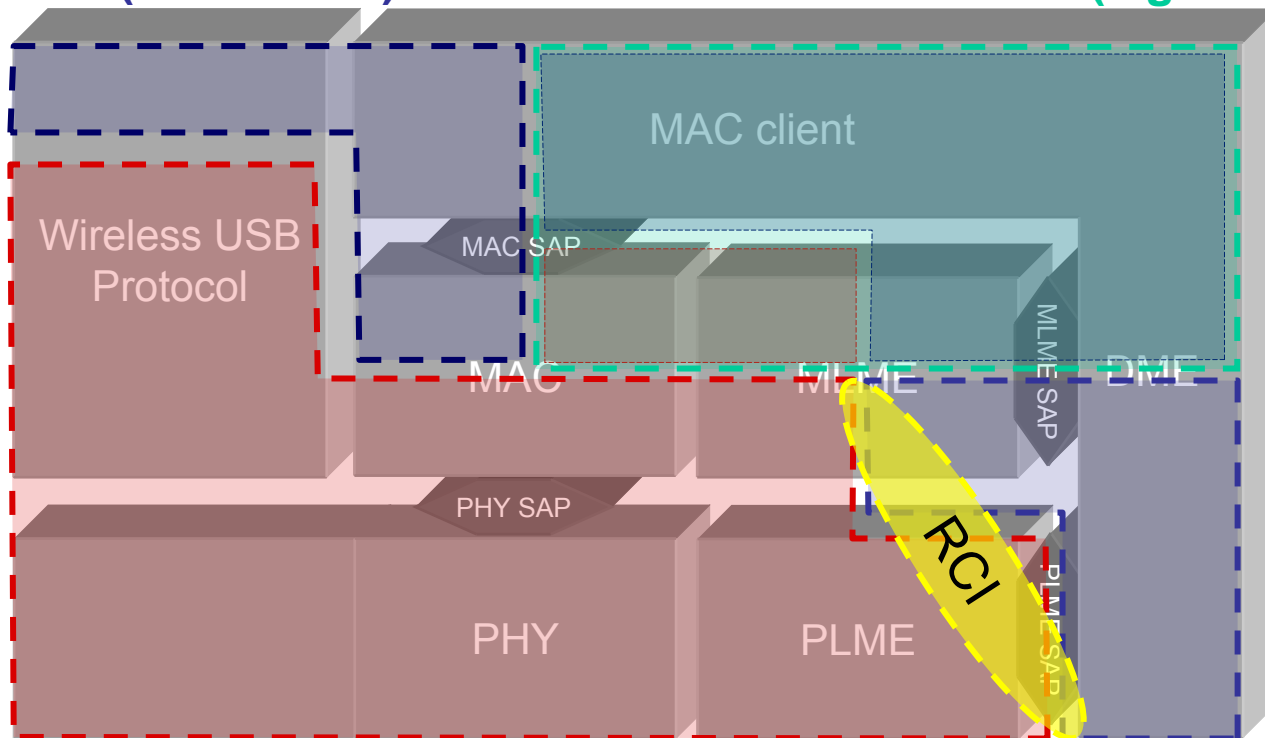


WUSB HWA and WiMedia



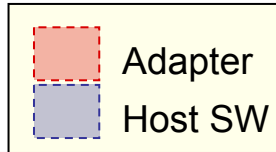
Host Client
(HWA class)

Extensions to HWA
(e.g. IP class)



Wireless USB Host Wire Adapter

Host Client
(RC class)



WiMedia Beaconsing Overview



- WiMedia beacon protocol
 - Beacon Period
 - Beacon Protection/BPOIE
 - Synchronization/BPST
 - Beacon Slots
 - Contraction/Expansion
 - Alien BP

WiMedia Reservations Overview

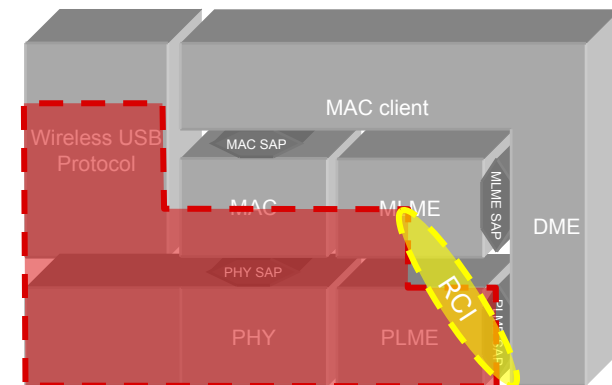


- WiMedia Distributed Reservation Protocol
 - Implicit DRP
 - Explicit DRP
 - DRP Information Element
 - DRP Availability Map

Radio Controller Responsibilities: Beaconing



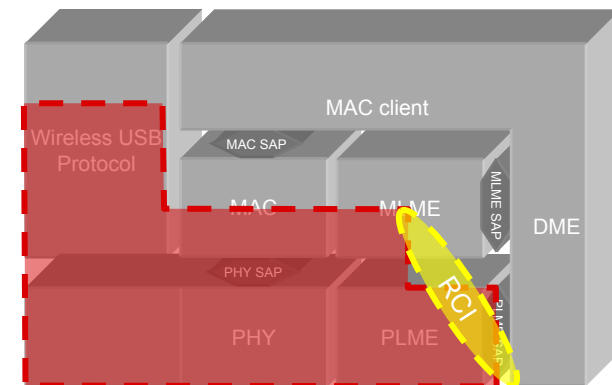
- Radio Controller is responsible for transmitting its beacon according to WiMedia rules.
 - Beacon Period(s) discovery
 - Super-frame synchronization
 - Beacon period Start Time (BPST)
 - Slowest clock in the Beaconing Group
 - Beacon Slot selection
 - Beacon Period contraction/expansion
 - Beacon transmission
 - Beacon reception
 - Processing of primary IEs
 - (see next slide)



Radio Controller Responsibilities: Primary IEs Processing



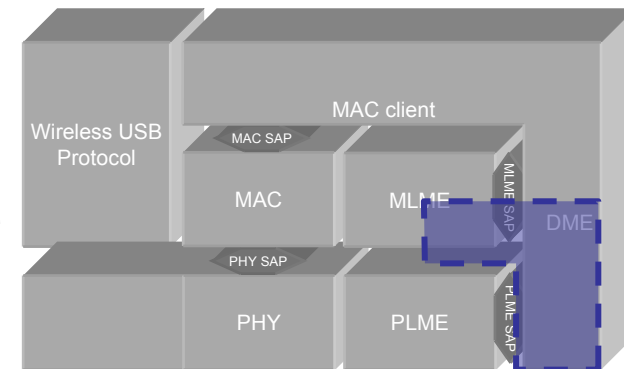
- Time critical Information Elements
 - DRP IE processing
 - BPOIE processing
 - Keep own BPOIE up-to-date
 - Keep own availability map up-to-date
 - Detection of conflicts
 - DRP-IE
 - Beacon Slot
 - Dev-ID



Radio Controller Function Driver Responsibilities: Configuration & Secondary IEs



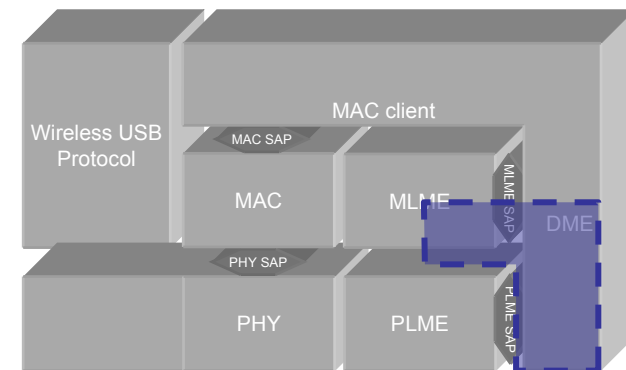
- Radio Controller Function Driver (RCFD) is responsible for the initial configuration of the adapter's radio
 - Device address
 - Addresses generation and conflict resolution
 - Channel scan and selection
 - Channel change
- It is RCFD's responsibility to instruct the adapter's radio to start and stop beaconing
- Information Elements
 - Generation and Management of other IE's (i.e. non beacon protocol) included in HWA's beacon
 - (see next slide)
 - Configuration of notification filters as appropriate
 - Processing of IE's received by the HWA
 - Response generation



Radio Control Function Driver Responsibilities: DRP & Power Mgt



- RCFD is entirely responsible for the management of all DRPs owned by the HWA
 - Coordinate requests of all serviced PALs
 - Medium Access Slots (MAS) allocation and redistribution amongst PALs.
 - Reservation Protocol (implicit and/or explicit)
 - Initiate a DRP request
 - Respond to a DRP request
 - Resolve DRP-IE conflicts
- Power Management
 - Hibernation and Wakeup
 - Default Transmit (TX) Power



WiMedia Information Elements Summary



- Adapter

- DRP Availability IE
- Beacon Period Occupancy IE
- Channel Change IE
- Hibernation IE
- DRP-IE (reception)

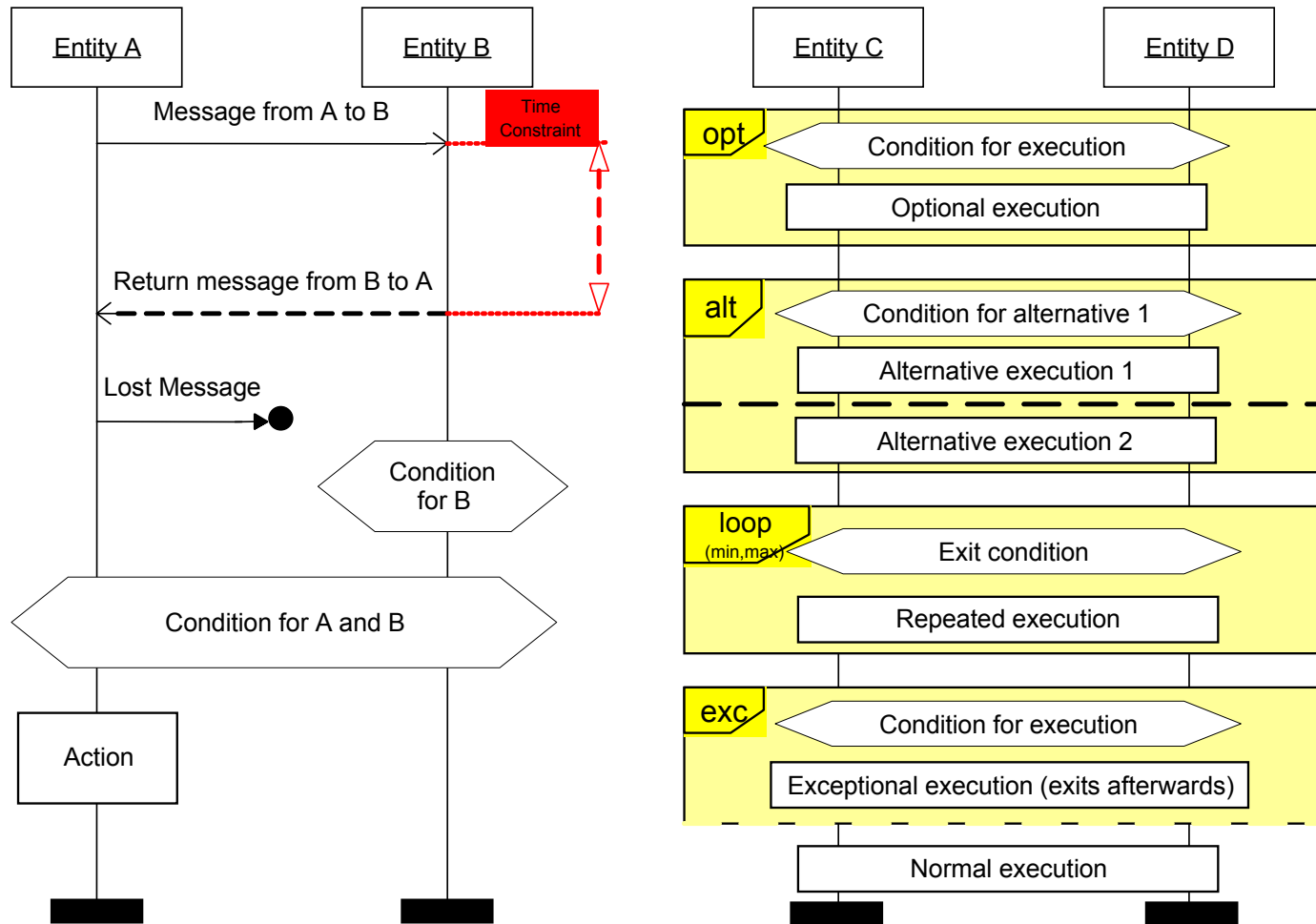
- Host

- DRP-IE (transmission)
- BP Switch IE
- Capabilities IE
- Identification IE
- PCA Availability IE
- Application-specific Probe IE
- Master Key Identifier (MKID) IE
- Application Specific IE (ASIE)

Not used by Wireless USB

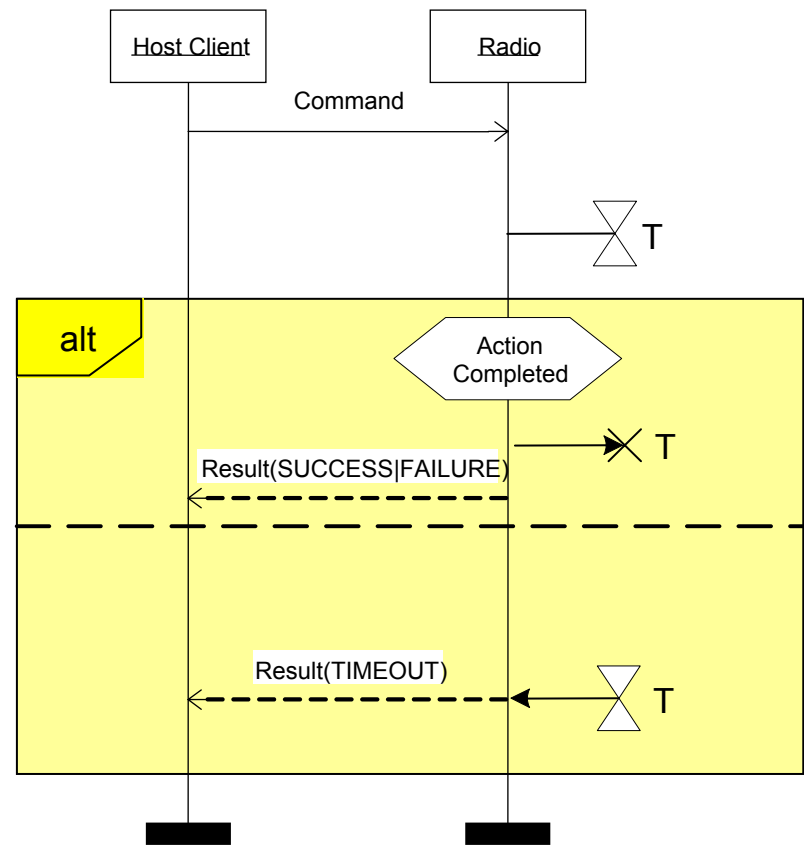
Basic Message Sequence Charts

(My) Graphical Syntax Definition



Request Timeout

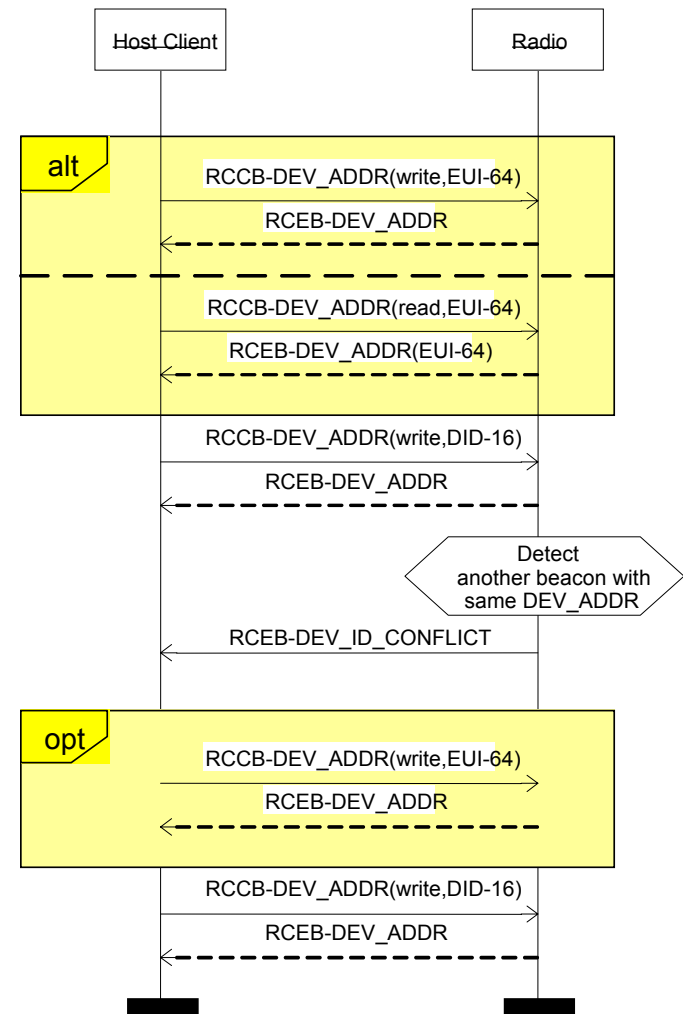
- If the operation requested cannot be completed within a certain time, a **TIMEOUT** failure must be returned in the **bResultCode** of the RCEB
- Length of the time-out is vendor and command specific



Device Address Management



- Each HWA radio must have a IEEE defined 64-bit extended unique identifier (EUI-64)
 - This can be either statically configured or assigned by the host
- Each HWA must also be assigned a 16-bit device address (DevAddr)
 - It is host's responsibility to assign one to the adapter and modify it as needed



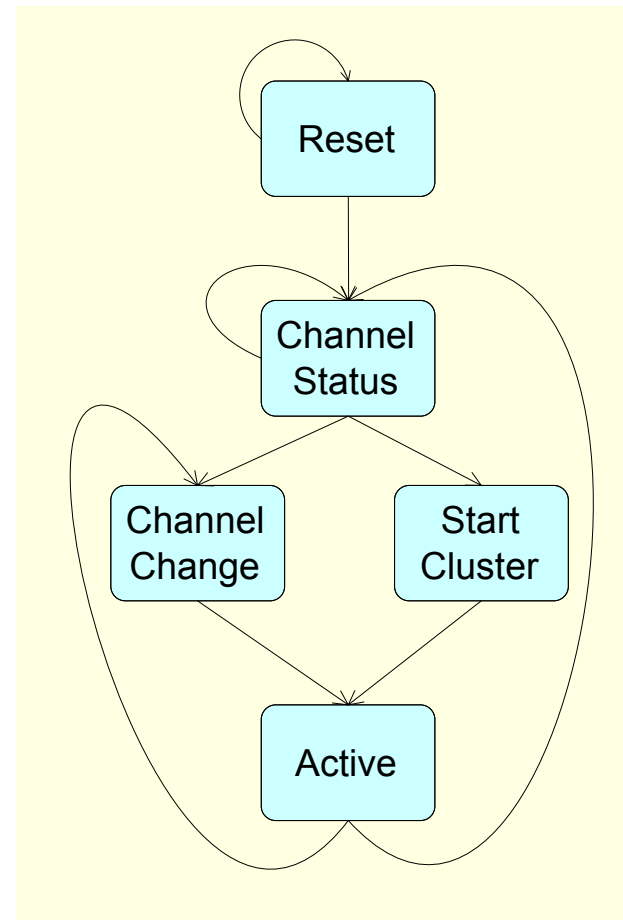


Sleep & Wake

- Hibernation
 - Host can instruct adapter radios to enter hibernation and stop beaconing
 - Beacon slot is reserved for a finite number of super-frames.
- It is host's responsibility to wake up a hibernating adapter's radio and determine next course of action
 - Restart beaconing if within the number of super-frame advertised before sleeping
 - Rescanning if not
- Orthogonal to power management schemes specific to each serviced protocol
 - E.g.: for Wireless USB Host with Remote Wake enabled
 - Radio should NOT hibernate, and continue beaconing normally
 - Reservations are maintained (optionally released)
 - MMCs are periodically transmitted in order to receive notification messages from WUSB devices.
 - Host is notified of any conflict.
 - E.g.: for Wireless USB Host with Remote Wake disabled
 - Channel Stop IE in MMC if needed
 - Radio can hibernate if no other protocol functions are active

Examples

- What follows are simple examples that illustrate some possible interactions between function driver and embedded radio controller, with respective responsibilities.

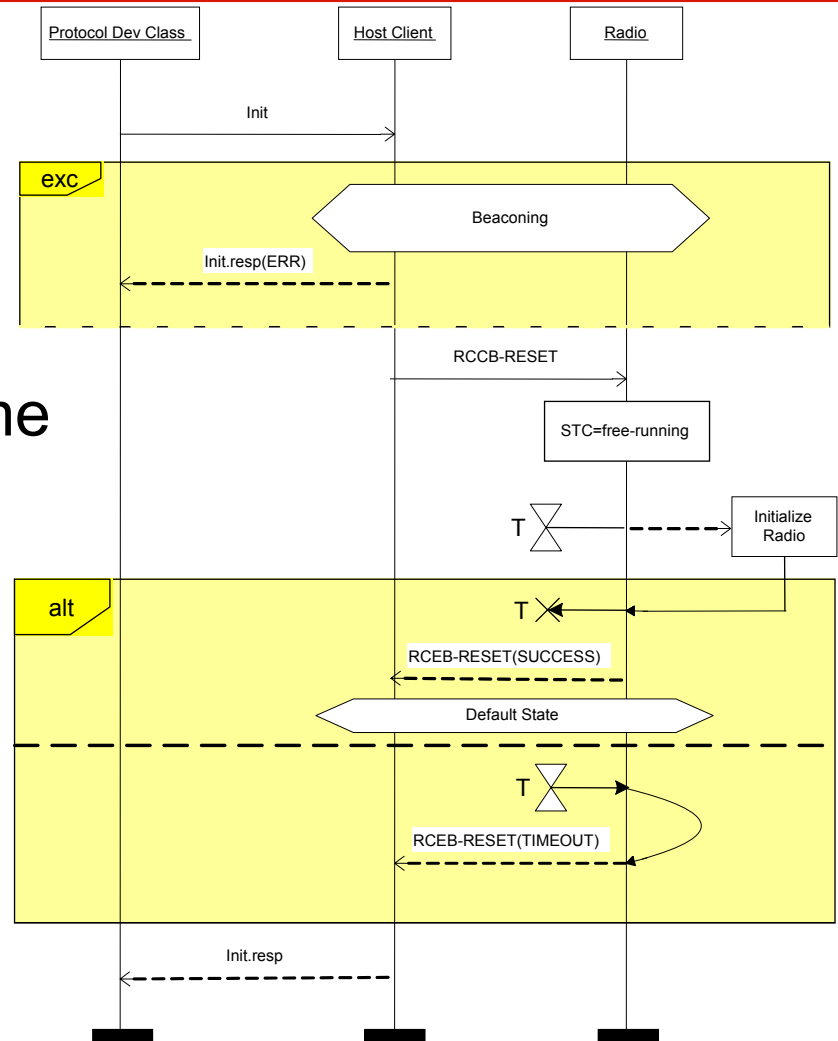


A simple flow

Example: Reset



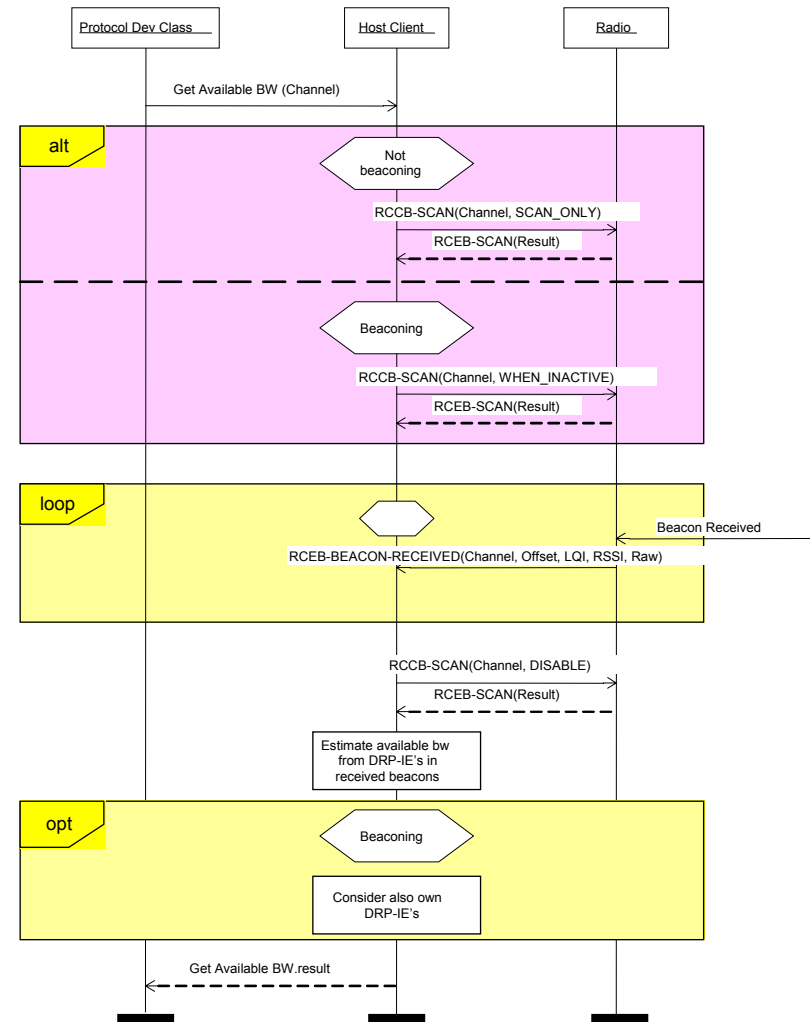
- Reset conditions:
 - Highest transmission power level
 - Free-running Superframe Time Counter (STC)
 - Scan disabled
 - Beacon notification off
 - Notification filters all off
 - Buffers empty



Example: Channel Status/Info



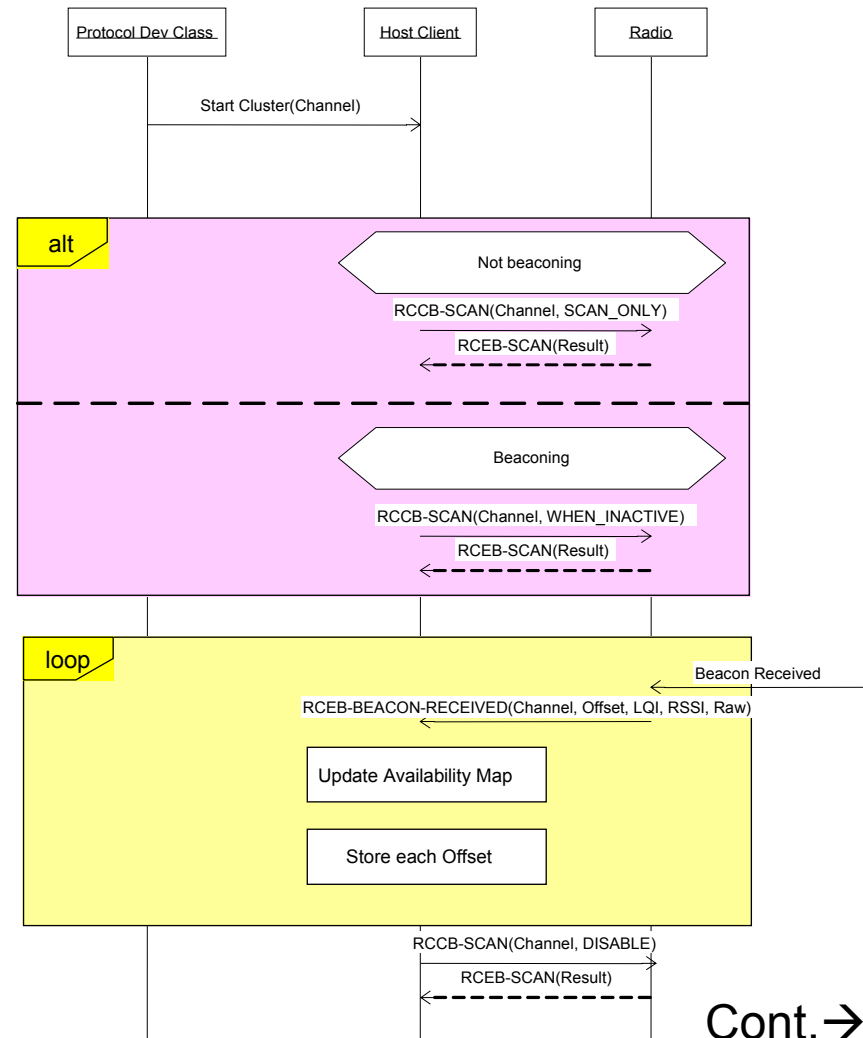
- Example: request from a protocol class driver to determine what channel is best or as periodical monitoring of active channel status



Example: Start Cluster



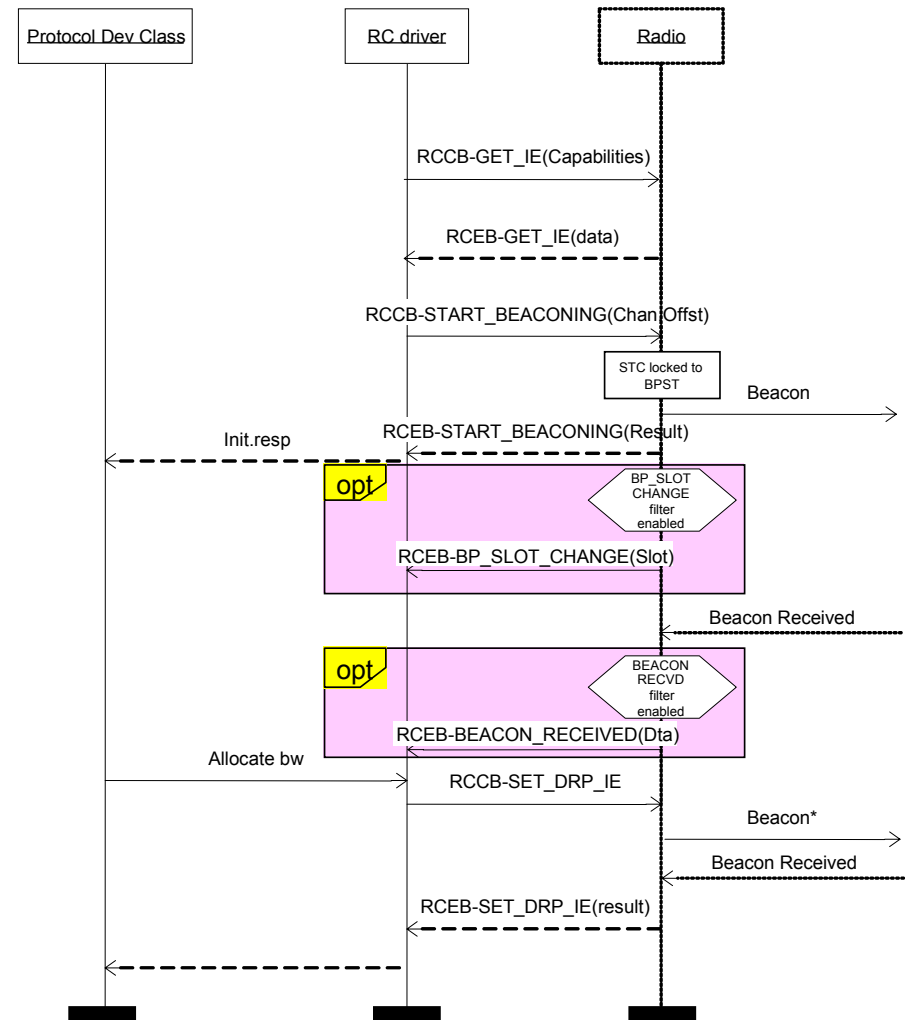
- Before it can start beaconing the RCFD must properly configure the Adapter's radio.
- It is radio's responsibility to detect any DRP-IE changes in received beacons which may affect its DRP availability map.
- Before joining a Beacon Period, the adapter's Superframe Time Counter (STC) is a free running-timer.



Cont. →

Example: Start Cluster (cont.)

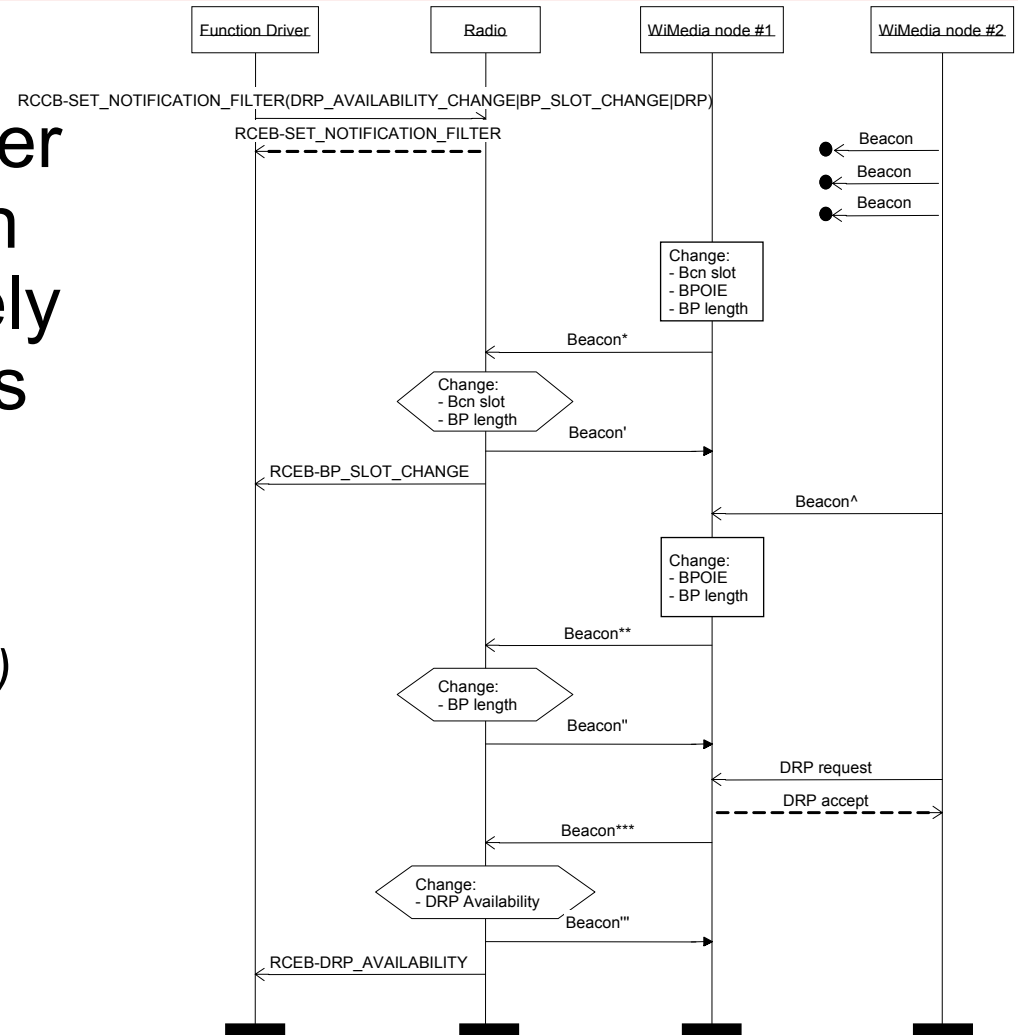
- Adapter must follow WiMedia MAC rules to select the proper beacon slot.
 - (see [here](#) for an illustrative example)
- Correctness of all elements contained in the transmitted beacon is adapter's responsibility.
 - Adapter should not change order of IE's set by the host, but should insert others as proper.



Example: Notifications



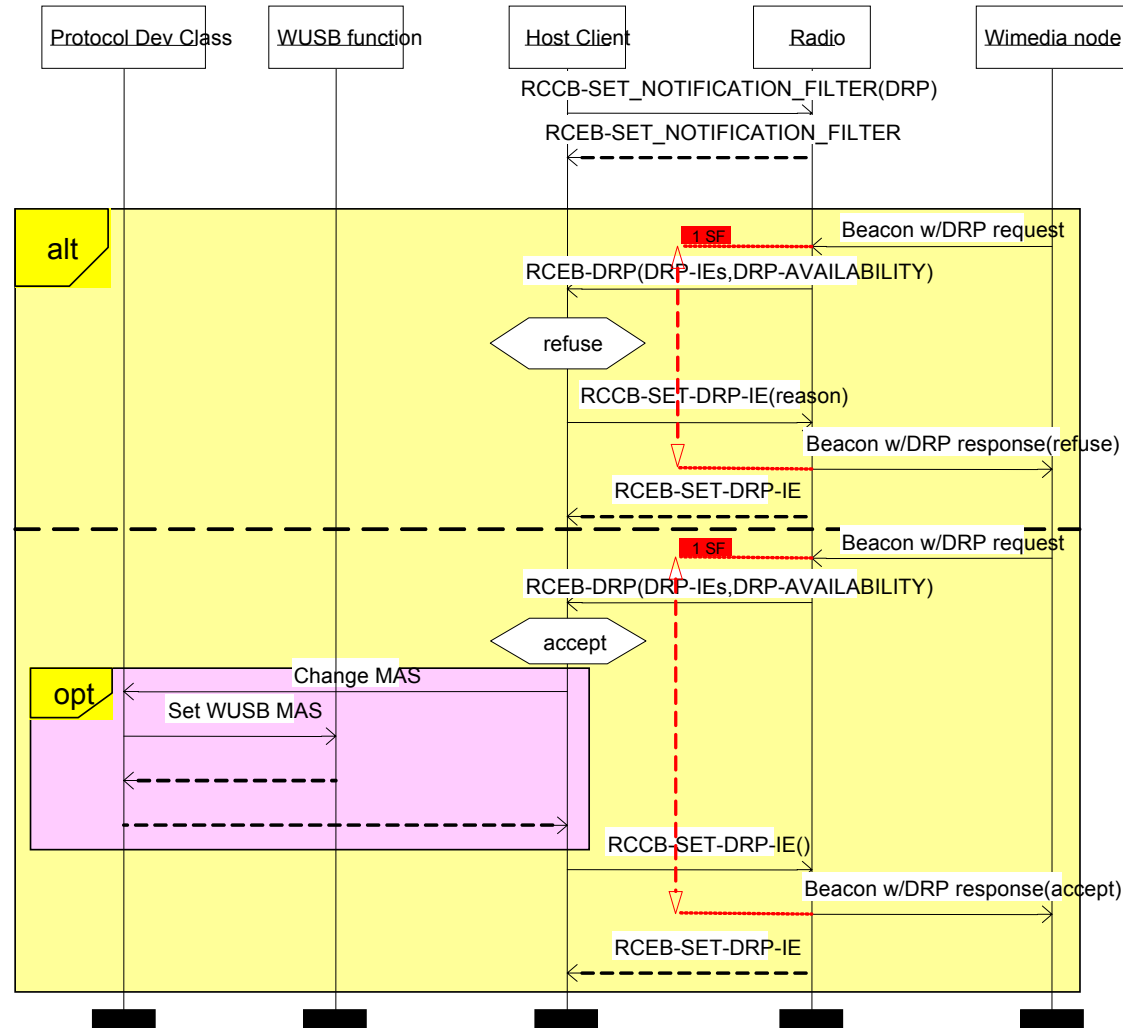
- The Radio Controller Function Driver can choose to selectively receive notifications of beacon protocol related events.
- By default (*reset state*) all notifications are disabled.



Example: Notifications (cont.)



- Upon reception of an implicit DRP request addressed to the device, a DRP-IE in response (accept, refuse or pending) must be included in next adapter's beacon.
- RCFD is responsible for modifying the DRP-IE set - and including a response - before next beacon is transmitted



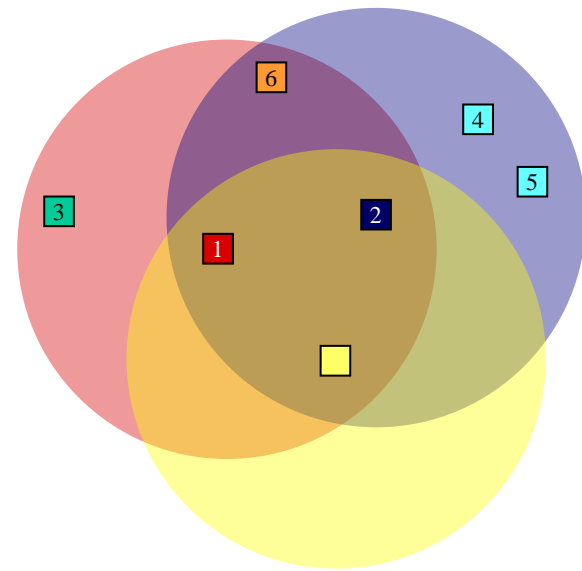
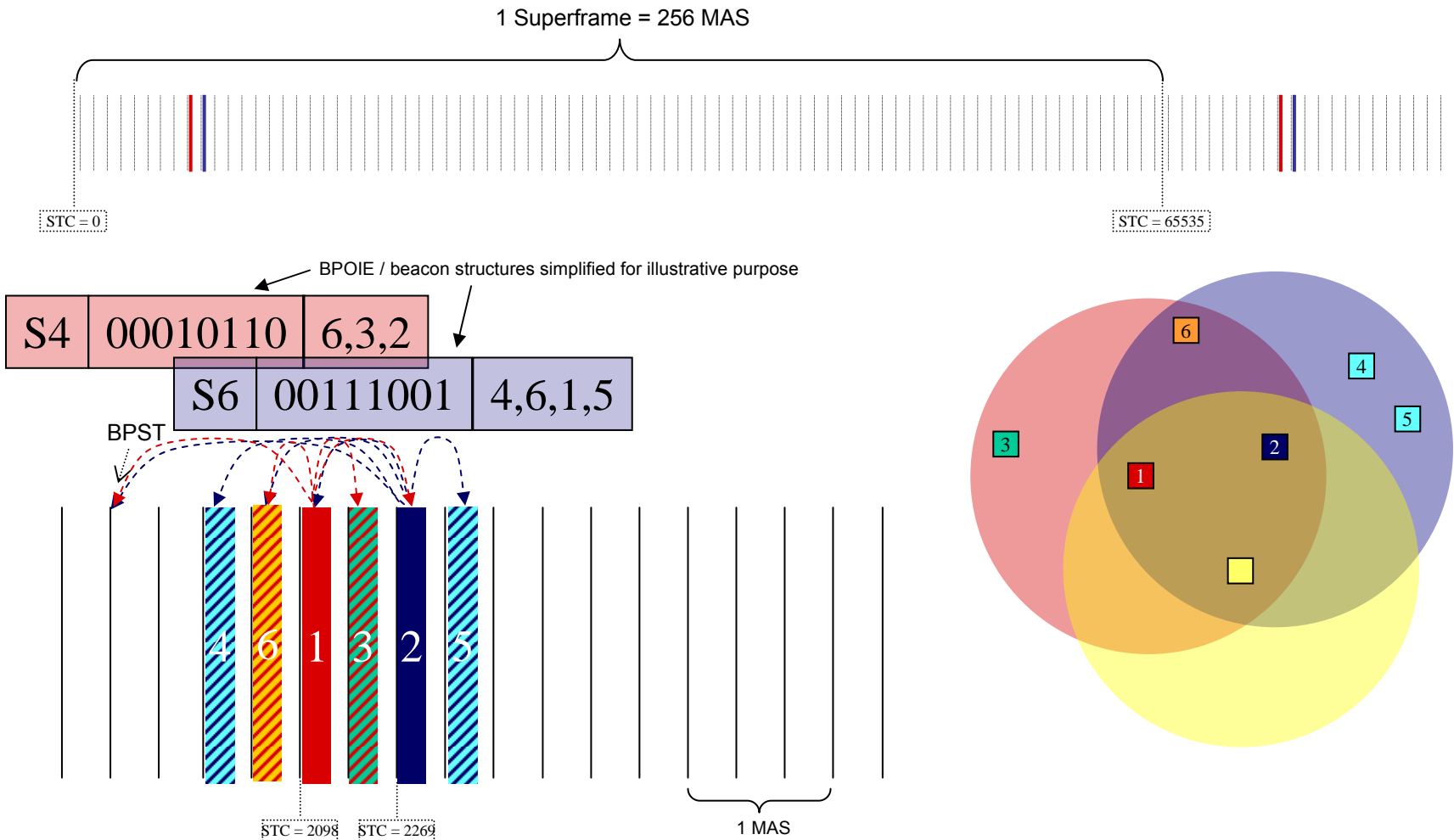


The End

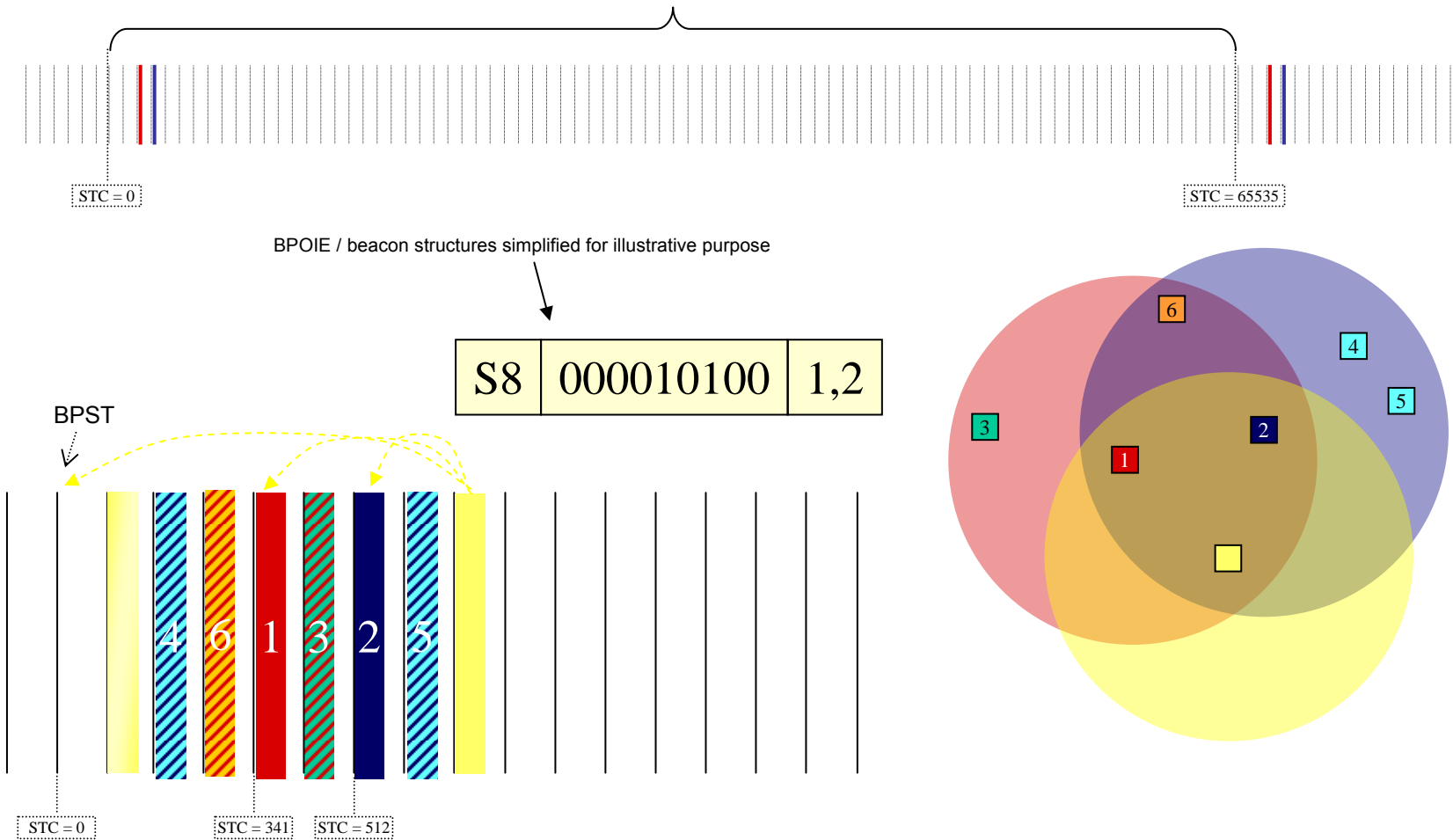


Back-up Foils

Example: Discovering a Beacon Period



Example: Joining a Beacon Period



Capabilities IE

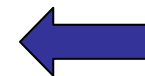
octets: 1	1	2	X
Element ID	Length (=2+X)	Capability Bitmap	Reserved

Octet	Bit	Attribute	Description
0	0	PCA	Capable of transmitting and receiving frames using the PCA mechanism
	1	Hard DRP	Capable of being the owner and target of Hard DRP reservations
	2	Soft DRP	Capable of being the owner and target of Soft DRP reservations
	3	Block ACK	Capable of transmitting and acknowledging frames using the B-ACK mechanism
	4	Explicit DRP negotiation	Capable of negotiating a DRP reservation using command frames
	5	Hibernation anchor	Capable of acting as a hibernation anchor
	6	Probe	Capable of responding to Probe IEs received in beacons and command frames
	7	Link feedback	Capable of generating and interpreting a Link Feedback IE
1	0	Range measurement	Capable of initiating and participating in range measurement calculations
	1-7	Reserved	Reserved

Descriptors

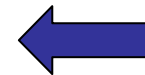


Offset	Field	Size	Value	Description
0	<i>bLength</i>	1	9	Size of this descriptor in bytes, including this field.
1	<i>bDescriptorType</i>	1	4	INTERFACE Descriptor Type
2	<i>bInterfaceNumber</i>	1	Number	Number of this interface
3	<i>bAlternateSetting</i>	1	0	Value used to select this alternate setting for the interface identified in the prior field
4	<i>bNumEndpoints</i>	1	1	Number of endpoints used by this interface.
5	<i>bInterfaceClass</i>	1	E0H	Wireless Controller
6	<i>bInterfaceSubclass</i>	1	01H	RF Controller
7	<i>bInterfaceProtocol</i>	1	02H	UWB Radio Control Interface
8	<i>iInterface</i>	1	Index	Index of String Descriptor describing this interface



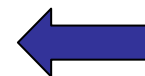
Interface

Offset	Field	Size	Value	Description
0	<i>bLength</i>	1	4	Size of this descriptor in bytes, including this field.
1	<i>bDescriptorType</i>	1	23H	Radio Control Descriptor Type
2	<i>bcdRCVersion</i>	2	0100H	Radio Control Interface Version number in Binary-Coded Decimal.



Class

Offset	Field	Size	Value	Description
0	<i>bLength</i>	1	7	Size of this descriptor in bytes, including this field.
1	<i>bDescriptorType</i>	1	5	ENDPOINT Descriptor Type
2	<i>bEndpointAddress</i>	1	Number	The address of this endpoint
3	<i>bmAttributes</i>	1	Bitmap	Interrupt endpoint of 00000011b.
4	<i>wMaxPacketSize</i>	2	200H	Maximum packet size this endpoint
6	<i>bInterval</i>	1	1	Interval for polling endpoint for data transfers. Expressed in frames or microframes depending on the device operating speed (i.e., either 1 millisecond or 125 μ s units).

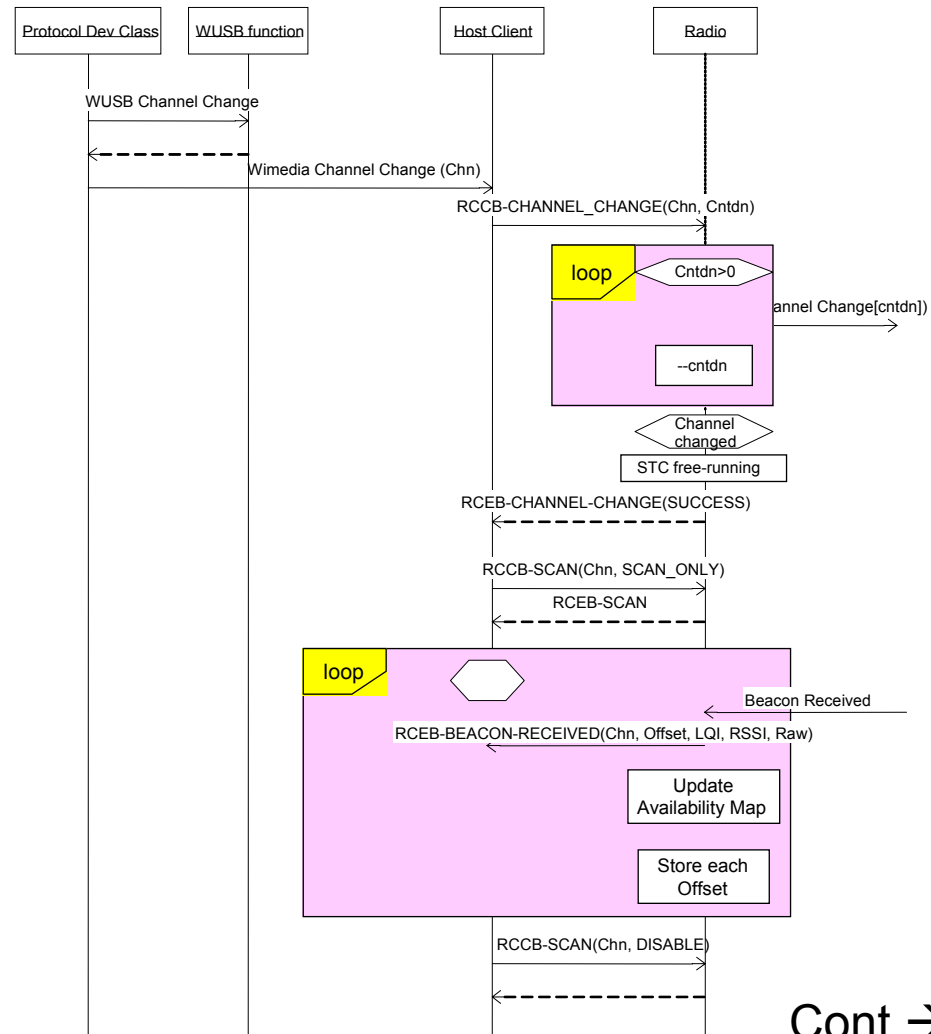


Endpoint

Example Channel Change



- When instructing the adapter's radio to change channel, the host must ensure that no packets are transmitted by any protocol functions before beaconing is successfully re-started.
- Adapter radios will switch to the new channel only after it has transmitted a Channel Change IE for the specified number of super-frames.



Cont. →

Example: Channel Change (cont.)

- It is the host's responsibility to ensure that other protocol functions are informed of any changes of their reserved channel time (medium access slots, MAS)

