USB 2.0 Specification Chapter 9 USB Device Framework

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Reference

- USB 2.0 specification
  - http://www.usb.org/developers/docs/usb_20_060112.zip
- USB in a Nutshell
  - http://www.beyondlogic.org/usbnutshell/usb1.shtml

Outline

9.1 USB Device States

9.2 Generic USB Device Operations

9.3 USB Device Requests

9.4 Standard Device Requests

9.5 Descriptors

9.6 Standard USB Descriptor Definitions

9.7 Device Class Definitions

Overview

- A USB device may be divided into three layers:
  - The top layer is the functionality provided by the serial bus device, for instance, a mouse or ISDN interface.
  - **The middle layer handles routing data between the bus interface and various endpoints on the device.**
    - **An endpoint is the ultimate consumer or provider of data. It may be thought of as a source or sink for data.**
  - The bottom layer is a bus interface that transmits and receives packets.
- This chapter describes the **common attributes** and operations of the middle layer of a USB device.
  - These attributes and operations are used by the function-specific portions of the device to communicate through the bus interface and ultimately with the host.

Overview

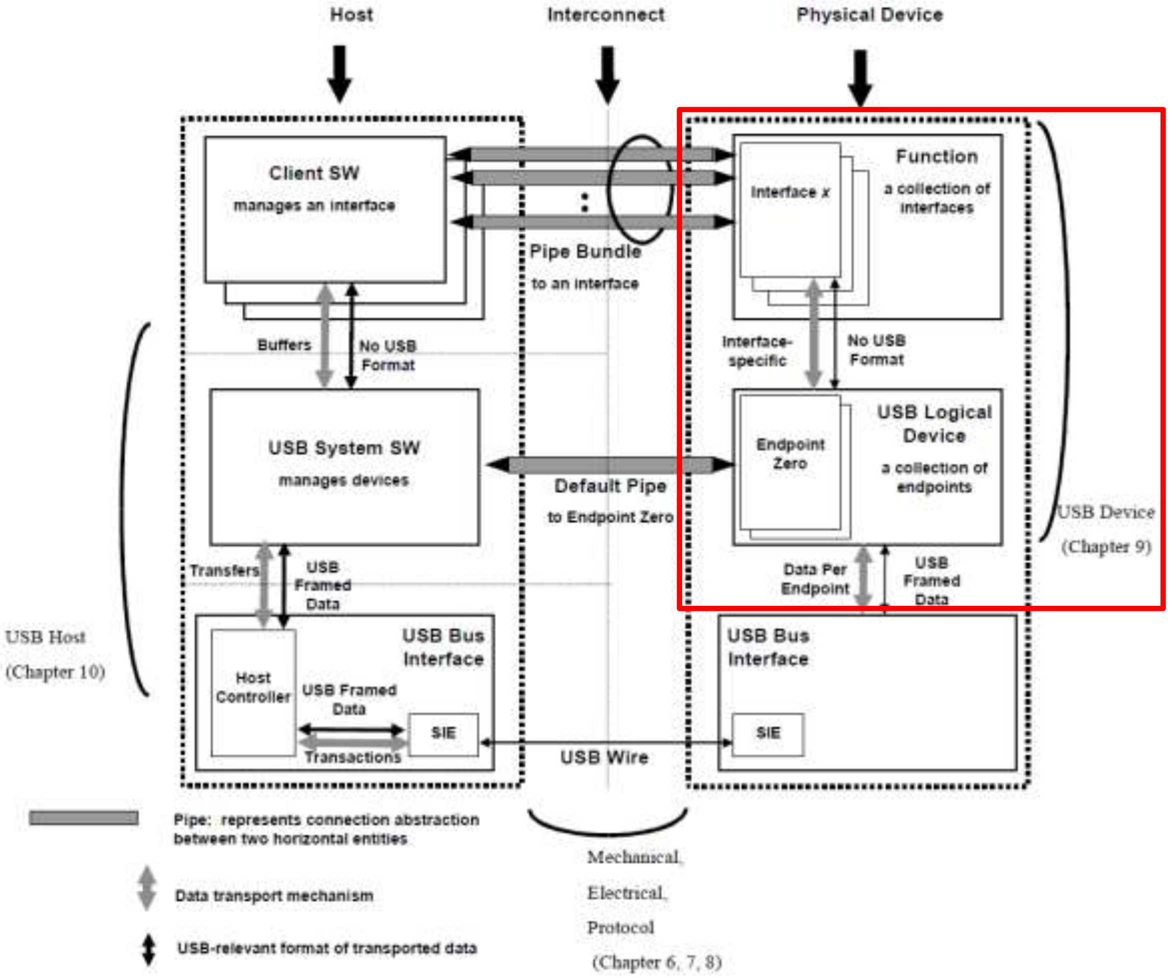


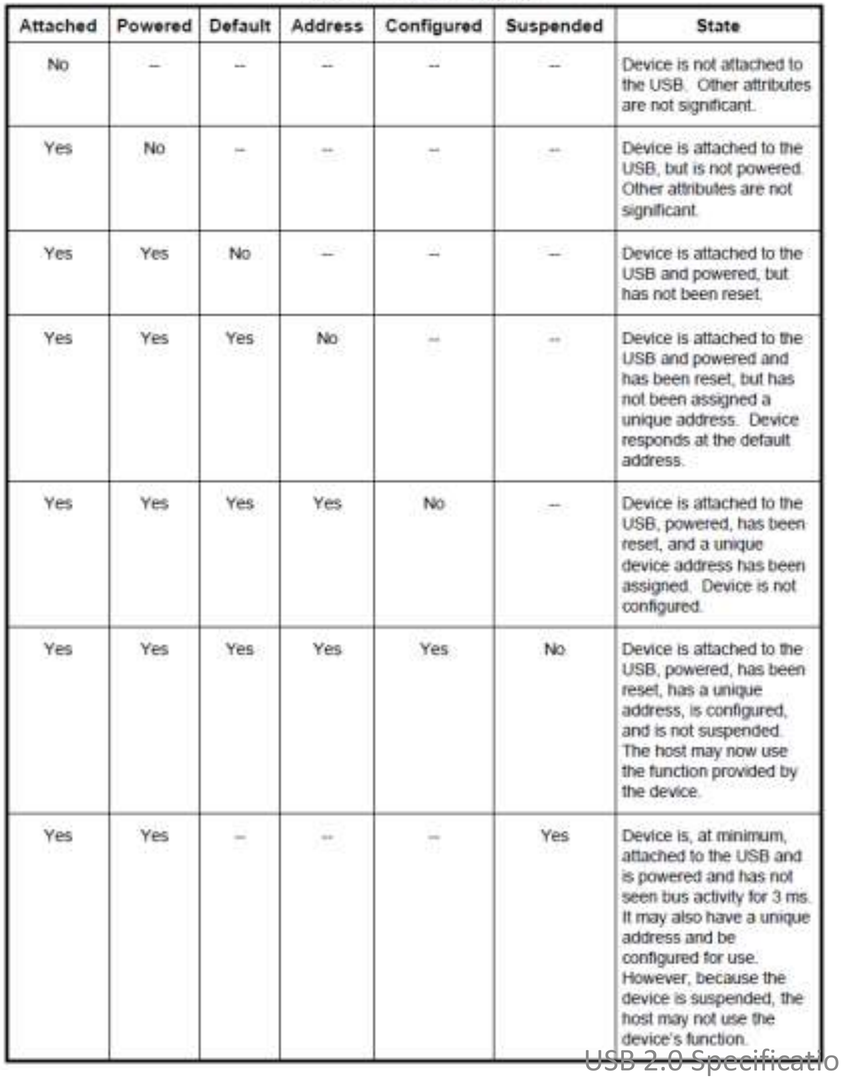
Figure 5-9. USB Host/Device Detailed View

9.1 USB Device States

- 9.1.1 Visible Device States
- 9.1.2 BUS Enumeration

9.1.1 Visible Device States

Table 9-1. Visible Device States



Attached	Powered	Default	Address	Configured	Suspended	State
No	--	--	--	--	--	Device is not attached to the USB. Other attributes are not significant.
Yes	No	--	--	--	--	Device is attached to the USB, but is not powered. Other attributes are not significant.
Yes	Yes	No	--	--	--	Device is attached to the USB and powered, but has not been reset.
Yes	Yes	Yes	No	--	--	Device is attached to the USB and powered and has been reset, but has not been assigned a unique address. Device responds at the default address.
Yes	Yes	Yes	Yes	No	--	Device is attached to the USB, powered, has been reset, and a unique device address has been assigned. Device is not configured.
Yes	Yes	Yes	Yes	Yes	No	Device is attached to the USB, powered, has been reset, has a unique address, is configured, and is not suspended. The host may now use the function provided by the device.
Yes	Yes	--	--	--	Yes	Device is, at minimum, attached to the USB and is powered and has not seen bus activity for 3 ms. It may also have a unique address and be configured for use. However, because the device is suspended, the host may not use the device's function.

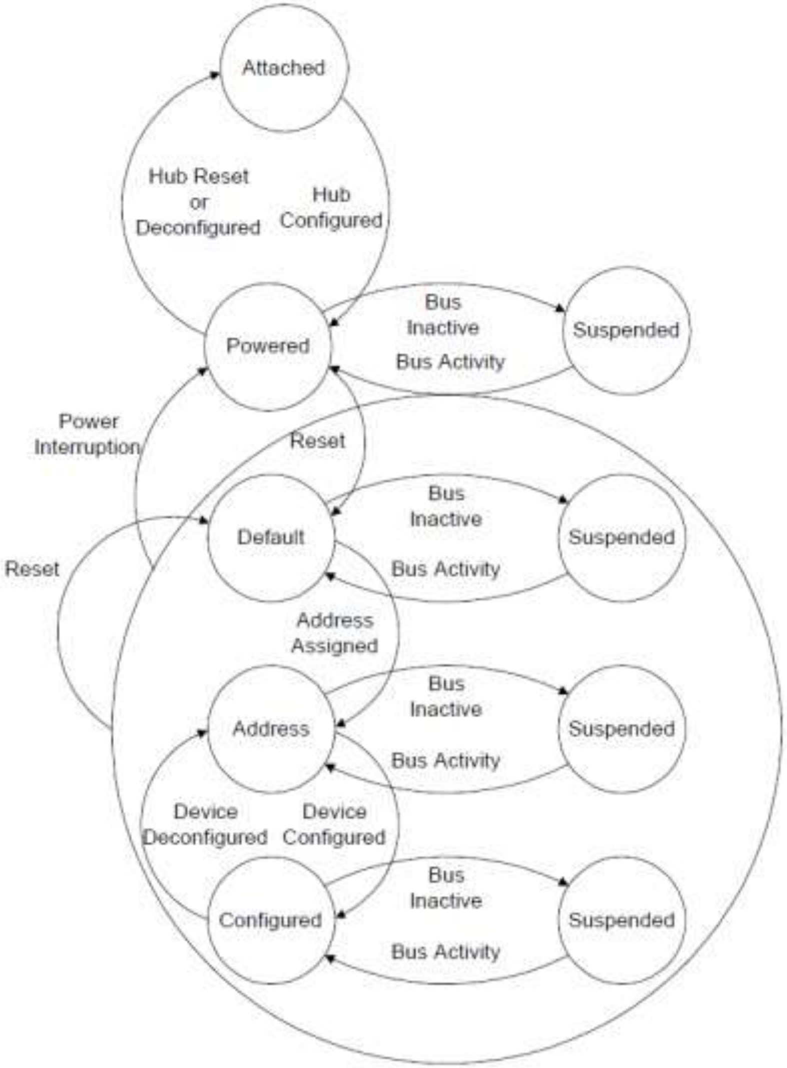


Figure 9-1. Device State Diagram

9.1.1 Visible Device States

- **Attached**

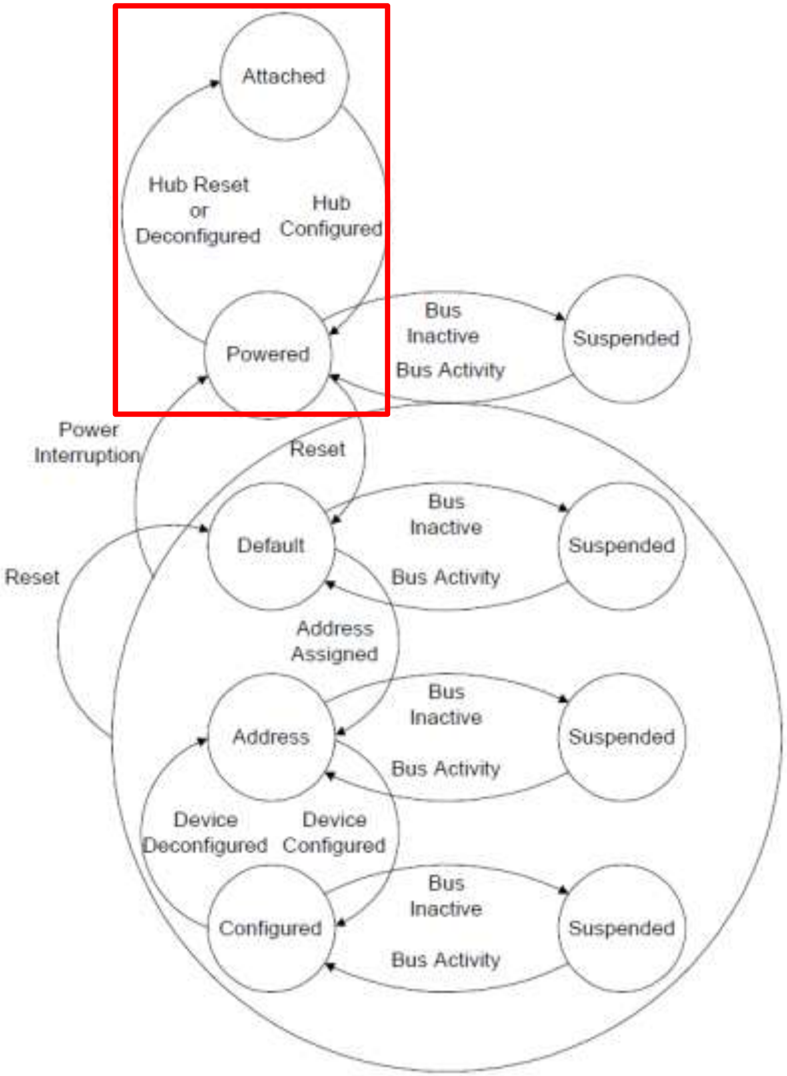


Figure 9-1. Device State Diagram

9.1.1 Visible Device States

- **Powered**

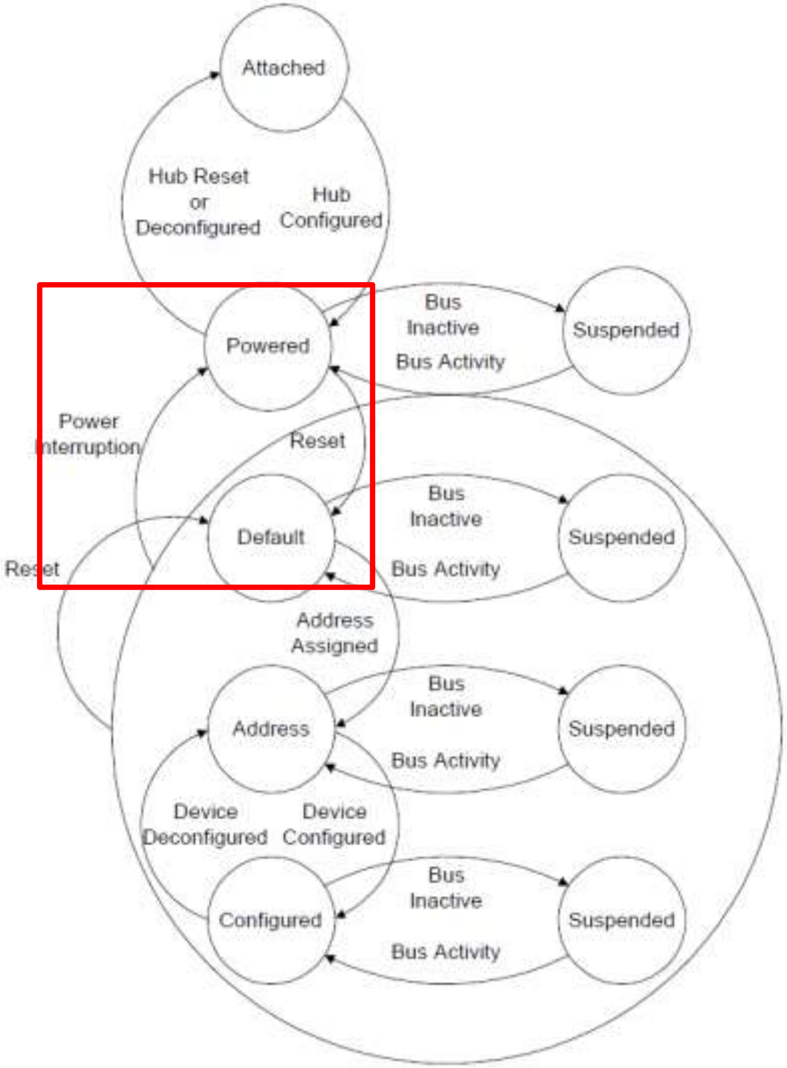


Figure 9-1. Device State Diagram

9.1.1 Visible Device States

- **Powered**
  - Type
    - Self-Powered
    - Bus-powered
  - Both self-powered or bus-powered devices they won’t be considered to be in the Powered state until they are attached to the USB and VBUS is applied to the device.

9.1.1 Visible Device States

- **Powered**
  - Device
    - Devices report their power source capability through the configuration descriptor.
    - The current power source is reported as part of a device's status.
    - Both mode is supported
      - If a configuration is capable of supporting both power modes, the power maximum reported for that configuration is the maximum the device will draw from VBUS in either mode.
      - The device must observe this maximum, regardless of its mode.
    - Only one mode is supported.
      - If a configuration supports only one power mode and the power source of the device changes, the device will lose its current configuration and address and return to the Powered state.
    - If a device is self-powered and its current configuration requires more than 100 mA, then if the device switches to being bus-powered, it must return to the Address state.
    - Self-powered hubs that use VBUS to power the Hub Controller are allowed to remain in the Configured state if local power is lost.

9.1.1 Visible Device States

- **Powered**
  - HUB
    - Bus powered hubs do not provide any downstream power until they are configured.
    - A USB device must be able to be addressed within a specified time period from when power is initially applied (refer to Chapter 7).
    - After an attachment to a port has been detected, the host may enable the port, which will also reset the device attached to the port.

9.1.1 Visible Device States

- **Default**

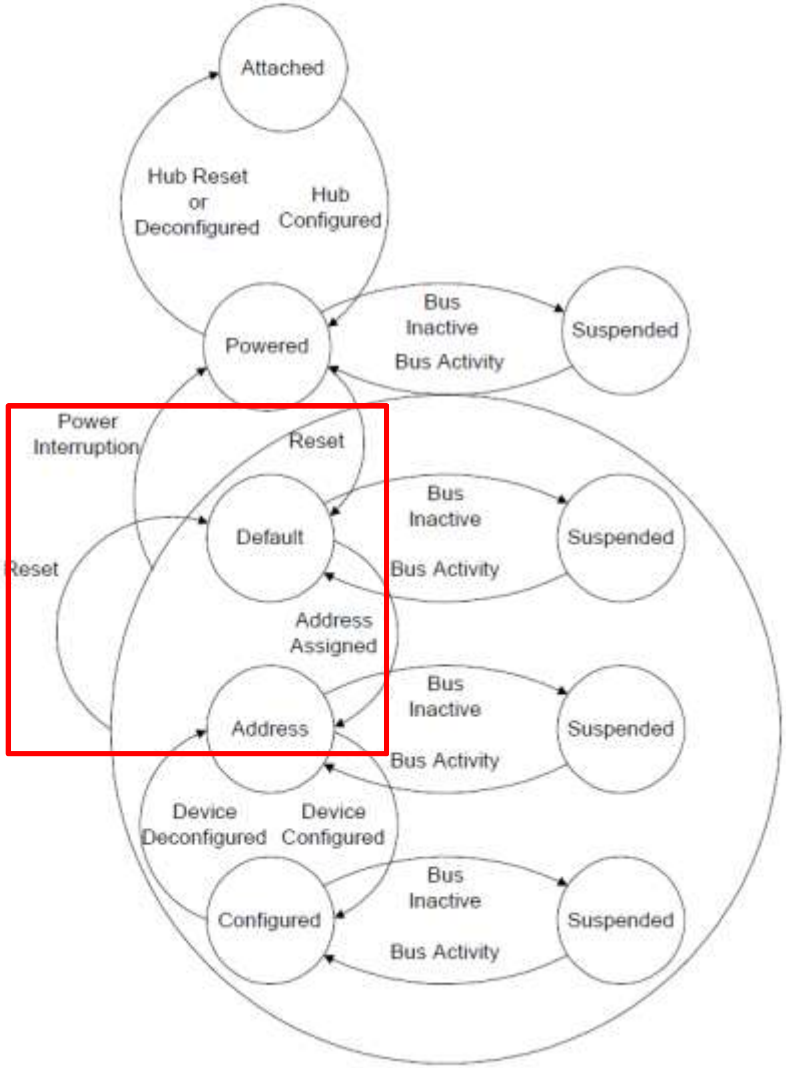


Figure 9-1. Device State Diagram

9.1.1 Visible Device States

- **Default**
  - **Device reset**
    - **After the device has been powered, it must not respond to any bus transactions until it has received a reset from the bus.**
    - **After receiving a reset, the device is then addressable at the default address.**
  - **Device speed**
    - **When the reset process is complete, the USB device is operating at the correct speed (i.e., low-/full-/highspeed).**
      - **The speed selection for low- and full-speed is determined by the device termination resistors.**
      - **A device that is capable of high-speed operation determines whether it will operate at high-speed as a part of the reset process (see Chapter 7 for more details).**
  - **Device behavior**
    - **A device capable of high-speed operation must reset successfully at full-speed when in an electrical environment that is operating at full-speed.**
    - **After the device is successfully reset, the device must also respond successfully to device and configuration descriptor requests and return appropriate information.**
    - **The device may or may not be able to support its intended functionality when operating at full-speed.**

9.1.1 Visible Device States

- **Address**
  - **All USB devices use the default address when initially powered or after the device has been reset.**
  - **Each USB device is assigned a unique address by the host after attachment or after reset.**

9.1.1 Visible Device States

- **Configured**
  - Before a USB device's function may be used, the device must be configured.
  - Configuration involves correctly processing a SetConfiguration() request with a non-zero configuration value.
  - Configuring a device or changing an alternate setting causes all of the status and configuration values associated with endpoints in the affected interfaces to be set to their default values.
  - This includes setting the data toggle of any endpoint using data toggles to the value DATA0.

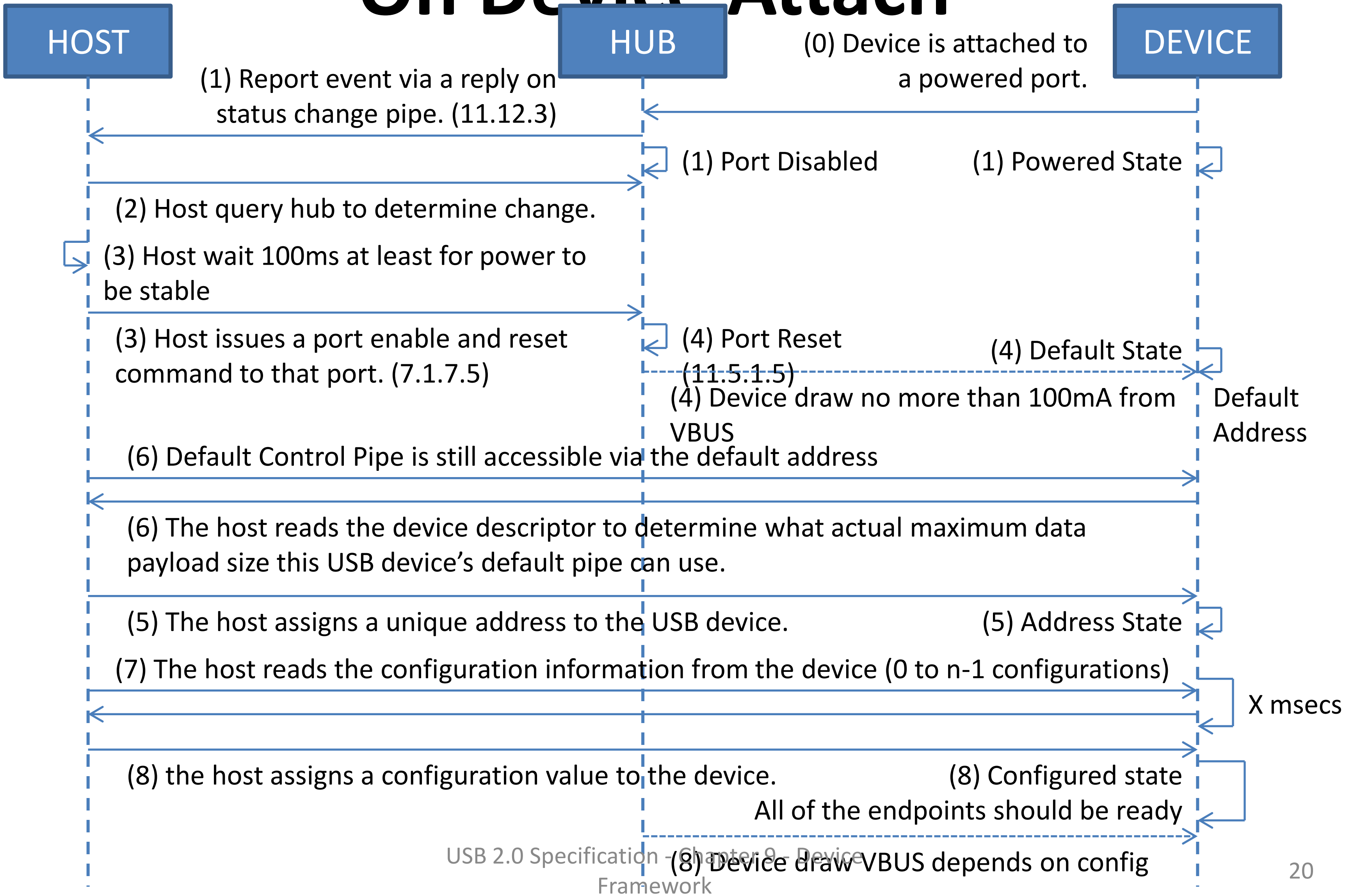
9.1.1 Visible Device States

- **Suspended**
  - When to automatically enter the Suspended state.
    - no bus traffic for a specified period , ex: 3ms (refer to Chapter 7).
  - Attached devices must be prepared to suspend at any time they are powered.
  - Suspend/Selective suspend.
    - Bus activity may cease due to the host entering a suspend mode of its own.
    - In addition, a USB device shall also enter the Suspended state when the hub port it is attached to is disabled.
  - Resume
    - A USB device may also request the host to exit suspend mode or selective suspend by using electrical signaling to indicate remote wakeup. (Optional)
    - If a USB device is capable of remote wakeup signaling, the device must support the ability of the host to enable and disable this capability.
    - When the device is reset, remote wakeup signaling must be disabled.

9.1.2 Bus Enumeration

- The host uses this process to identify and manage the device state changes when a USB device is attached to or removed.

9.1.2 Bus Enumeration On Device Attach



HOST

HUB

DEVICE

(0) Device is attached to a powered port.

(1) Report event via a reply on status change pipe. (11.12.3)

(1) Port Disabled

(1) Powered State

(2) Host query hub to determine change.

(3) Host wait 100ms at least for power to be stable

(3) Host issues a port enable and reset command to that port. (7.1.7.5)

(4) Port Reset (11.5.1.5)

(4) Default State

(4) Device draw no more than 100mA from VBUS

Default Address

(6) Default Control Pipe is still accessible via the default address

(6) The host reads the device descriptor to determine what actual maximum data payload size this USB device’s default pipe can use.

(5) The host assigns a unique address to the USB device.

(5) Address State

(7) The host reads the configuration information from the device (0 to n-1 configurations)

X msecs

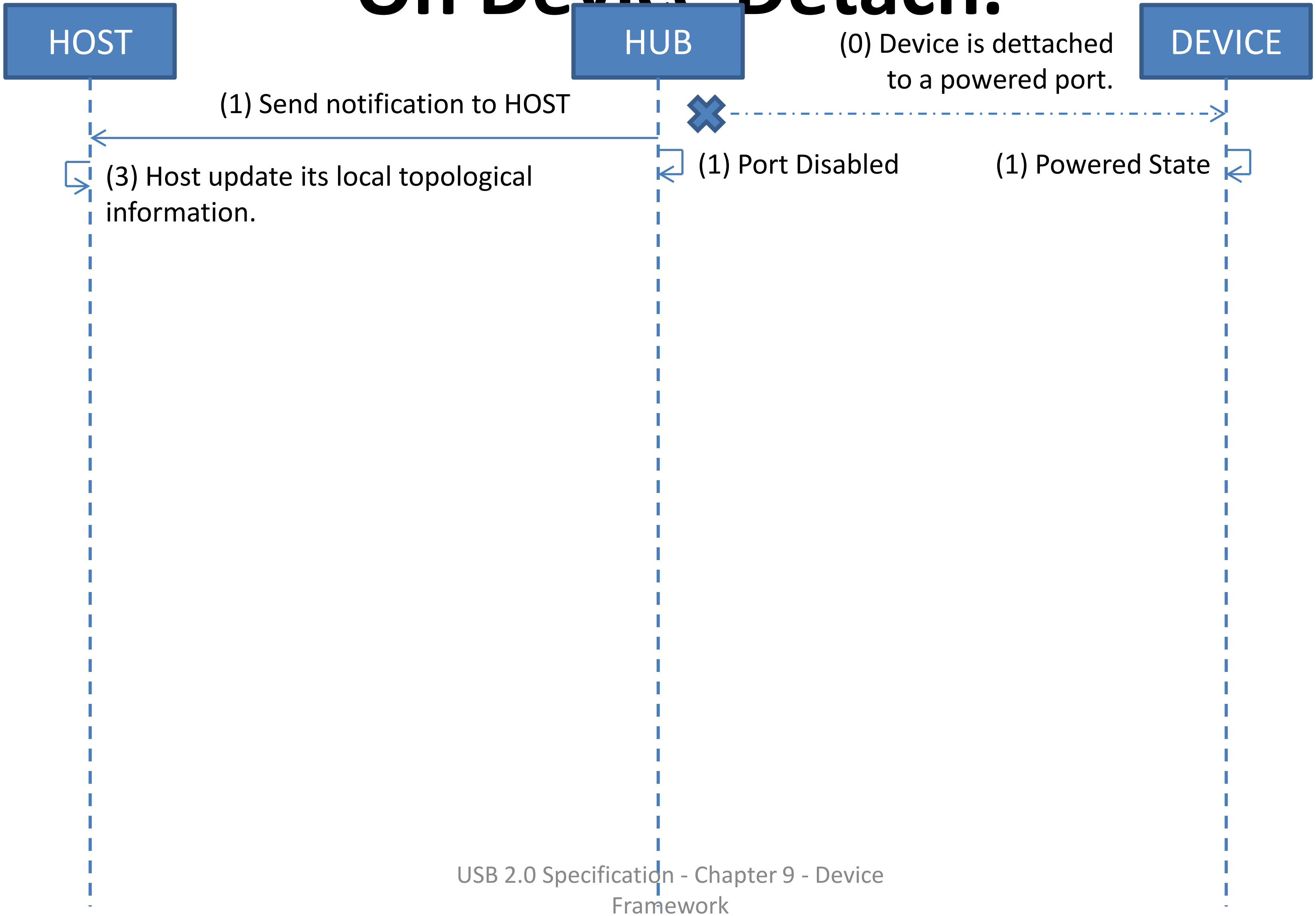
(8) the host assigns a configuration value to the device.

(8) Configured state

All of the endpoints should be ready

(8) Device draw VBUS depends on config

9.1.2 Bus Enumeration On Device Detach.



HOST

HUB

DEVICE

(0) Device is dettached to a powered port.

(1) Send notification to HOST

(1) Port Disabled

(1) Powered State

(3) Host update its local topological information.

9.2 Generic USB Device Operations

- 9.2.1 Dynamic Attachment and Removal
- 9.2.2 Address Assignment
- 9.2.3 Configuration
- 9.2.4 Data Transfer
- 9.2.5 Power Management
- 9.2.6 Request Processing
- 9.2.7 Request Error

9.2.1 Dynamic Attachment and Removal

- The hub that provides the attachment point or port is responsible for reporting any change in the state of the port.
- When host enables the hub port when device is attached, will also lead device resetting.
  - A reset (port reset) USB device has the following characteristics:
    - Responds to the default USB address
    - Is not configured
    - Is not initially suspended

9.2.2 Address Assignment

- The host is responsible for assigning a unique address to the device.
  - This is done after the device has been reset by the host, and the hub port where the device is attached has been enabled.

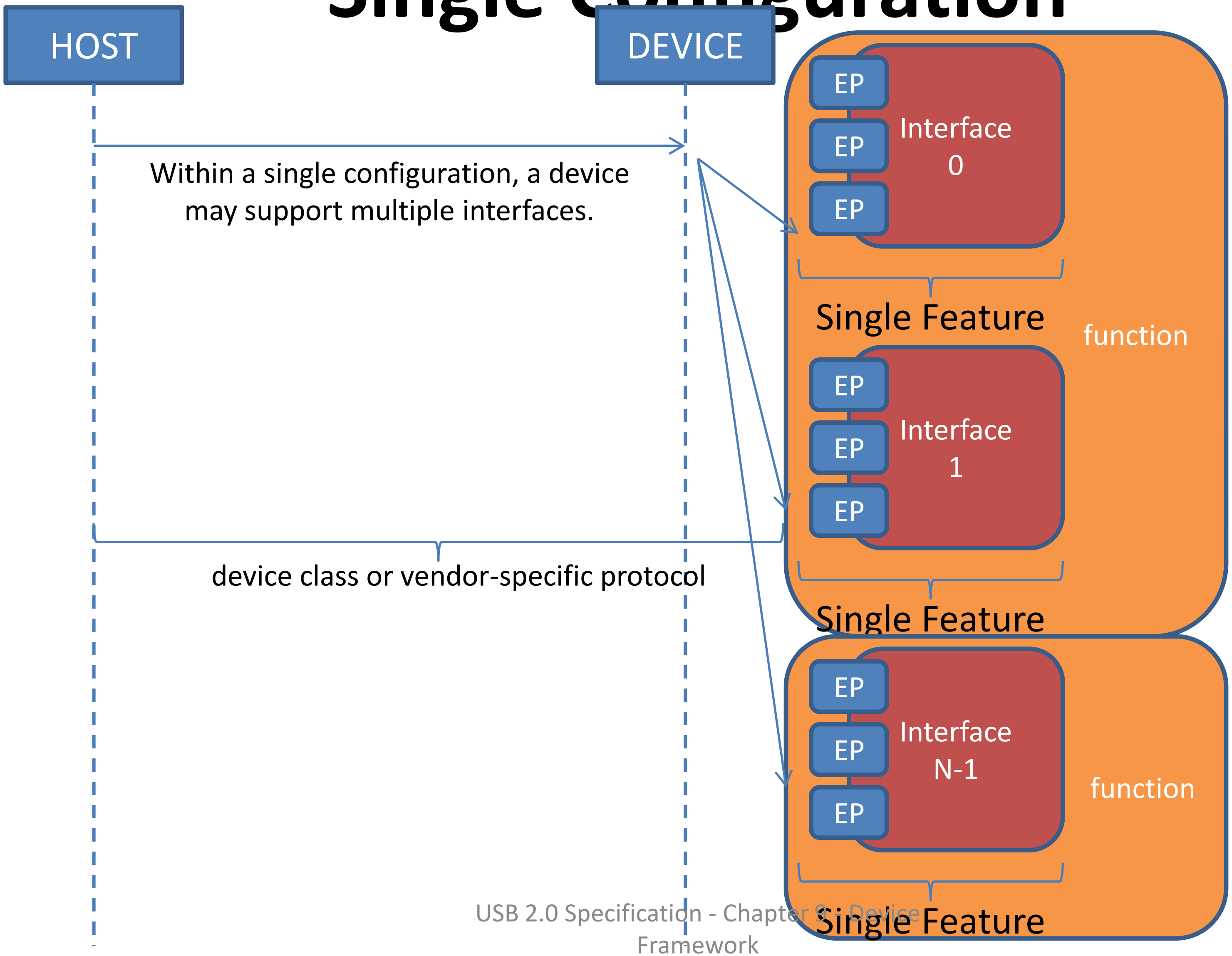
9.2.3 Configuration

- The host is responsible for configuring a USB device.
  - The host typically requests configuration information from the USB device to determine the device's capabilities.
  - As part of the configuration process, the host sets the device configuration and, where necessary, selects the appropriate alternate settings for the interfaces.

9.2.3 Configuration

- Within a single configuration, a device may support multiple interfaces.

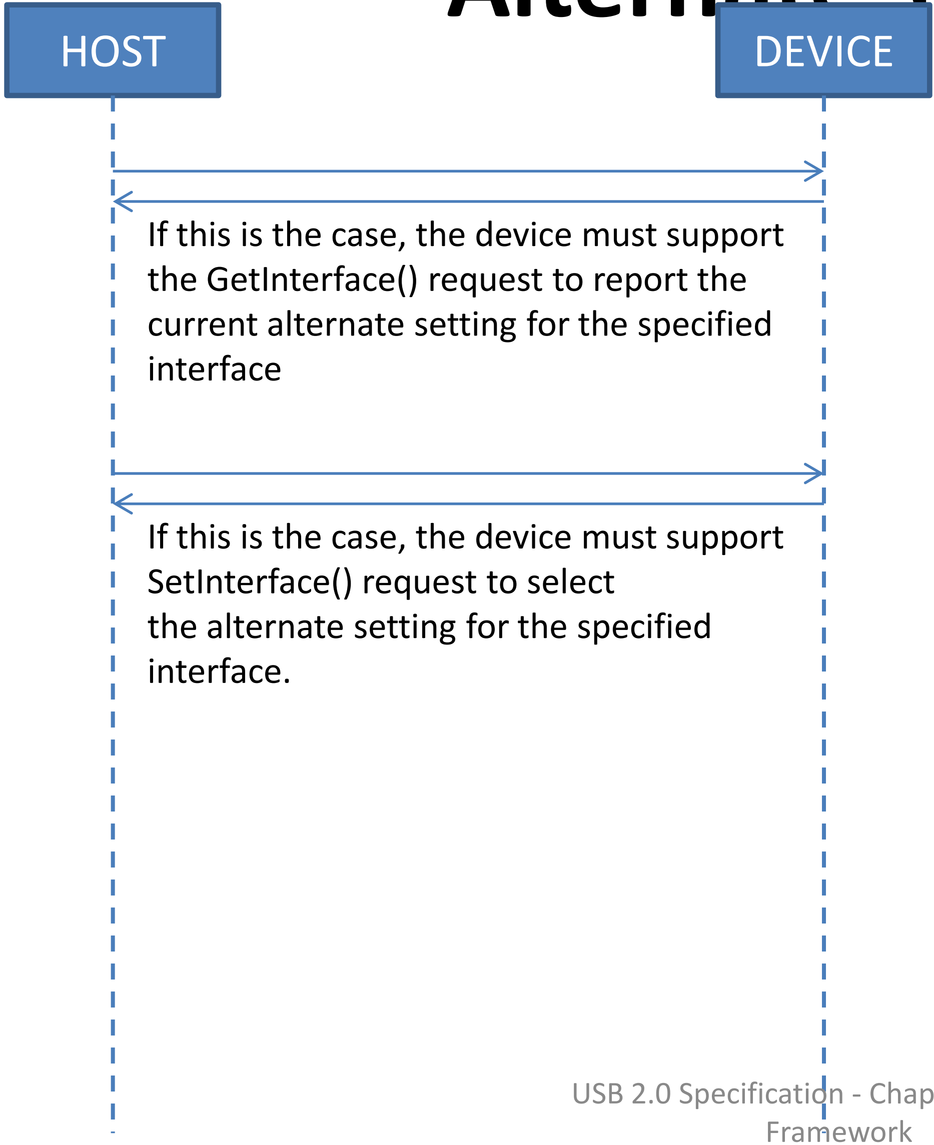
9.2.3 Configuration
Single Configuration



Within a single configuration, a device may support multiple interfaces.

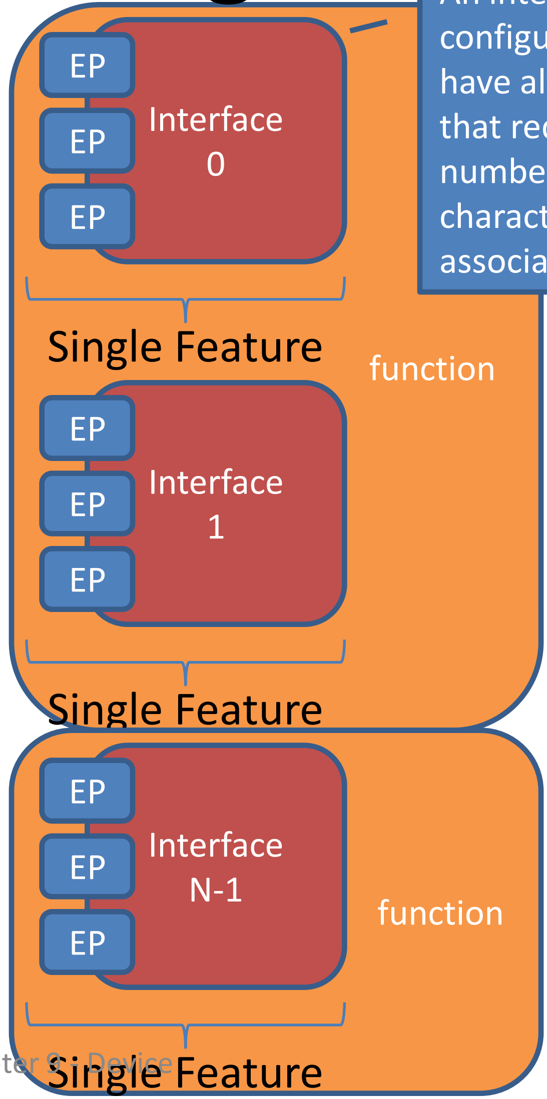
device class or vendor-specific protocol

9.2.3 Configuration Alternate settings



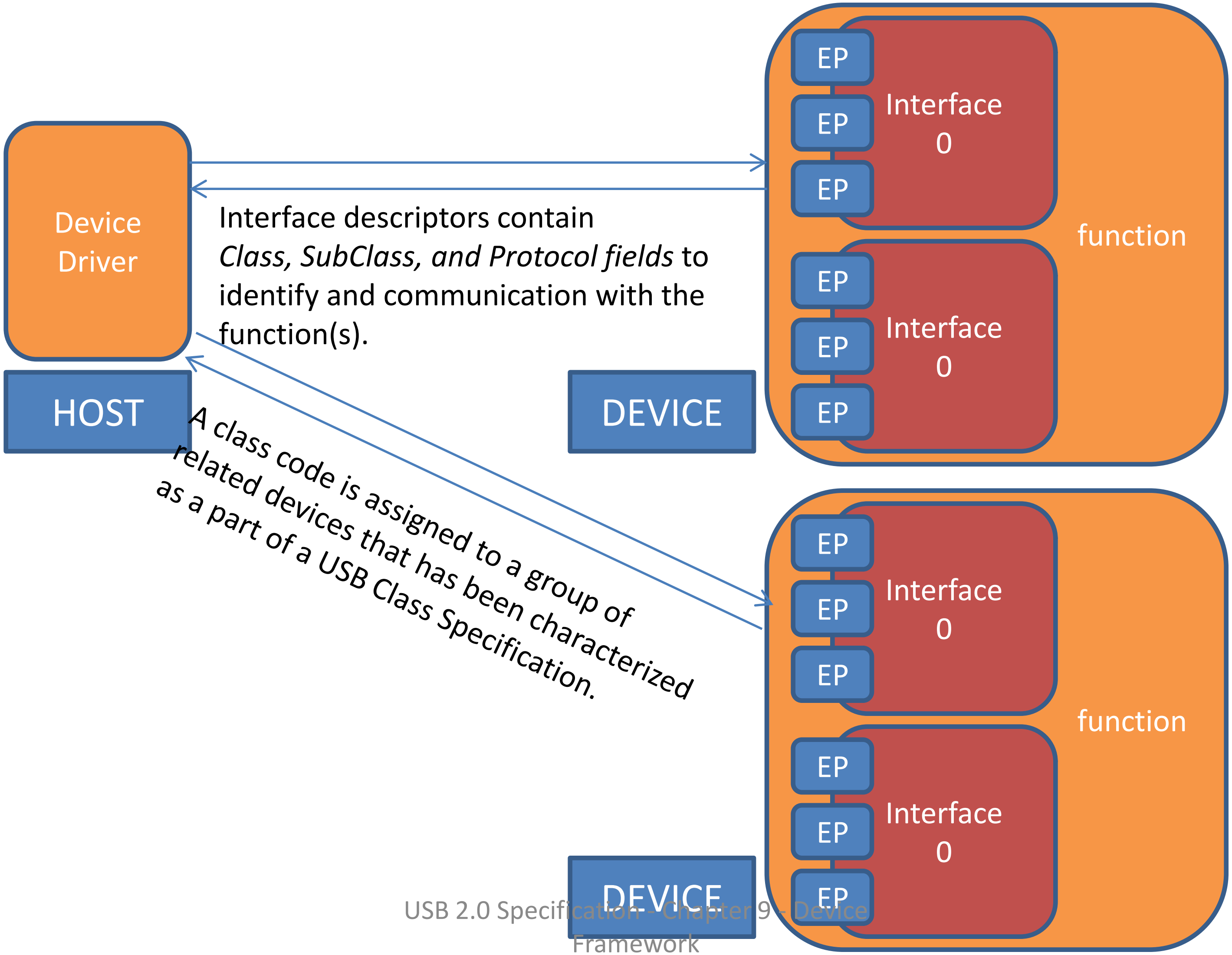
If this is the case, the device must support the GetInterface() request to report the current alternate setting for the specified interface

If this is the case, the device must support SetInterface() request to select the alternate setting for the specified interface.



An interface within a configuration may have alternate settings that redefine the number or characteristics of the associated endpoints.

9.2.3 Configuration Alternate settings



Interface descriptors contain *Class, SubClass, and Protocol fields* to identify and communication with the function(s).

A class code is assigned to a group of related devices that has been characterized as a part of a USB Class Specification.

9.2.4 Data Transfer

- Data may be transferred between a USB device endpoint and the host in one of 4 ways. (Chapter 5).
  - An endpoint number may be used for different types of data transfers in different alternate settings.
  - However, once an alternate setting is selected (including the default setting of an interface), a USB device endpoint uses only one data transfer method until a different alternate setting is selected.

4 types of transfer:
Control
Isochronous
Bulk
Interrupt

9.2.5 Power Management

- **9.2.5.1 Power Budgeting**
- **9.2.5.2 Remote Wakeup**

9.2.5.1 Power Budgeting

- During device enumeration, a host evaluates a device's power requirements.
  - If the power requirements of a particular configuration exceed the power available to the device, Host Software shall not select that configuration.
  - USB devices shall limit the power they consume from VBUS to one unit load (100mA?) or less until configured.
    - Depending on the power capabilities of the port to which the device is attached, a USB device may be able to draw up to five unit loads (500mA?) from VBUS after configuration.
  - Suspended devices, whether configured or not, shall limit their bus power consumption as defined in Chapter 7.

9.2.5.2 Remote Wakeup

- Remote wakeup allows a suspended USB device to signal a host that may also be suspended.
  - This notifies the host that it should resume from its suspended mode.
  - A USB device reports its ability to support remote wakeup in a configuration descriptor.
    - If a device supports remote wakeup, it must also allow the capability to be enabled and disabled using the standard USB requests.
    - Remote wakeup is accomplished using electrical signaling described in Section 7.1.7.7.

9.2.6 Request Processing

- A device may begin processing of a request as soon as the device returns the ACK following the Setup.
  - excepts SetAddress() requests (see Section 9.4.6).
- The device is expected to “complete” processing of the request before it allows the Status stage to complete successfully.
  - (Polling.)
- Some requests initiate operations that take many milliseconds to complete.
  - (Indication.)
  - For requests such as this, the device class is required to define a method other than Status stage completion to indicate that the operation has completed.
  - For example, a reset on a hub port takes at least 10 ms (ex: 10 frames/80 microframes)to complete.
    - The SetPortFeature(PORT_RESET) (see Chapter 11) request “completes” when the reset on the port is initiated.
    - Note: (High-speed: 125 µs microframe, Full-Speed: 1 ms frame).

9.2.6 Request Processing

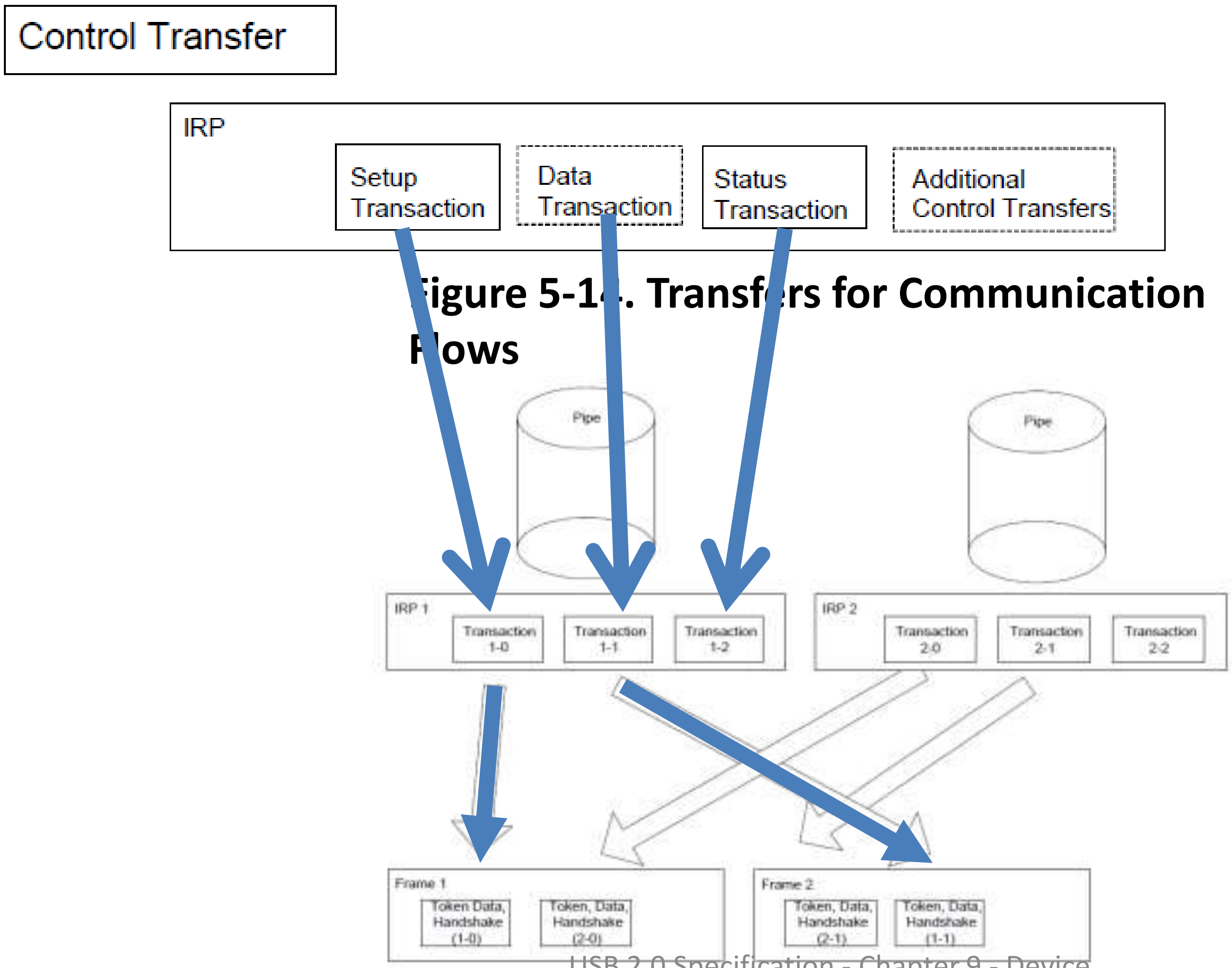


Figure 5-14. Transfers for Communication Flows

A control transfer is an OUT Setup transaction followed by multiple IN or OUT Data transactions followed by one "opposite of data direction" Status transaction.

Figure 5-15. Arrangement of IRPs to Transactions/(Micro)frames

9.2.6 Request Processing

- Completion of the reset operation is signaled when the port's status change is set to indicate that the port is now enabled.

– This technique prevents the host from having to constantly poll for a completion when it is known that the request will take a relatively long period of time.

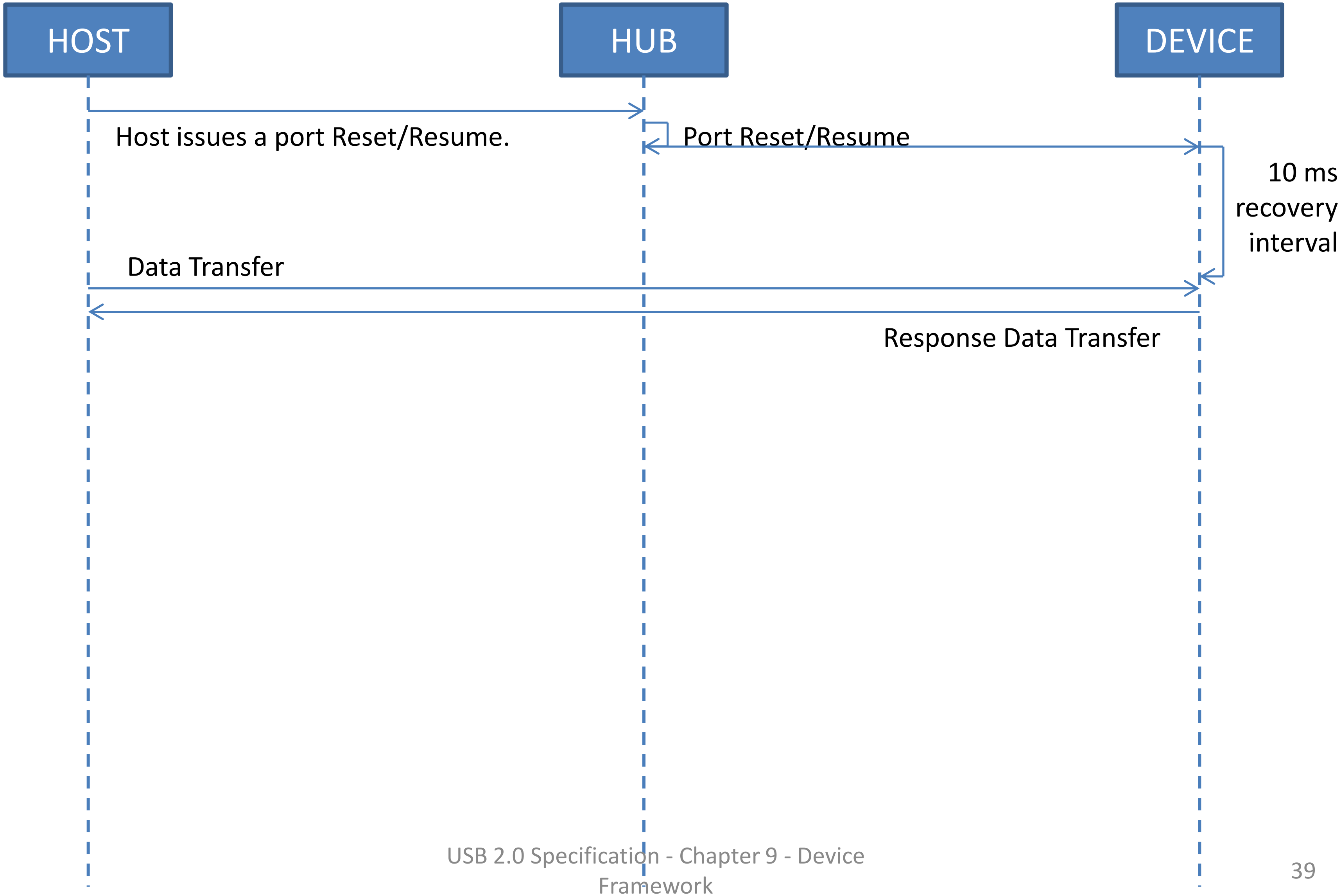
9.2.6.1 Request Processing Timing

- USB sets an upper limit of 5 seconds as the upper limit for any command to be processed.
  - This limit is not applicable in all instances.
  - It should be noted that the limitations given below are intended to encompass a wide range of implementations.
  - Implementations should strive to complete requests in times that are as short as possible.

9.2.6.2 Reset/Resume Recovery Time

- After a port is reset or resumed, the USB System Software is expected to provide a "recovery" interval of 10 ms before the device attached to the port is expected to respond to data transfers.
  - The device may ignore any data transfers during the recovery interval.
  - After the end of the recovery interval, the device must accept data transfers at any time.

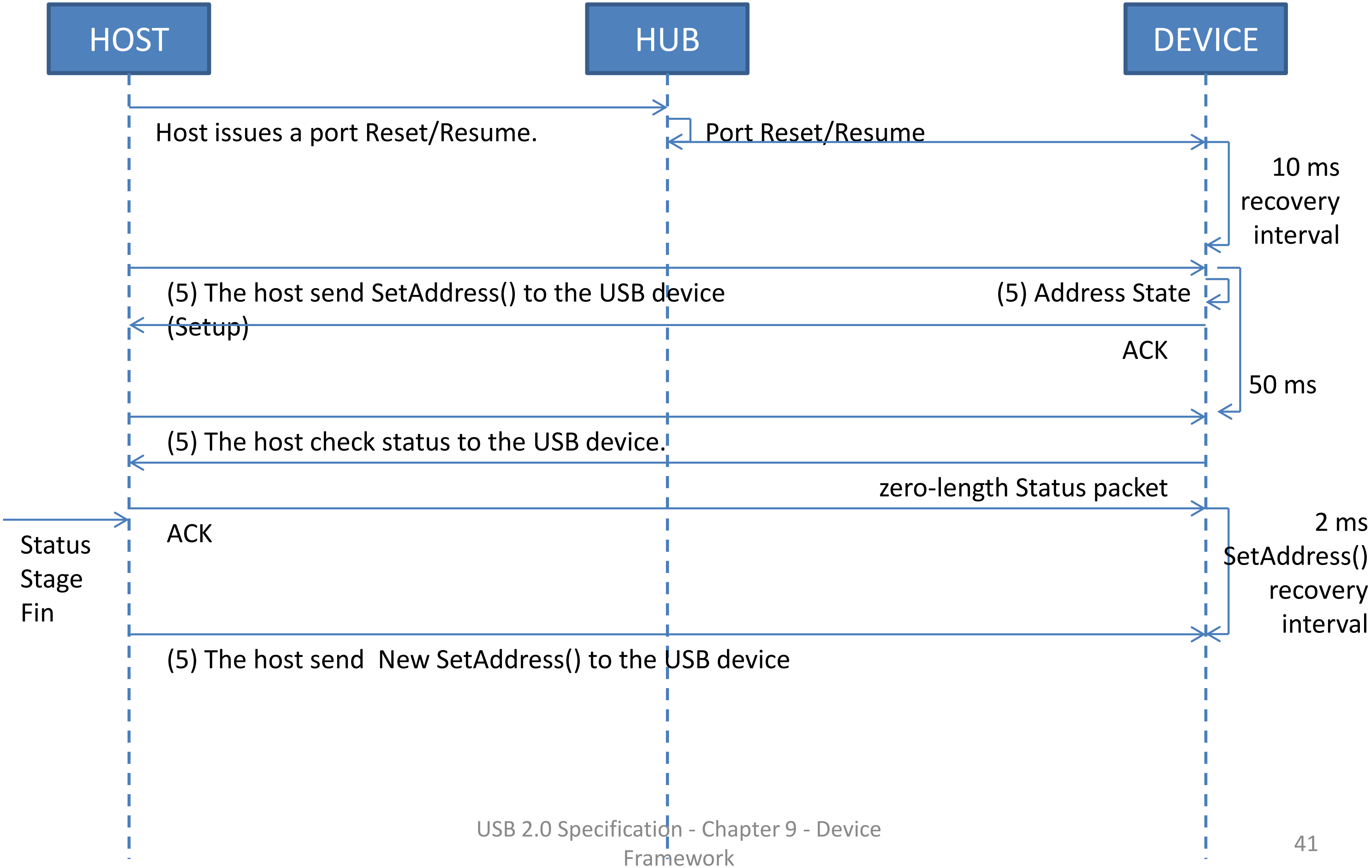
9.2.6.2 Reset/Resume Recovery Time



9.2.6.3 Set Address Processing

- After the reset/resume recovery interval if a device receives a SetAddress() request, the device must be able to complete processing of the request and be able to successfully complete the Status stage of the request within 50 ms.
- In the case of the SetAddress() request, the Status stage successfully completes when the
  - device sends the zero-length Status packet
  - or when the device sees the ACK in response to the Status stage data packet.
- After successful completion of the Status stage, the device is allowed a SetAddress() recovery interval of 2 ms.
  - At the end of this interval, the device must be able to accept Setup packets addressed to the new address.
  - Also, at the end of the recovery interval, the device must not respond to tokens sent to the old address (unless, of course, the old and new address is the same).

9.2.6.3 Set Address Processing



HOST

HUB

DEVICE

Host issues a port Reset/Resume.

Port Reset/Resume

10 ms recovery interval

(5) The host send SetAddress() to the USB device (Setup)

(5) Address State

ACK

50 ms

(5) The host check status to the USB device.

zero-length Status packet

Status Stage Fin

ACK

2 ms SetAddress() recovery interval

(5) The host send New SetAddress() to the USB device

9.2.6.4 Standard Device Requests

- There are 3 kinds of Standard device requests.
  - Require no Data stage.
  - Require Data stage transfer to the host
  - Require Data stage transfer to the Device.

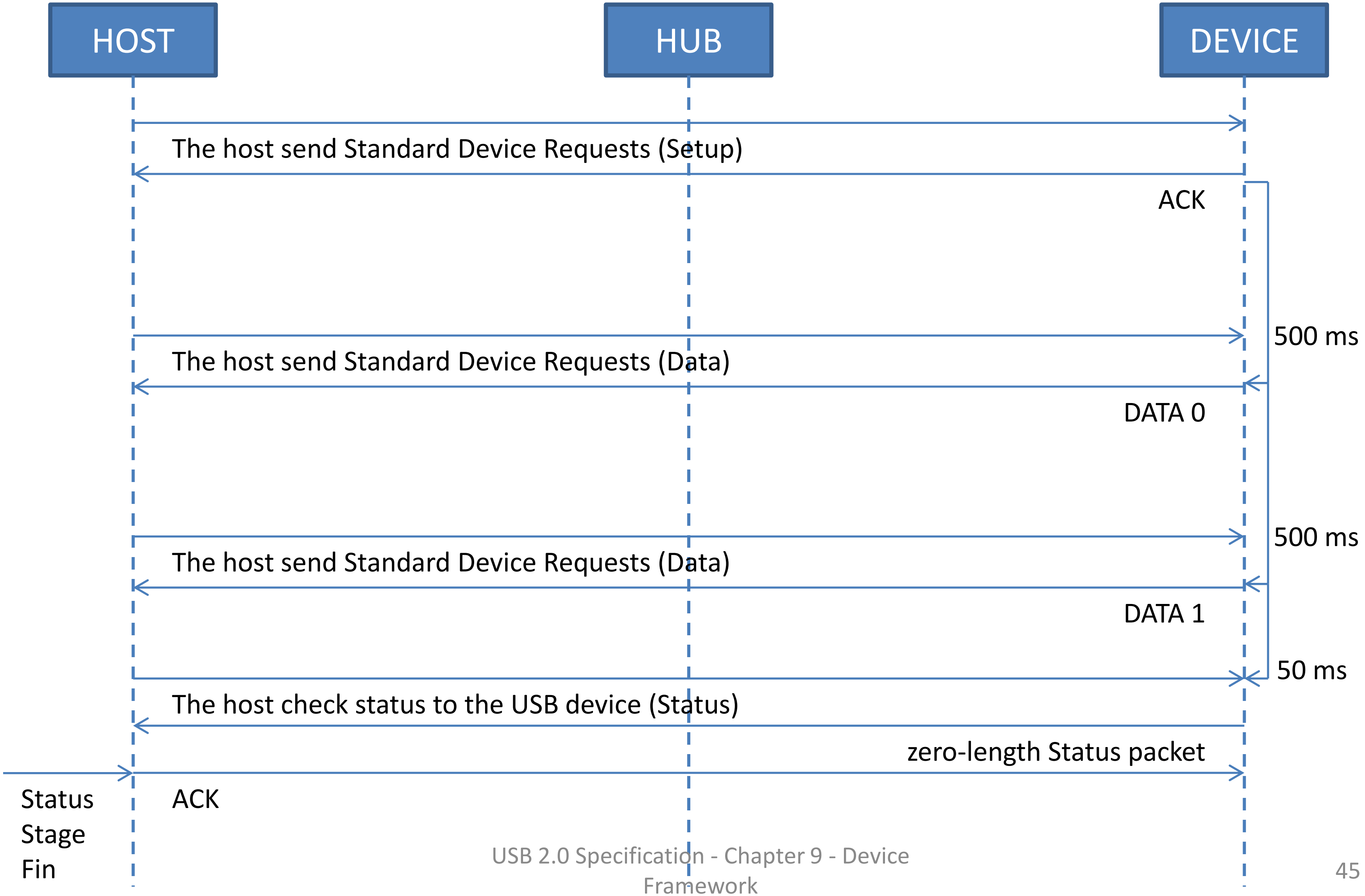
9.2.6.4 Standard Device Requests

- Standard device requests require no Data stage:
  - A device must be able to
    - complete the request,
    - successfully complete the Status stage of the request,
    - within 50 ms of receipt of the request.
  - This limitation applies to requests to the request types
    - Device
    - Interface
    - Endpoint.

9.2.6.4 Standard Device Requests

- Standard device requests require Data stage transfer to the host
  - A device must be able to
    - return the first data packet to the host within 500 ms of receipt of the request.
    - For subsequent data packets, if any, the device must be able to return them within 500 ms of successful completion of the transmission of the previous packet.
    - The device must then be able to successfully complete the status stage within 50 ms after returning the last data packet.

9.2.6.4 Standard Device Requests



HOST

HUB

DEVICE

The host send Standard Device Requests (Setup)

ACK

500 ms

The host send Standard Device Requests (Data)

DATA 0

500 ms

The host send Standard Device Requests (Data)

DATA 1

50 ms

The host check status to the USB device (Status)

zero-length Status packet

ACK

Status
Stage
Fin

9.2.6.4 Standard Device Requests

- Standard device requests require Data stage transfer to the Device
  - The 5-second limit applies.
  - This means that the device must be capable of accepting all data packets from the host and successfully completing the Status stage if the host provides the data at the maximum rate at which the device can accept it.
  - Delays between packets introduced by the host add to the time allowed for the device to complete the request.

9.2.6.5 Class-specific Requests

- Unless specifically exempted in the class document, all class-specific requests must meet the timing limitations for standard device requests.
  - If a class document provides an exemption, the exemption may only be specified on a request-by-request basis.
  - Faster response may be required for standard and class-specific requests.

9.2.6.6 Speed Dependent Descriptors

- The device always knows its operational speed due to having to manage its transceivers correctly as part of reset processing (Chapter 7)
- A device also operates at a single speed after completing the reset sequence.
  - In particular, there is no speed switch during normal operation.
  - However, a high-speed capable device may have configurations that are speed dependent.
    - High-speed capable devices must support reporting their speed dependent configurations.

9.2.6.6 Speed Dependent Descriptors

- A high-speed capable device responds with descriptor information that is valid for the current operating speed.
  - For example, when a device is asked for configuration descriptors, it only returns those for the current operating speed (e.g., full speed).
  - However, there must be a way to determine the capabilities for both high- and full-speed operation.

9.2.6.6 Speed Dependent Descriptors

- Two descriptors allow a high-speed capable device to report configuration information about the other operating speed.
  - The (other_speed) device_qualifier descriptor
  - The other_speed_configuration descriptor.
- These two descriptors are retrieved by the host by using the GetDescriptor request with the corresponding descriptor type values.
  - Note: These descriptors are not retrieved unless the host explicitly issues the corresponding GetDescriptor requests.
  - If these two requests are not issued, the device would simply appear to be a single speed device.

9.2.6.6 Speed Dependent Descriptors

- Devices that are high-speed capable must set the version number in the bcdUSB field of their descriptors to 0200H.
  - This indicates that such devices support the other_speed requests defined by USB 2.0.
  - A device with descriptor version numbers less than 0200H should cause a Request Error response if it receives these other_speed requests.
  - A USB 1.x device should not be issued the other_speed requests.

9.2.7 Request Error

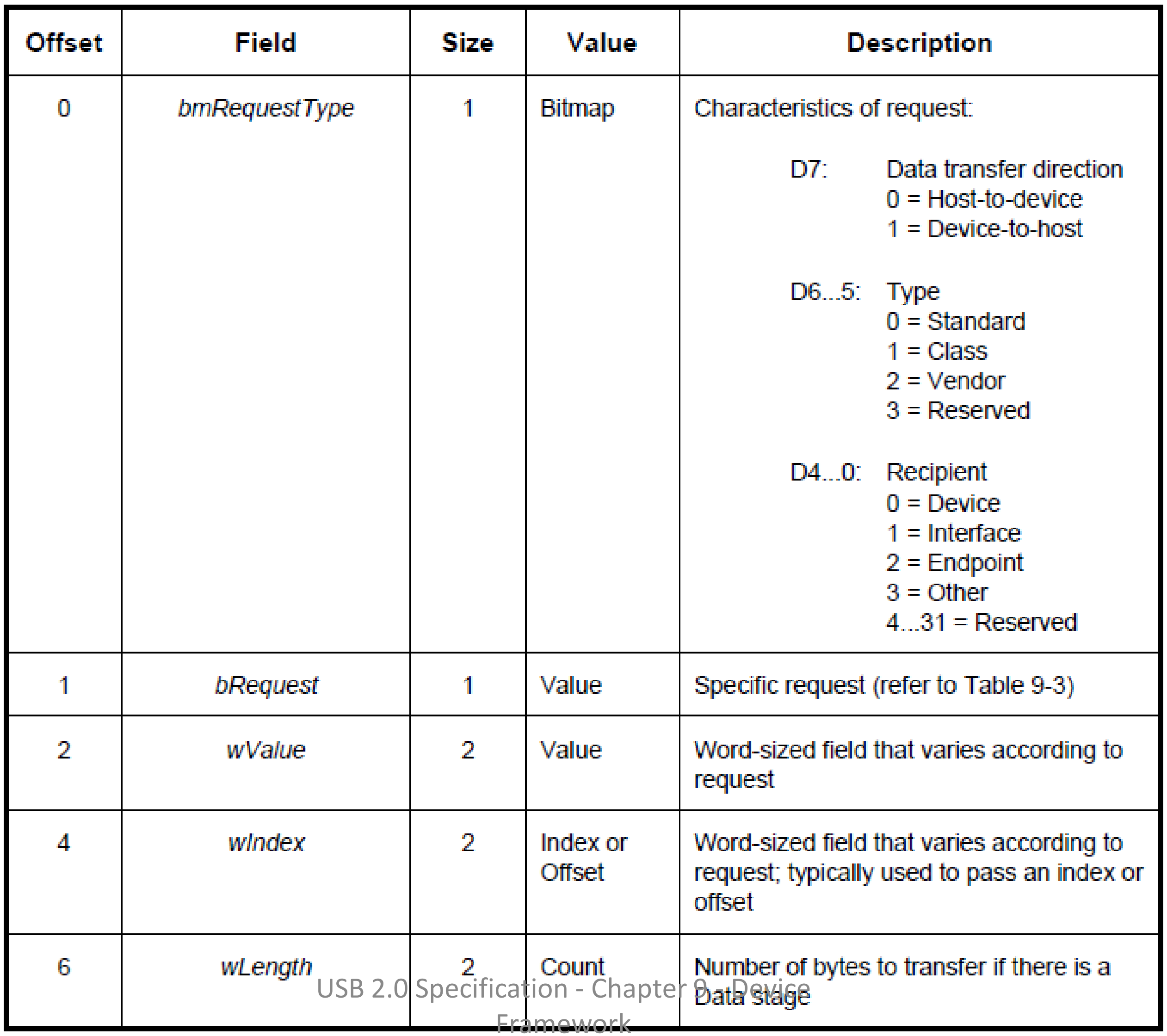
- Occurred when request is received by a device
  - that is not defined for the device,
  - is inappropriate for the current setting of the device,
  - has values that are not compatible with the request.
- The device deals with the Request Error by returning a STALL PID in response to
  - the next Data stage transaction
  - or in the Status stage of the message.

9.3 USB Device Requests

- All USB devices respond to requests from the host on the device's Default Control Pipe.
  - The request and the request's parameters are sent to the device in the Setup packet.
  - The host is responsible for establishing the values passed in the fields.
  - Every Setup packet has eight bytes.

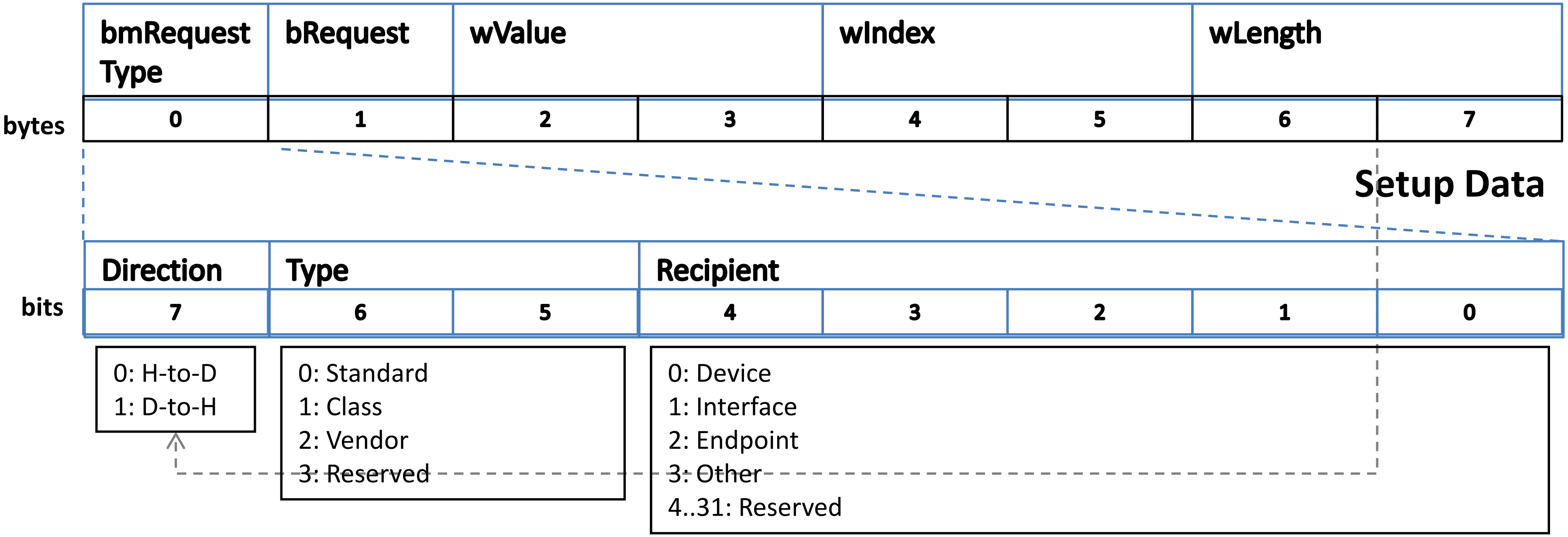
9.3 USB Device Requests

Table 9-2. Format of Setup Data



Offset	Field	Size	Value	Description
0	*bmRequestType*	1	Bitmap	Characteristics of request: D7: Data transfer direction 0 = Host-to-device 1 = Device-to-host D6...5: Type 0 = Standard 1 = Class 2 = Vendor 3 = Reserved D4...0: Recipient 0 = Device 1 = Interface 2 = Endpoint 3 = Other 4...31 = Reserved
1	*bRequest*	1	Value	Specific request (refer to Table 9-3)
2	*wValue*	2	Value	Word-sized field that varies according to request
4	*wIndex*	2	Index or Offset	Word-sized field that varies according to request; typically used to pass an index or offset
6	*wLength*	2	Count	Number of bytes to transfer if there is a Data stage

9.3 USB Device Requests



	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Setup Data

	Direction	Type		Recipient				
bits	7	6	5	4	3	2	1	0

Direction	Type	Recipient
0: H-to-D 1: D-to-H	0: Standard 1: Class 2: Vendor 3: Reserved	0: Device 1: Interface 2: Endpoint 3: Other 4..31: Reserved

- **9.3.1 bmRequestType**
  - Direction
    - this field identifies the direction of data transfer in the second phase of the control transfer.
    - The state of the Direction bit is ignored if the wLength field is zero, signifying there is no Data stage.
  - Type
    - Standard (Table 9-3), all devices must support.
    - A device class may define additional requests. A device vendor may also define requests supported by the device.
  - Recipient
    - When an interface or endpoint is specified, the wIndex field identifies the interface or endpoint.

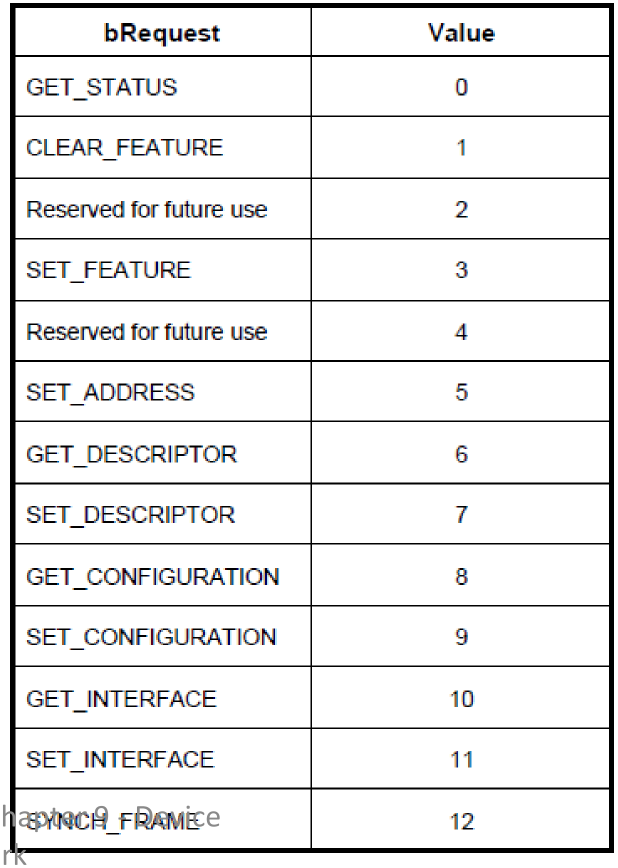
9.3 USB Device Requests

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Setup Data

- **9.3.2 bRequest**
  - The Type bits in the bmRequestType field modify the meaning of this field.
  - USB 2.0 specification only defines standard requests.
- **9.3.3 wValue**
  - The contents of this field vary according to the request.
  - It is used to pass a parameter to the device, specific to the request.

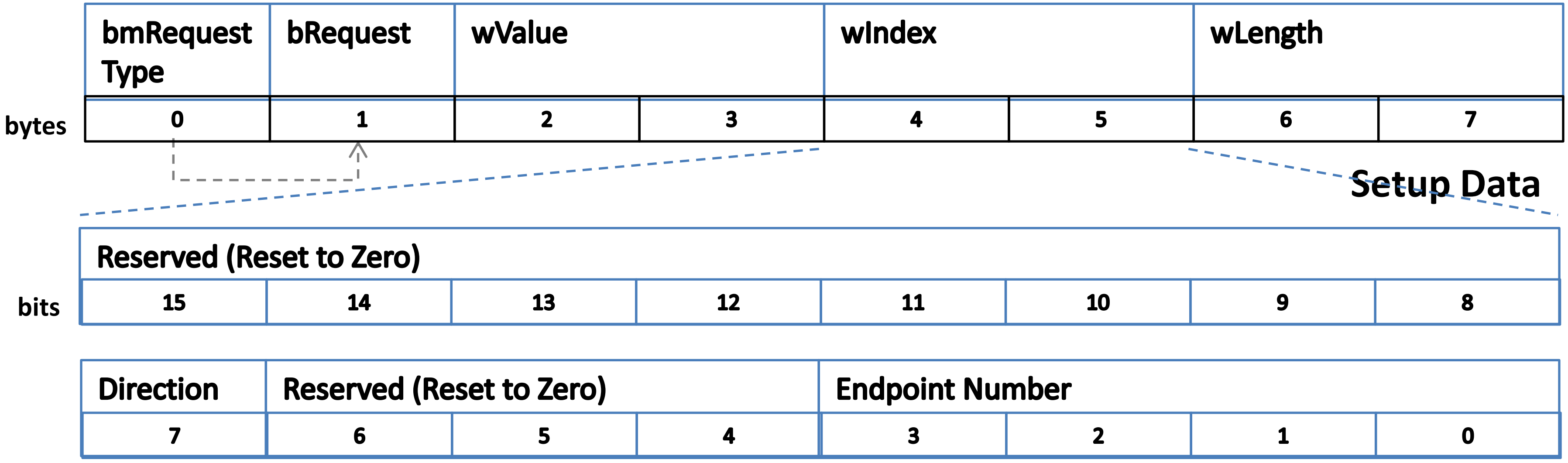
Table 9-4. Standard Request Codes



bRequest	Value
GET_STATUS	0
CLEAR_FEATURE	1
Reserved for future use	2
SET_FEATURE	3
Reserved for future use	4
SET_ADDRESS	5
GET_DESCRIPTOR	6
SET_DESCRIPTOR	7
GET_CONFIGURATION	8
SET_CONFIGURATION	9
GET_INTERFACE	10
SET_INTERFACE	11
SYNCH_FRAME	12

9.3 USB Device Requests

- **9.3.4 wIndex**
  - It is used to pass a parameter to the device, specific to the request.
  - For Endpoint Case
    - Direction
      - 0 for OUT endpoint, 1 for IN endpoint.
      - Control Pipe:
        - » Should be set to 0.
        - » But device may accept either value.



	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Setup Data

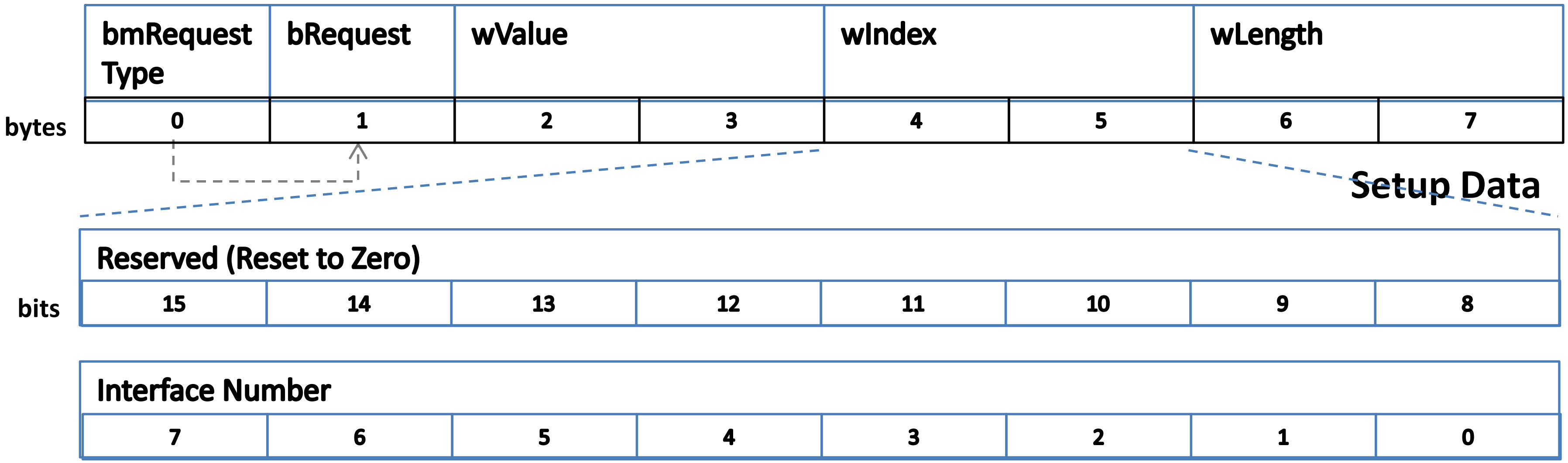
	Reserved (Reset to Zero)							
bits	15	14	13	12	11	10	9	8

Direction	Reserved (Reset to Zero)			Endpoint Number			
7	6	5	4	3	2	1	0

0: OUT EP
1: IN EP

9.3 USB Device Requests

- **9.3.4 wIndex**
  - It is used to pass a parameter to the device, specific to the request.
  - For Interface Case



	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Setup Data

	Reserved (Reset to Zero)							
bits	15	14	13	12	11	10	9	8

Interface Number							
7	6	5	4	3	2	1	0

9.3 USB Device Requests

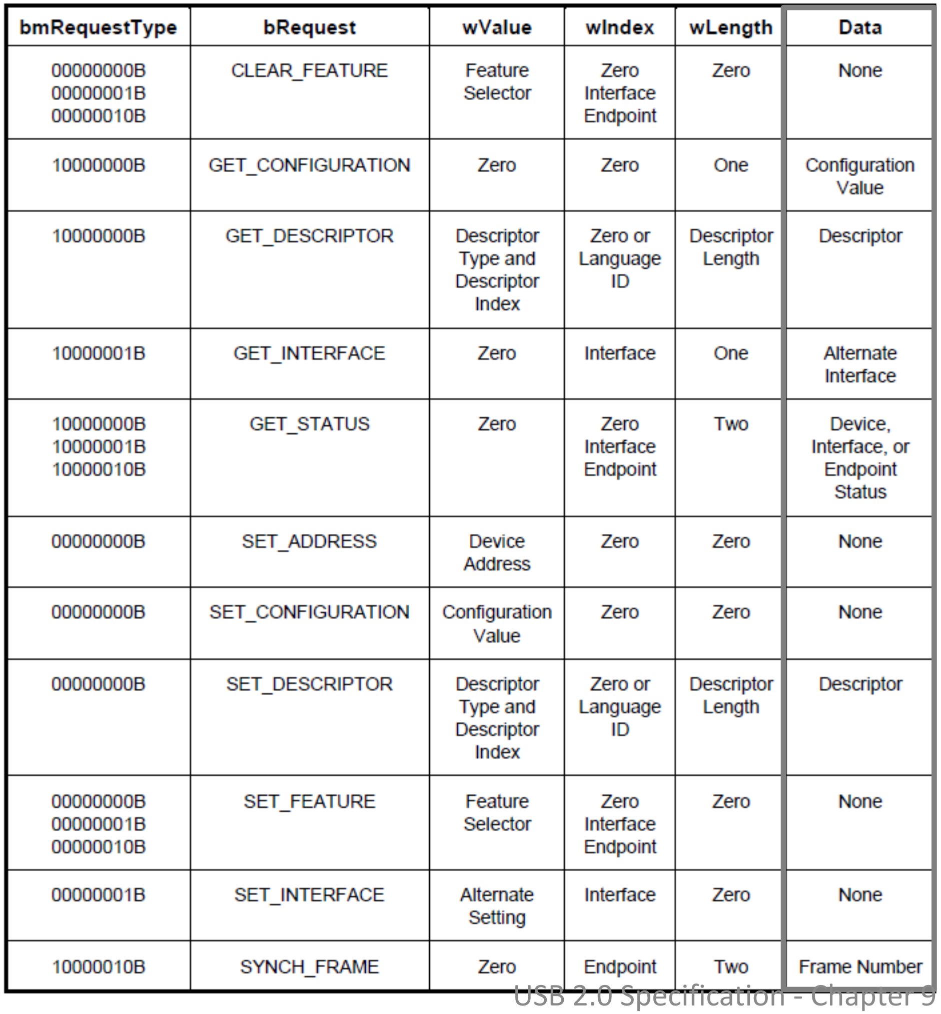
- **9.3.5 wLength**
  - This field specifies the length of the data transferred during the second phase of the control transfer.
    - On an input request, a device must never return more data than is indicated by the wLength value; it may return less.
    - On an output request, wLength will always indicate the exact amount of data to be sent by the host.

9.4 Standard Device Requests

- USB devices must respond to standard device requests, even if the device has not yet been assigned an address or has not been configured.

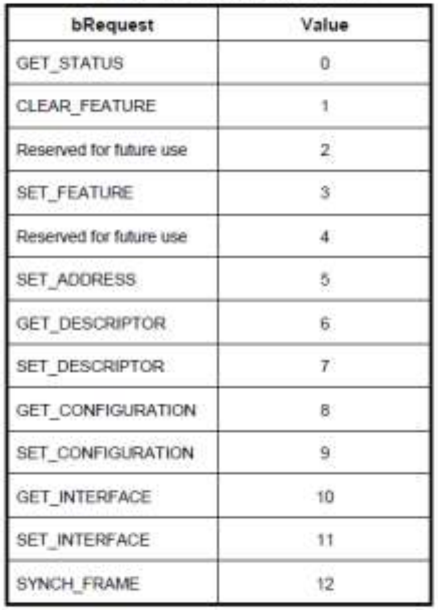
9.4 Standard Device Requests

Table 9-3. Standard Device Requests



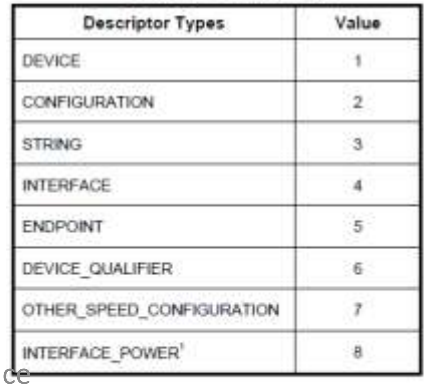
bmRequestType	bRequest	wValue	wIndex	wLength	Data
00000000B 00000001B 00000010B	CLEAR_FEATURE	Feature Selector	Zero Interface Endpoint	Zero	None
10000000B	GET_CONFIGURATION	Zero	Zero	One	Configuration Value
10000000B	GET_DESCRIPTOR	Descriptor Type and Descriptor Index	Zero or Language ID	Descriptor Length	Descriptor
10000001B	GET_INTERFACE	Zero	Interface	One	Alternate Interface
10000000B 10000001B 10000010B	GET_STATUS	Zero	Zero Interface Endpoint	Two	Device, Interface, or Endpoint Status
00000000B	SET_ADDRESS	Device Address	Zero	Zero	None
00000000B	SET_CONFIGURATION	Configuration Value	Zero	Zero	None
00000000B	SET_DESCRIPTOR	Descriptor Type and Descriptor Index	Zero or Language ID	Descriptor Length	Descriptor
00000000B 00000001B 00000010B	SET_FEATURE	Feature Selector	Zero Interface Endpoint	Zero	None
00000001B	SET_INTERFACE	Alternate Setting	Interface	Zero	None
10000010B	SYNCH_FRAME	Zero	Endpoint	Two	Frame Number

Table 9-4. Standard Request Codes



bRequest	Value
GET_STATUS	0
CLEAR_FEATURE	1
Reserved for future use	2
SET_FEATURE	3
Reserved for future use	4
SET_ADDRESS	5
GET_DESCRIPTOR	6
SET_DESCRIPTOR	7
GET_CONFIGURATION	8
SET_CONFIGURATION	9
GET_INTERFACE	10
SET_INTERFACE	11
SYNCH_FRAME	12

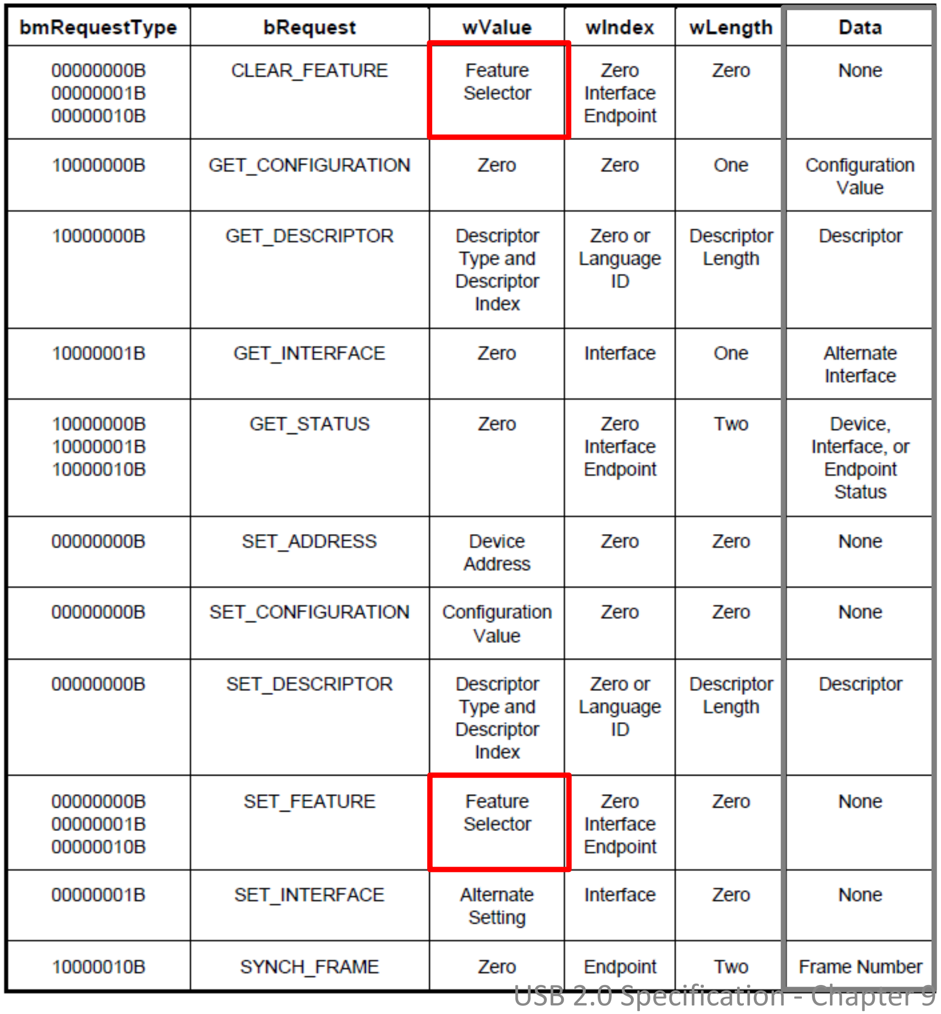
Table 9-5. Descriptor Types



Descriptor Types	Value
DEVICE	1
CONFIGURATION	2
STRING	3
INTERFACE	4
ENDPOINT	5
DEVICE_QUALIFIER	6
OTHER_SPEED_CONFIGURATION	7
INTERFACE_POWER[1]	8

9.4 Standard Device Requests

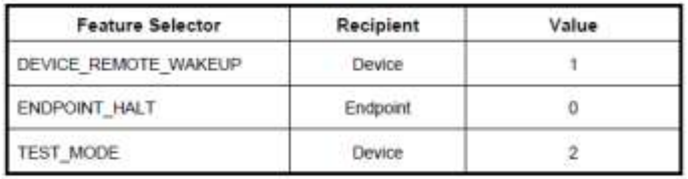
Table 9-3. Standard Device Requests



bmRequestType	bRequest	wValue	wIndex	wLength	Data
00000000B 00000001B 00000010B	CLEAR_FEATURE	Feature Selector	Zero Interface Endpoint	Zero	None
10000000B	GET_CONFIGURATION	Zero	Zero	One	Configuration Value
10000000B	GET_DESCRIPTOR	Descriptor Type and Descriptor Index	Zero or Language ID	Descriptor Length	Descriptor
10000001B	GET_INTERFACE	Zero	Interface	One	Alternate Interface
10000000B 10000001B 10000010B	GET_STATUS	Zero	Zero Interface Endpoint	Two	Device, Interface, or Endpoint Status
00000000B	SET_ADDRESS	Device Address	Zero	Zero	None
00000000B	SET_CONFIGURATION	Configuration Value	Zero	Zero	None
00000000B	SET_DESCRIPTOR	Descriptor Type and Descriptor Index	Zero or Language ID	Descriptor Length	Descriptor
00000000B 00000001B 00000010B	SET_FEATURE	Feature Selector	Zero Interface Endpoint	Zero	None
00000001B	SET_INTERFACE	Alternate Setting	Interface	Zero	None
10000010B	SYNCH_FRAME	Zero	Endpoint	Two	Frame Number

- Feature selectors are used when enabling or setting features, such as remote wakeup, specific to a device, interface, or endpoint

Table 9-6. Standard Feature Selectors



Feature Selector	Recipient	Value
DEVICE_REMOTE_WAKEUP	Device	1
ENDPOINT_HALT	Endpoint	0
TEST_MODE	Device	2

9.4 Standard Device Requests

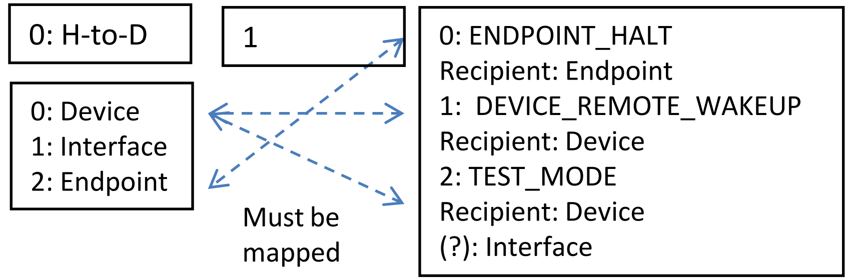
- Feature selectors are used when enabling or setting features, such as remote wakeup, specific to a device, interface, or endpoint.
  - If an unsupported or invalid request is made to a USB device, the device responds by returning STALL in the Data or Status stage of the request.
  - If the device detects the error in the Setup stage, it is preferred that the device returns STALL at the earlier of the Data or Status stage.
  - Receipt of an unsupported or invalid request does NOT cause the optional Halt feature on the control pipe to be set.
  - If for any reason, the device becomes unable to communicate via its Default Control Pipe due to an error condition, the device must be reset to clear the condition and restart the Default Control Pipe.

9.4.1 Clear Feature

- This request is used to clear or disable a specific feature.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Direction	CLEAR FEATURE	FEATURE Selector	Zero Interface Endpoint 0	Zero 0



0: H-to-D

1

0: Device
1: Interface
2: Endpoint

Must be mapped

0: ENDPOINT_HALT
Recipient: Endpoint
1: DEVICE_REMOTE_WAKEUP
Recipient: Device
2: TEST_MODE
Recipient: Device
(?): Interface

Data
None

9.4.1 Clear Feature

- A ClearFeature() request that references
  - a feature
    - that cannot be cleared
    - that does not exist
  - or an interface or endpoint that does not exist
  - will cause the device to respond with a Request Error.

- **Default state:**
  - **Not specified.**
- **Address state:**
  - **Valid**
  - references to interfaces or to endpoints other than endpoint zero shall cause the device to respond with a Request Error.
- **Configured state:**
  - **Valid.**

9.4.2 Get Configuration

- This request returns the current device configuration value.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7
	Direction 0x80	GET_CONFIG	Zero 0		Zero 0		One 1	
	1: D-to-H 0: Device	8						

Data
ConfigValue

9.4.1 Get Configuration

- If the returned value is zero, the device is not configured.

- **Default state:**
  - **Not specified.**
- **Address state:**
  - **The value zero must be returned.**
- **Configured state:**
  - The non-zero *bConfigurationValue of the current configuration must be returned.*

9.4.3 Get Descriptor

- This request returns the current device configuration value.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Direction 0x80	GET DESCRIPTOR	Descriptor Type (HI) and Descriptor Index (LO)	Zero or Language ID (9.6.7)	Descriptor Length
1: D-to-H 0: Device	6	High byte: Descriptor Types 1: DEVICE 2: CONFIGURATION 3: STRING 4: INTERFACE 5: ENDPOINT 6: DEVICE_QUALIFIER 7: OTHER_SPEED_CONFIG 8: INTERFACE_POWER Low Byte: Descriptor Index	String Descriptors: Language ID Others: Zero	The number of bytes to return.

Data Descriptor

9.4.3 Get Descriptor

- wValue:
  - The descriptor index is used to select a specific descriptor (only for configuration and string descriptors) when several descriptors of the same type are implemented in a device.
    - For example, a device can implement several configuration descriptors.
    - The range of values used for a descriptor index is from 0 to one less than the number (n-1) of descriptors of that type implemented by the device.
  - For other standard descriptors that can be retrieved via a GetDescriptor() request, a descriptor index of zero must be used.

9.4.3 Get Descriptor

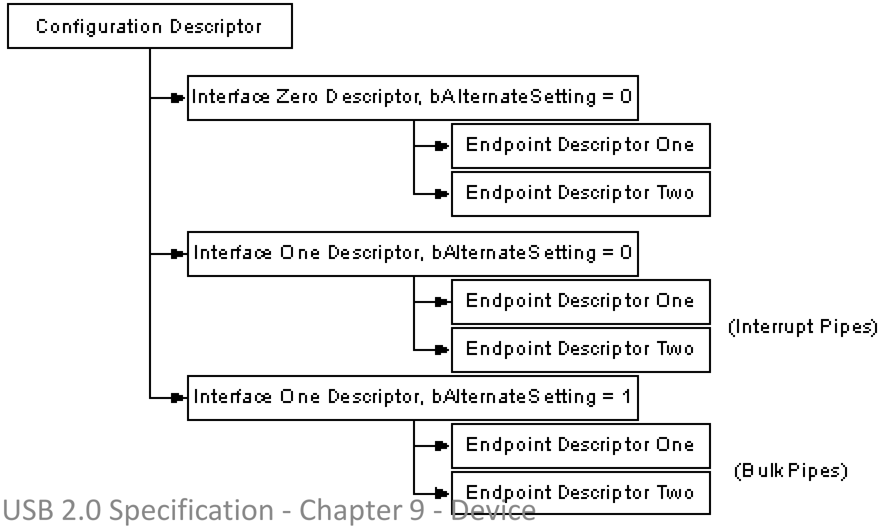
- wIndex
  - Language ID for string descriptors
  - or is reset to zero for other descriptors.
- wLength
  - It specifies the number of bytes to return.
    - If the descriptor is longer than the *wLength field,* only the initial bytes of the descriptor are returned. (use wLength)
    - If the descriptor is shorter than the wLength field, the device indicates the end of the control transfer by sending a short packet when further data is requested.
      - A short packet is defined as a packet shorter than the maximum payload size or a zero length data packet (refer to Chapter 5).

9.4.3 Get Descriptor

- The standard request to a device supports three types of descriptors:
  - device (also device_qualifier)
    - A high-speed capable device supports the device_qualifier descriptor to return information about the device for the speed at which it is not operating (including *wMaxPacketSize for the default endpoint and the number of configurations for the other speed).*
  - String
  - configuration (also other_speed_configuration)

9.4.3 Get Descriptor

- configuration (also other_speed_configuration)
  - The other_speed_configuration returns information in the same structure as a configuration descriptor, but for a configuration if the device were operating at the other speed.
  - A request for a configuration descriptor returns the configuration descriptor, all interface descriptors, and endpoint descriptors for all of the interfaces in a single request.
  - The first interface descriptor follows the configuration descriptor.
    - The endpoint descriptors for the first interface follow the first interface descriptor.
  - If there are additional interfaces, their interface descriptor and endpoint descriptors follow the first interface's endpoint descriptors.
  - Class-specific and/or vendor-specific descriptors follow the standard descriptors they extend or modify.



USB in a NutShell, http://www.beyondlogic.org/usbnutshell/usb5.shtml

9.4.3 Get Descriptor

- All devices must provide a device descriptor and at least one configuration descriptor.
  - If a device does not support a requested descriptor, it responds with a Request Error.

- **Default state:**
  - This is a valid request when the device is in the Default state.
- **Address state:**
  - This is a valid request when the device is in the Address state.
- **Configured state:**
  - This is a valid request when the device is in the Configured state.

9.4.4 Get Interface

- This request returns the selected alternate setting for the specified interface.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7
	Direction 0x81	GET Interface	Zero 0		Interface n		One 1	

1: D-to-H

10

1: Interface

Data
Alternate
Setting

9.4.4 Get Interface

- Some USB devices have configurations with interfaces that have mutually exclusive settings.
- This request allows the host to determine the currently selected alternate setting.
- If the interface specified does not exist, then the device responds with a Request Error.

- **Default state:**
  - Device behavior when this request is received while the device is in the Default state is not specified.
- **Address state:**
  - A Request Error response is given by the device.
- **Configured state:**
  - Valid.

9.4.5 Get Status

- This request returns status for the specified recipient.
  - The data returned is the current status of the specified recipient.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7
	Direction	GET STATUS	Zero 0		Zero Interface Endpoint 0		Two 2	
	1: D-to-H	0						
	0: Device 1: Interface 2: Endpoint							

Data
Device, Interface, or Endpoint Status

9.4.5 Get Status

- If an interface or an endpoint is specified that does not exist, then the device responds with a Request Error.

- **Default state:**
  - Device behavior when this request is received while the device is in the Default state is not specified.
- **Address state:**
  - If an interface or an endpoint other than endpoint zero is specified, then the device responds with a Request Error.
- **Configured state:**
  - If an interface or endpoint that does not exist is specified, then the device responds with a Request Error.

9.4.5 Get Status

Reserved (Reset to Zero)							
15	14	13	12	11	10	9	8

Reserved (Reset to Zero)						Remote Wakeup	Self Powered
7	6	5	4	3	2	1	0
						0: disabled 1: enable	0: bus power 1: Self Power

Figure 9-4, DATA returned by device

- A GetStatus() request to a device returns the information shown in Figure 9-4.
  - Self Powered
    - The Self Powered field may not be changed by the SetFeature() or ClearFeature() requests.
  - Remote Wakeup
    - It indicates whether the device is currently enabled to request remote wakeup.
    - The default mode is disabled.
    - It can be modified by the SetFeature() and ClearFeature() requests using the DEVICE_REMOTE_WAKEUP feature selector.
    - This field is reset to zero when the device is reset.

9.4.5 Get Status

- A GetStatus() request to an interface returns the information shown in Figure 9-5.

Reserved (Reset to Zero)							
15	14	13	12	11	10	9	8

Reserved (Reset to Zero)							
7	6	5	4	3	2	1	0

Figure 9-5, DATA returned by Interface

9.4.5 Get Status

Reserved (Reset to Zero)							
15	14	13	12	11	10	9	8

Reserved (Reset to Zero)							Halt
7	6	5	4	3	2	1	0

0: Normal
1: Halted

Figure 9-6, DATA returned by Endpoint

- A GetStatus() request to a endpoint returns the information shown in Figure 9-4.
  - The Halt feature is required to be implemented for all interrupt and bulk endpoint types.
  - Set Halt
    - The Halt feature may optionally be set with the SetFeature(ENDPOINT_HALT) request.
    - When set by the SetFeature() request, the endpoint exhibits the same stall behavior as if the field had been set by a hardware condition.

9.4.5 Get Status

- Clear Halt
  - If the condition causing a halt has been removed, clearing the *Halt feature via a* ClearFeature(ENDPOINT_HALT) request results in the endpoint no longer returning a STALL.
  - For endpoints using data toggle, regardless of whether an endpoint has the *Halt feature set, a* ClearFeature(ENDPOINT_HALT) request always results in the data toggle being reinitialized to DATA0.
  - The *Halt feature is reset to zero after either a SetConfiguration() or SetInterface() request even if the* requested configuration or interface is the same as the current configuration or interface.

9.4.5 Get Status

- It is neither required nor recommended that the *Halt feature be implemented for the Default Control Pipe.*
  - However, devices may set the *Halt feature of the Default Control Pipe in order to reflect a functional error* condition.
  - If the feature is set to one, the device will return STALL in the Data and Status stages of each standard request to the pipe except GetStatus(), SetFeature(), and ClearFeature() requests.
  - The device need not return STALL for class-specific and vendor-specific requests.

9.4.6 Set Address

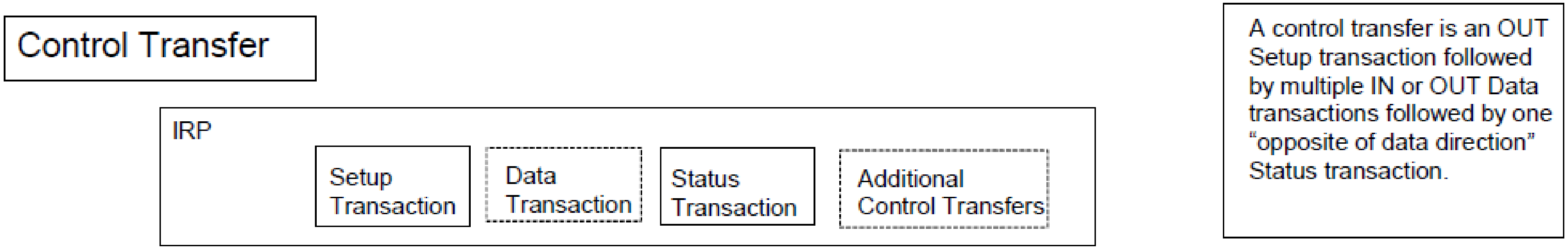
- This request sets the device address for all future device accesses.
  - The wValue field specifies the device address to use for all subsequent accesses.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7
	Direction 0	SET ADDRESS	Device Address		Zero 0		Zero 0	
	0: H-to-D 0: Device	5						

Data
None

9.4.6 Set Address

- As noted elsewhere, requests actually may result in up to three stages.
  - In the first stage, the Setup packet is sent to the device.
  - In the optional second stage, data is transferred between the host and the device.
  - In the final stage, status is transferred between the host and the device.



Control Transfer

IRP

Setup Transaction

Data Transaction

Status Transaction

Additional Control Transfers

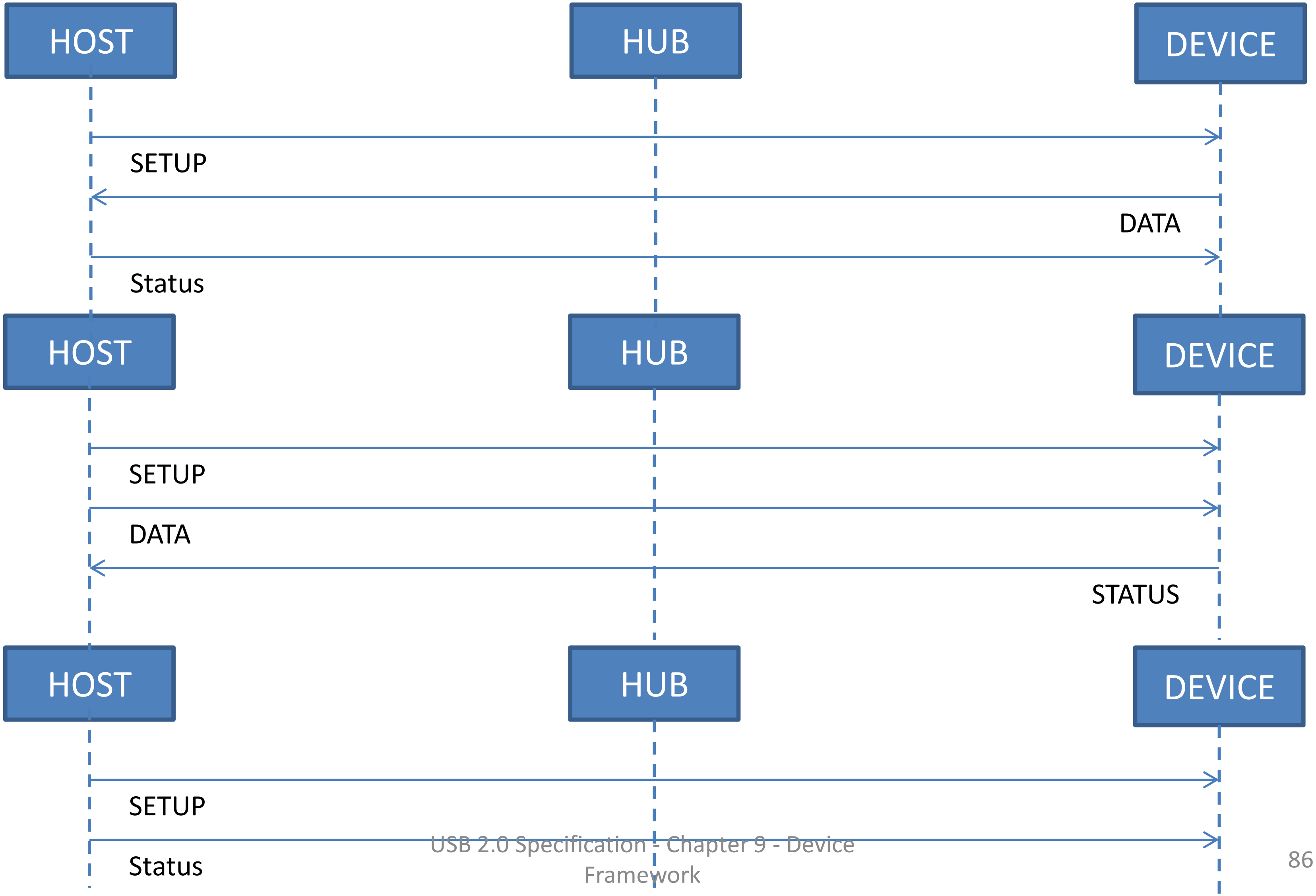
A control transfer is an OUT Setup transaction followed by multiple IN or OUT Data transactions followed by one "opposite of data direction" Status transaction.

Figure 5-14. Transfers for Communication Flows

9.4.6 Set Address

- The direction of data and status transfer depends on whether the host is sending data to the device or the device is sending data to the host.
- The Status stage transfer is always in the opposite direction of the Data stage.
- If there is no Data stage, the Status stage is from the device to the host.

9.4.6 Set Address



9.4.6 Set Address

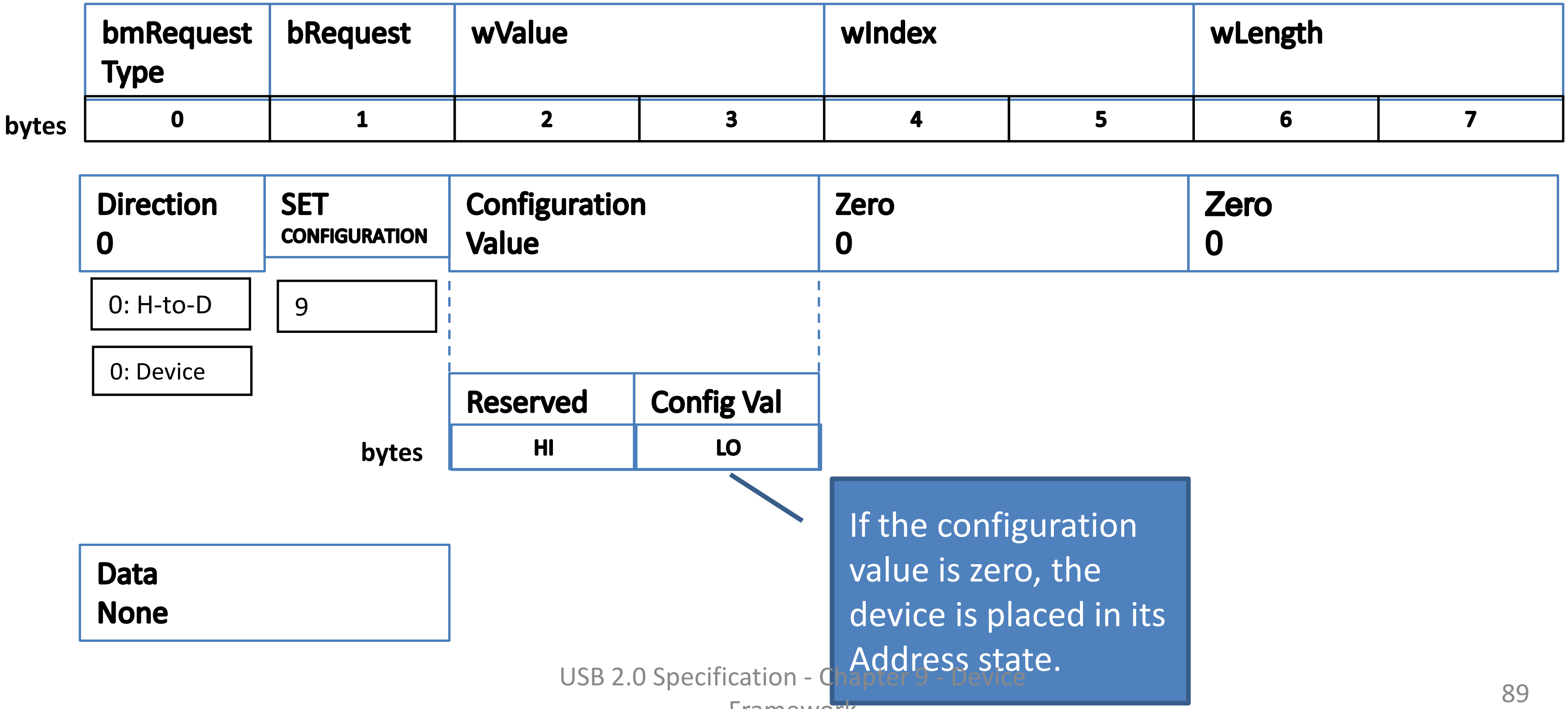
- Stages after the initial Setup packet assume the same device address as the Setup packet.
- The USB device does not change its device address until after the Status stage of SetAddress is completed successfully.
  - Note that this is a difference between this request and all other requests.
  - For all other requests, the operation indicated must be completed before the Status stage.
  - **Check 9.2.6.3**

9.4.6 Set Address

- **Default state:**
  - If the address specified is non-zero, then the device shall enter the Address state;
  - otherwise, the device remains in the Default state (this is not an error condition)
- **Address state:**
  - If the address specified is zero, then the device shall enter the Default state;
  - otherwise, the device remains in the Address state but uses the newly-specified address.
- **Configured state:**
  - Not Specified.

9.4.7 Set Configuration

- This request sets the device configuration.
  - The lower byte of the wValue field specifies the desired configuration.
  - This configuration value must be zero or match a configuration value from a configuration descriptor.



	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Direction 0	SET CONFIGURATION	Configuration Value	Zero 0	Zero 0
0: H-to-D 0: Device	9			

	Reserved	Config Val
bytes	HI	LO

Data None

If the configuration value is zero, the device is placed in its Address state.

9.4.7 Set Configuration

- **Default state:**
  - Not specified.
- **Address state:**
  - If the specified configuration value is zero, then the device remains in the Address state.
  - If the specified configuration value matches the configuration value from a configuration descriptor, then that configuration is selected and the device enters the Configured state.
  - Otherwise, the device responds with a Request Error.
- **Configured state:**
  - If the specified configuration value is zero, then the device enters the Address state.
  - If the specified configuration value matches the configuration value from a configuration descriptor, then that configuration is selected and the device remains in the Configured state.
  - Otherwise, the device responds with a Request Error.

9.4.8 Set Descriptor

- This request is optional and may be used to update existing descriptors or new descriptors may be added.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Direction 0	SET DESCRIPTOR	Descriptor Type and Descriptor Index	Language ID (9.6.7) or Zero 0	Descriptor Length
0: H-to-D 0: Device	7	High byte: Descriptor Types 1: DEVICE 2: CONFIGURATION 3: STRING 4: INTERFACE 5: ENDPOINT 6: DEVICE_QUALIFIER 7: OTHER_SPEED_CONFIG 8: INTERFACE_POWER Low Byte: Descriptor Index		

Data Descriptor

9.4.8 Set Descriptor

- wValue
  - The descriptor index is used to select a specific descriptor (only for configuration and string descriptors) when several descriptors of the same type are implemented in a device.
    - For example, a device can implement several configuration descriptors.
    - For other standard descriptors that can be set via a SetDescriptor() request, a descriptor index of zero must be used.

9.4.8 Set Descriptor

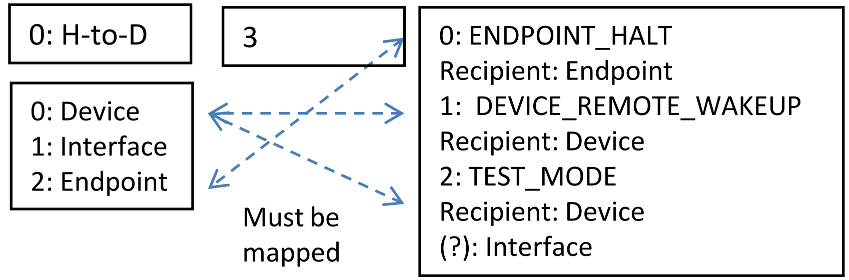
- wIndex
  - The wIndex field specifies the Language ID for string descriptors or is reset to zero for other descriptors.
- wLength
  - The wLength field specifies the number of bytes to transfer from the host to the device.
- If this request is not supported, the device will respond with a Request Error.

- **Default state:**
  - Not specified
- **Address state:**
  - Valid if supported.
- **Configured state:**
  - Valid if supported.

9.4.9 Set Feature

- This request is used to set or enable a specific feature.

	bmRequest Type	**bRequest**	**wValue**		**wIndex**		**wLength**	
bytes	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	Direction	**SET FEATURE**	**FEATURE Selector**		**Test Selector**	**Zero Interface Endpoint 0**	**Zero 0**	



0: H-to-D

0: Device
1: Interface
2: Endpoint

3

Must be mapped

0: ENDPOINT_HALT
Recipient: Endpoint
1: DEVICE_REMOTE_WAKEUP
Recipient: Device
2: TEST_MODE
Recipient: Device
(?): Interface

Data
None

9.4.9 Set Feature

- The TEST_MODE feature is only defined for a device recipient (i.e., bmRequestType = 0) and the lower byte of wIndex must be zero.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7
	Direction 0	SET FEATURE	FEATURE Selector		Test Selector	Zero 0	Zero 0	

0: H-to-D

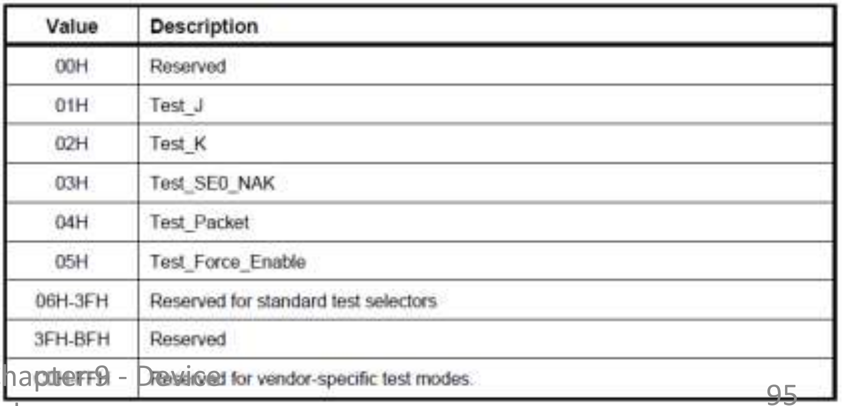
0: Device

3

2: TEST_MODE
Recipient: Device

Data
None

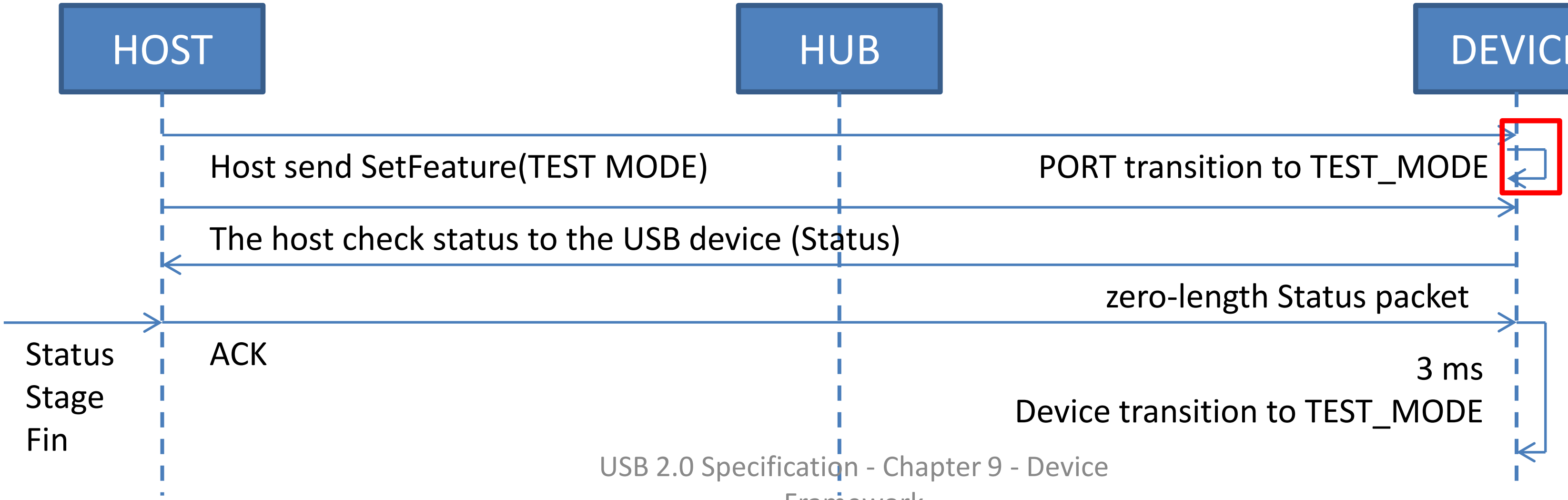
Table 9-7. Test Mode Selectors



Value	Description
00H	Reserved
01H	Test_J
02H	Test_K
03H	Test_SE0_NAK
04H	Test_Packet
05H	Test_Force_Enable
06H-3FH	Reserved for standard test selectors
3FH-BFH	Reserved
C0H-FFH	Reserved for vendor-specific test modes.

9.4.9 Set Feature

- Setting the TEST_MODE feature puts the device upstream facing port into test mode.
  - The device will respond with a request error if the request contains an invalid test selector.
  - The transition to test mode must be complete no later than 3 ms after the completion of the status stage of the request.


HOST
HUB
DEVICE
Host send SetFeature(TEST MODE)
PORT transition to TEST_MODE
The host check status to the USB device (Status)
zero-length Status packet
Status
Stage
Fin
ACK
3 ms
Device transition to TEST_MODE

9.4.9 Set Feature

- The power to the device must be cycled to exit test mode of an upstream facing port of a device.
- See Section 7.1.20 for definitions of each test mode.
- A device must support the TEST_MODE feature when in the
  - Default state
  - Address state
  - or Configured high-speed device states.

9.4.9 Set Feature

- A SetFeature() request that references a feature that cannot be set or that does not exist causes a STALL to be returned in the Status stage of the request.

- **Default state:**
  - A device must be able to accept a SetFeature(TEST_MODE, TEST_SELECTOR) request when in the Default State.
  - Device behavior for other SetFeature requests while the device is in the Default state is not specified.
- **Address state:**
  - If an interface or an endpoint other than endpoint zero is specified, then the device responds with a Request Error.
- **Configured state:**
  - Valid

9.4.10 Set Interface

- This request allows the host to select an alternate setting for the specified interface.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Direction 1	SET Interface	Alternate Setting	Interface n	Zero 0
0: H-to-D 1: Interface	11			

Data
None

9.4.10 Set Interface

- Some USB devices have configurations with interfaces that have mutually exclusive settings.
  - This request allows the host to select the desired alternate setting.
  - If a device only supports a default setting for the specified interface, then a STALL may be returned in the Status stage of the request.
  - This request cannot be used to change the set of configured interfaces (the SetConfiguration() request must be used instead).

9.4.10 Set Interface

- If the interface or the alternate setting does not exist, then the device responds with a Request Error.
- If wLength is non-zero, then the behavior of the device is not specified.

- **Default state:**
  - Not specified.
- **Address state:**
  - The device must respond with a Request Error.
- **Configured state:**
  - Valid.

9.4.11 Synch Frame

- This request is used to set and then report an endpoint’s synchronization frame.

	bmRequest Type	bRequest	wValue		wIndex		wLength	
bytes	0	1	2	3	4	5	6	7

Direction 82	SYNCH FRAME	Zero 0	Endpoint X	Two 2
1: D-to-H	11			
2: Endpoint				

Data Frame Number

9.4.11 Synch Frame

- When an endpoint supports isochronous transfers, the endpoint may also require per-frame transfers to vary in size according to a specific pattern.
  - The host and the endpoint must agree on which frame the repeating pattern begins.
  - The number of the frame in which the pattern began is returned to the host.
- If a high-speed device supports the Synch Frame request, it must internally synchronize itself to the zeroth microframe and have a time notion of classic frame.
  - Only the frame number is used to synchronize and reported by the device endpoint (i.e., no microframe number).
  - The endpoint must synchronize to the zeroth microframe.

9.4.11 Synch Frame

- This value is only used for isochronous data transfers using implicit pattern synchronization.
- If wValue is non-zero or wLength is not two, then the behavior of the device is not specified.
- If the specified endpoint does not support this request, then the device will respond with a Request Error.

- **Default state:**
  - Not specified.
- **Address state:**
  - The device shall respond with a Request Error.
- **Configured state:**
  - Valid.

9.5 Descriptors

- USB devices report their attributes using descriptors.
- A descriptor is a data structure with a defined format.
  - Each descriptor begins with a byte-wide field that contains the total number of bytes in the descriptor followed by a byte-wide field that identifies the descriptor type.

	bLength N	bDescriptor Type	…		
bytes	0	1	…	N-2	N-1

9.5 Descriptors

- Using descriptors allows concise storage of the attributes of individual configurations because each configuration may reuse descriptors or portions of descriptors from other configurations that have the same characteristics.
- In this manner, the descriptors resemble individual data records in a relational database.

9.5 Descriptors

- String Descriptors
  - Where appropriate, descriptors contain references to string descriptors that provide displayable information describing a descriptor in human-readable form.
    - The inclusion of string descriptors is optional.
  - However, the reference fields within descriptors are mandatory.
  - If a device does not support string descriptors, string reference fields must be reset to zero to indicate no string descriptor is available.

9.5 Descriptors

- Return length of descriptor
  - The length < specification
    - If a descriptor returns with a value in its length field that is less than defined by this specification, the descriptor is invalid and should be rejected by the host.
  - The length > specification
    - If the descriptor returns with a value in its length field that is greater than defined by this specification, the extra bytes are ignored by the host,
    - but the next descriptor is located using the length returned rather than the length expected.

9.5 Descriptors

- Class or Vendor specific descriptors
- A device may return class- or vendor-specific descriptors in two ways:
  - 1. If they use the same format as standard descriptors (e.g., start with bLength + bDescriptor bytes)
    - they must be returned interleaved with standard descriptors in the configuration information returned by a GetDescriptor(Configuration) request.
    - In this case, the class or vendor-specific descriptors must follow a related standard descriptor they modify or extend.
  - 2. If they use independent of configuration information or use a nonstandard format
    - a GetDescriptor() request specifying the class or vendor specific descriptor type and index may be used to retrieve the descriptor from the device.
    - A class or vendor specification will define the appropriate way to retrieve these descriptors.

9.6 Standard USB Descriptor Definitions

- 9.6.1 Device Descriptor
- 9.6.2 Device_Qualifier Descriptor
- 9.6.3 Configuration Descriptor
- 9.6.4 Other_Speed_Configuration Descriptor
- 9.6.5 Interface Descriptor
- 9.6.6 Endpoint Descriptor
- 9.6.6 String Descriptor

9.6 Standard USB Descriptor Definitions

- The standard descriptors defined in this specification may only be modified or extended by revision of the Universal Serial Bus Specification.
- Note: An extension to the USB 1.0 standard endpoint descriptor has been published in Device Class Specification for Audio Devices Revision 1.0.
  - This is the only extension defined outside USB Specification that is allowed.
  - Future revisions of the USB Specification that extend the standard endpoint descriptor will do so as to not conflict with the extension defined in the Audio Device Class Specification Revision 1.0.

9.6.1 Device Descriptor

- A device descriptor describes general information about a USB device.
  - It includes information that applies globally to the device and all of the device's configurations.
- A USB device has only one device descriptor.
- A high-speed capable device that has different device information for full-speed and high-speed must also have a device_qualifier descriptor (see Section 9.6.2).

9.6.1 Device Descriptor

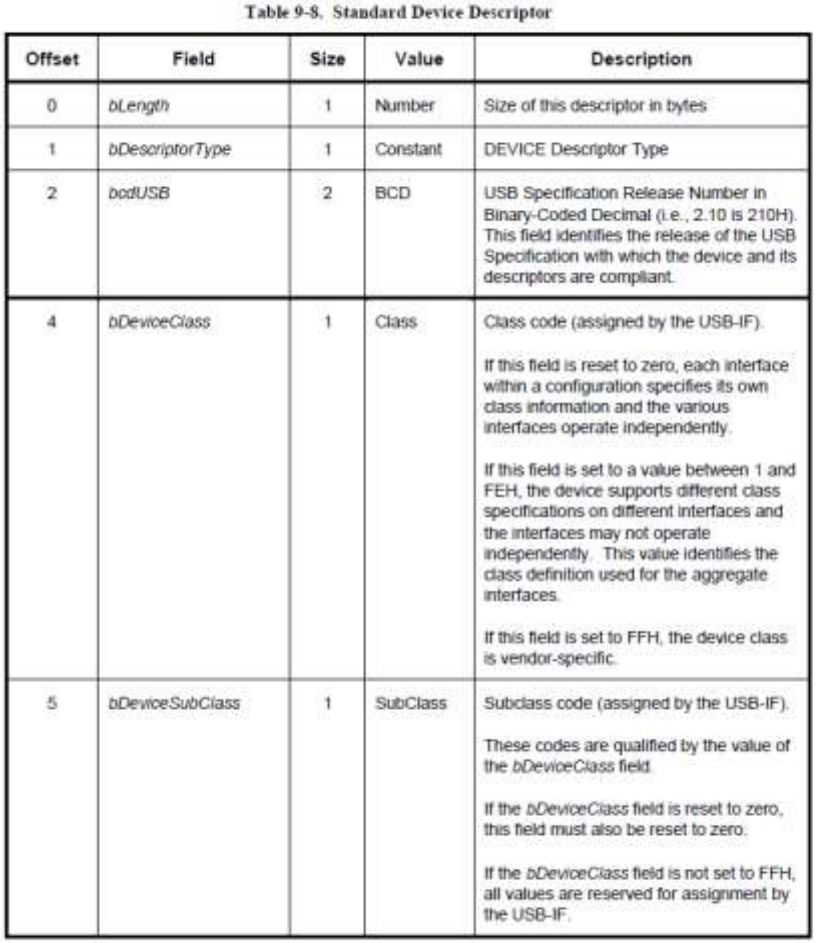


Table 9-8. Standard Device Descriptor

Offset	Field	Size	Value	Description
0	*bLength*	1	Number	Size of this descriptor in bytes
1	*bDescriptorType*	1	Constant	DEVICE Descriptor Type
2	*bcdUSB*	2	BCD	USB Specification Release Number in Binary-Coded Decimal (i.e., 2.10 is 210H). This field identifies the release of the USB Specification with which the device and its descriptors are compliant.
4	*bDeviceClass*	1	Class	Class code (assigned by the USB-IF). If this field is reset to zero, each interface within a configuration specifies its own class information and the various interfaces operate independently. If this field is set to a value between 1 and FEH, the device supports different class specifications on different interfaces and the interfaces may not operate independently. This value identifies the class definition used for the aggregate interfaces. If this field is set to FFH, the device class is vendor-specific.
5	*bDeviceSubClass*	1	SubClass	Subclass code (assigned by the USB-IF). These codes are qualified by the value of the *bDeviceClass* field. If the *bDeviceClass* field is reset to zero, this field must also be reset to zero. If the *bDeviceClass* field is not set to FFH, all values are reserved for assignment by the USB-IF.

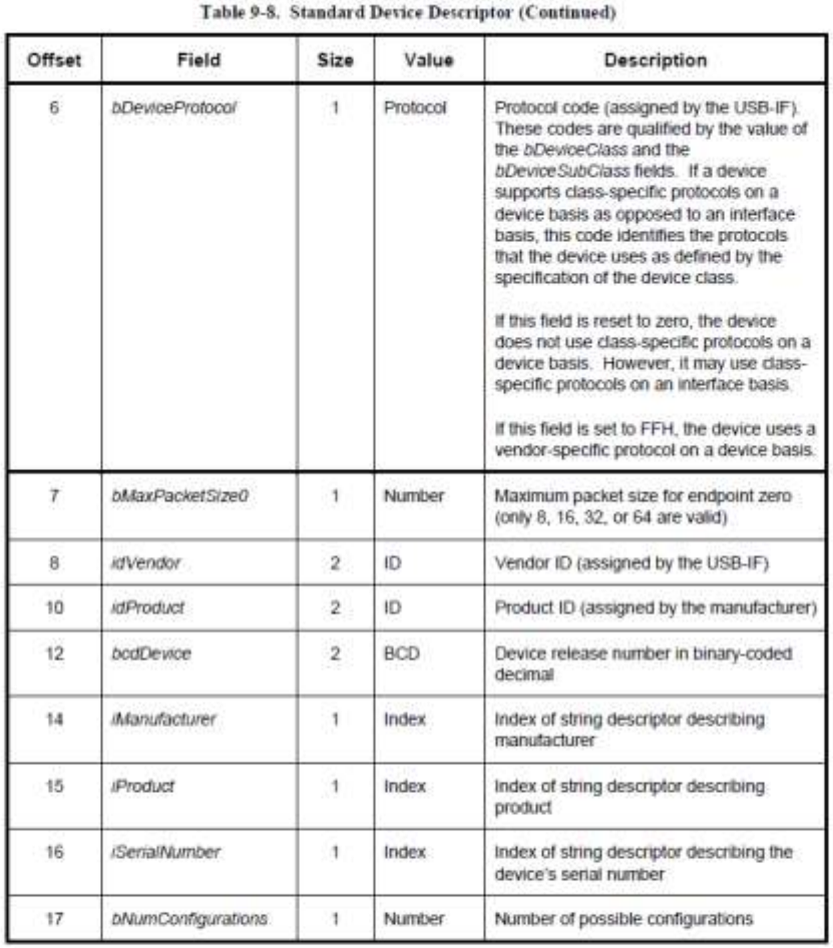


Table 9-8. Standard Device Descriptor (Continued)

Offset	Field	Size	Value	Description
6	*bDeviceProtocol*	1	Protocol	Protocol code (assigned by the USB-IF). These codes are qualified by the value of the *bDeviceClass* and the *bDeviceSubClass* fields. If a device supports class-specific protocols on a device basis as opposed to an interface basis, this code identifies the protocols that the device uses as defined by the specification of the device class. If this field is reset to zero, the device does not use class-specific protocols on a device basis. However, it may use class-specific protocols on an interface basis. If this field is set to FFH, the device uses a vendor-specific protocol on a device basis.
7	*bMaxPacketSize0*	1	Number	Maximum packet size for endpoint zero (only 8, 16, 32, or 64 are valid)
8	*idVendor*	2	ID	Vendor ID (assigned by the USB-IF)
10	*idProduct*	2	ID	Product ID (assigned by the manufacturer)
12	*bcdDevice*	2	BCD	Device release number in binary-coded decimal
14	*iManufacturer*	1	Index	Index of string descriptor describing manufacturer
15	*iProduct*	1	Index	Index of string descriptor describing product
16	*iSerialNumber*	1	Index	Index of string descriptor describing the device's serial number
17	*bNumConfigurations*	1	Number	Number of possible configurations

9.6.1 Device Descriptor

	bLength 0x12	bDescriptor Type	bcdUSB		bDevice Class	bDevice SubClass	bDevice Protocol	bMax PacketSize0
bytes	0	1	2	3	4	5	6	7
	Number 0x12	Device 1	Version Number 02XXH		Class code	SubClass Code	Protocol	SizeForEP0 (8,16,32,64)

	idVendor		idProduct		bcdDevice		iManufacturer	iProduct
bytes	8	9	10	11	12	13	14	15
	Vendor ID		Product ID		Device release Number		Index of string Desc	Index of string Desc

	iSerial Number	bNum Configs
bytes	16	17

9.6.1 Device Descriptor

- bsdUSB
  - The DEVICE descriptor of a high-speed capable device has a version number of 2.0 (0200H).
    - If the device is full-speed only or low-speed only, this version number indicates that it will respond correctly to a request for the device_qualifier desciptor (i.e., it will respond with a request error).
      - The bcdUSB field contains a BCD version number.
        - » The value of the bcdUSB field is 0xJJMN for version JJ.M.N (JJ – major version number, M – minor version number, N – sub-minor version number), e.g., version 2.1.3 is represented with value 0x0213 and version 2.0 is represented with a value of 0x0200.

9.6.1 Device Descriptor

- bDeviceClass
  - Zero
    - If this field is reset to zero, each interface within a configuration specifies its own class information and the various interfaces operate independently.
  - 0x01 - 0xFE
    - The device supports different class specifications on different interfaces and the interfaces may not operate independently.
    - This value identifies the class definition used for the aggregate interfaces.
  - 0xFF
    - Vendor-specific device class.

9.6.1 Device Descriptor

- bDeviceSubClass
  - These codes are qualified by the value of the bDeviceClass field.
  - Zero
    - If the bDeviceClass field is reset to zero, this field must also be reset to zero.
  - If the bDeviceClass field is not set to FFH, all values are reserved for assignment by the USB-IF.

9.6.1 Device Descriptor

- bDeviceProtocol
  - These codes are qualified by the value of the bDeviceClass and the bDeviceSubClass fields.
    - If a device supports class-specific protocols on a device basis as opposed to an interface basis, this code identifies the protocols that the device uses as defined by the specification of the device class.
  - Zero
    - The device does not use class-specific protocols on a device basis.
    - However, it may use class specific protocols on an interface basis.
  - 0xFF
    - The device uses a vendor-specific protocol on a device basis.

9.6.1 Device Descriptor

- bMaxPacketSize0
  - If the device is operating at high-speed, the *bMaxPacketSize0 field must be 64 indicating a 64 byte* maximum packet.
  - High-speed operation does not allow other maximum packet sizes for the control endpoint (endpoint 0).

9.6.1 Device Descriptor

- bNumConfigurations
  - This field indicates the number of configurations at the current operating speed.
  - Configurations for the other operating speed are not included in the count.
    - If there are specific configurations of the device for specific speeds, the bNumConfigurations field only reflects the number of configurations for a single speed, not the total number of configurations for both speeds.

9.6.1 Device Descriptor

- Default Control Pipe of the Device
  - All USB devices have a Default Control Pipe.
    - The maximum packet size of a device’s Default Control Pipe is described in the device descriptor.
  - Endpoints specific to a configuration and its interface(s) are described in the configuration descriptor.
  - A configuration and its interface(s) do not include an endpoint descriptor for the Default Control Pipe.
  - Other than the maximum packet size, the characteristics of the Default Control Pipe are defined by this specification and are the same for all USB devices.

9.6.2 Device_Qualifier Descriptor

- The device_qualifier descriptor describes information about a high-speed capable device that would change if the device were operating at the other speed.
  - For example, if the device is currently operating at full-speed, the device_qualifier returns information about how it would operate at high-speed and vice-versa.

9.6.2 Device_Qualifier Descriptor

	bLength	bDescriptor Type	bcdUSB		bDevice Class	bDevice SubClass	bDevice Protocol	bMax PacketSize0
bytes	0	1	2	3	4	5	6	7
	Number 0x0A	Qualifier 0x06	Version Number 02XXH		Class code	SubClass Code	Protocol	SizeForEP0 (8,16,32,64)

	bNum Configs	bReserved
bytes	8	9
	Number	Zero 0

9.6.2 Device_Qualifier Descriptor

- The version number for this descriptor must be at least 2.0 (0200H).
- The host accesses this descriptor using the GetDescriptor() request.

9.6.2 Device_Qualifier Descriptor

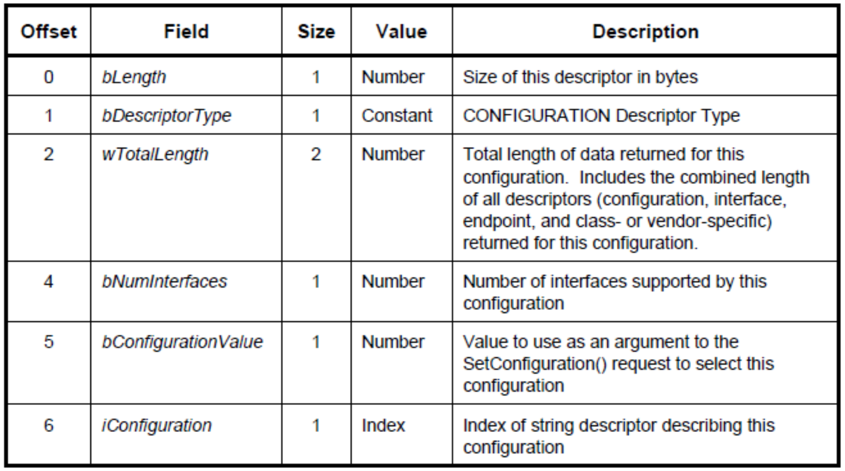
- If a full-speed only device (with a device descriptor version number equal to 0200H) receives a GetDescriptor() request for a device_qualifier, it must respond with a request error.
- The host must not make a request for an other_speed_configuration descriptor unless it first successfully retrieves the device_qualifier descriptor.

9.6.3 Configuration Descriptor

- The configuration descriptor describes information about a specific device configuration.
  - The descriptor contains a bConfigurationValue field with a value that, when used as a parameter to the SetConfiguration() request, causes the device to assume the described configuration.

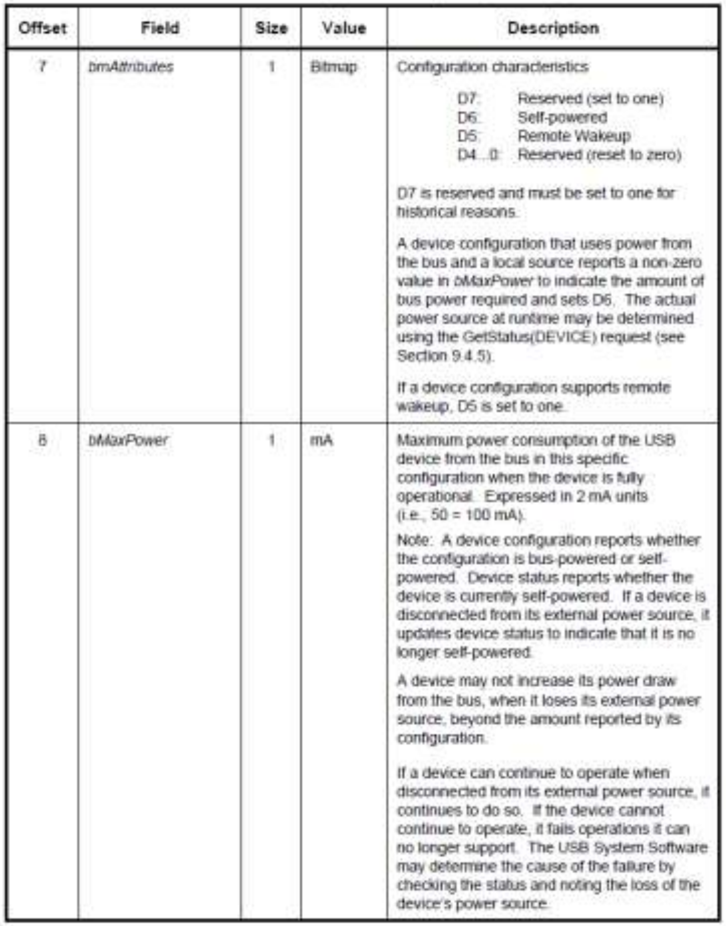
9.6.3 Configuration Descriptor

Table 9-10. Standard Configuration Descriptor



Offset	Field	Size	Value	Description
0	*bLength*	1	Number	Size of this descriptor in bytes
1	*bDescriptorType*	1	Constant	CONFIGURATION Descriptor Type
2	*wTotalLength*	2	Number	Total length of data returned for this configuration. Includes the combined length of all descriptors (configuration, interface, endpoint, and class- or vendor-specific) returned for this configuration.
4	*bNumInterfaces*	1	Number	Number of interfaces supported by this configuration
5	*bConfigurationValue*	1	Number	Value to use as an argument to the SetConfiguration() request to select this configuration
6	*iConfiguration*	1	Index	Index of string descriptor describing this configuration

Table 9-10. Standard Configuration Descriptor (Continued)



Offset	Field	Size	Value	Description
7	*bmAttributes*	1	Bitmap	Configuration characteristics D7: Reserved (set to one) D6: Self-powered D5: Remote Wakeup D4...0: Reserved (reset to zero) D7 is reserved and must be set to one for historical reasons. A device configuration that uses power from the bus and a local source reports a non-zero value in *bMaxPower* to indicate the amount of bus power required and sets D6. The actual power source at runtime may be determined using the GetStatus(DEVICE) request (see Section 9.4.5). If a device configuration supports remote wakeup, D5 is set to one.
8	*bMaxPower*	1	mA	Maximum power consumption of the USB device from the bus in this specific configuration when the device is fully operational. Expressed in 2 mA units (i.e., 50 = 100 mA). Note: A device configuration reports whether the configuration is bus-powered or self-powered. Device status reports whether the device is currently self-powered. If a device is disconnected from its external power source, it updates device status to indicate that it is no longer self-powered. A device may not increase its power draw from the bus, when it loses its external power source, beyond the amount reported by its configuration. If a device can continue to operate when disconnected from its external power source, it continues to do so. If the device cannot continue to operate, it fails operations it can no longer support. The USB System Software may determine the cause of the failure by checking the status and noting the loss of the device's power source.

9.6.3 Configuration Descriptor

	bLength	bDescriptor Type	wTotalLength		bNumber Interfaces	bConfig Value	iConfig	bmAttrib
bytes	0	1	2	3	4	5	6	7
	Number 0x09	Configuration 0x02	Number		Number	Number	Index	Attributes

D7: Reserved (Set to 1)
D6: Self-powered
D5: Remote Wakeup
D4-0: Reserved (reset to 0)

bMax Power (mA)
8
Power

9.6.3 Configuration Descriptor

- Interface
  - The descriptor describes the number of interfaces provided by the configuration.
    - Each interface may operate independently.
      - For example,
        - » 1st Configuration, an ISDN device might be configured with two interfaces, each providing 64 Kb/s bi-directional channels that have separate data sources or sinks on the host.
        - » 2nd Configuration might present the ISDN device as a single interface, bonding the two channels into one 128 Kb/s bi-directional channel.
  - When the host requests the configuration descriptor, all related interface and endpoint descriptors are returned (refer to Section 9.4.3).

9.6.3 Configuration Descriptor

- Endpoint
  - A USB device has one or more configuration descriptors.
    - Each configuration has one or more interfaces and each interface has zero or more endpoints.
    - An endpoint is not shared among interfaces within a single configuration unless the endpoint is used by alternate settings of the same interface.
    - Endpoints may be shared among interfaces that are part of different configurations without this restriction.

9.6.3 Configuration Descriptor

- Once configured, devices may support limited adjustments to the configuration.
- If a particular interface has alternate settings, an alternate may be selected after configuration.

9.6.3 Configuration Descriptor

- bmAttributes
  - D7
    - is reserved and must be set to one for historical reasons.
  - D6 Self-Powered
    - A device configuration that uses power from the bus and a local source reports a non-zero value in bMaxPower to indicate the amount of bus power required and sets D6.
    - The actual power source at runtime may be determined using the GetStatus(DEVICE) request (see Section 9.4.5).
  - D5 Remote Wakeup
    - If a device configuration supports remote wakeup, D5 is set to one.

9.6.3 Configuration Descriptor

- bMaxPower
  - – Maximum power consumption of the USB device from the bus in this specific configuration when the device is fully operational.
    - Expressed in 2 mA units (i.e., 50 = 100 mA).
  - – Power draw
    - If a device is disconnected from its external power source, it updates device status to indicate that it is no longer self-powered.
    - If a device is disconnected from its external power source, it updates device status to indicate that it is no longer self-powered.

9.6.3 Configuration Descriptor

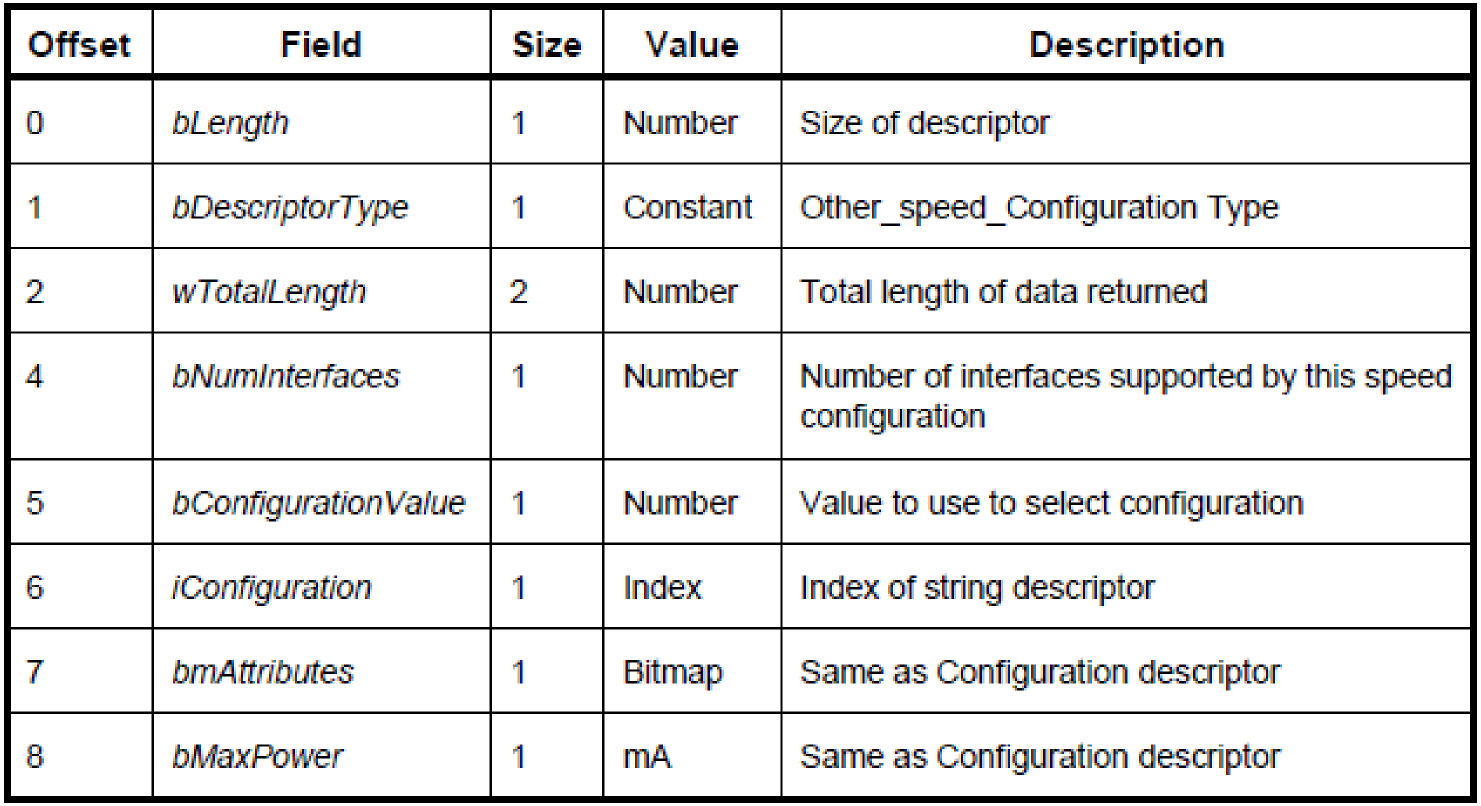
- bMaxPower
  - Power draw
    - If a device can continue to operate when disconnected from its external power source, it continues to do so.
    - If the device cannot continue to operate, it fails operations it can no longer support.
    - The USB System Software may determine the cause of the failure by checking the status and noting the loss of the device's power source.

9.6.4 Other_Speed_Configuration Descriptor

- The other_speed_configuration descriptor shown in Table 9-11 describes a configuration of a highspeed capable device if it were operating at its other possible speed.
- The structure of the other_speed_configuration is identical to a configuration descriptor.
- The host accesses this descriptor using the GetDescriptor() request.

9.6.4 Other_Speed_Configuration Descriptor

Table 9-11. Other_Speed_Configuration Descriptor



Offset	Field	Size	Value	Description
0	*bLength*	1	Number	Size of descriptor
1	*bDescriptorType*	1	Constant	Other_speed_Configuration Type
2	*wTotalLength*	2	Number	Total length of data returned
4	*bNumInterfaces*	1	Number	Number of interfaces supported by this speed configuration
5	*bConfigurationValue*	1	Number	Value to use to select configuration
6	*iConfiguration*	1	Index	Index of string descriptor
7	*bmAttributes*	1	Bitmap	Same as Configuration descriptor
8	*bMaxPower*	1	mA	Same as Configuration descriptor

9.6.4 Other_Speed_Configuration Descriptor

	bLength	bDescriptor Type	wTotalLength		bNumber Interfaces	bConfig Value	iConfig	bmAttrib
bytes	0	1	2	3	4	5	6	7
	Number 0x09	Other_Speed 0x07	Number		Number	Number	Index	Attributes

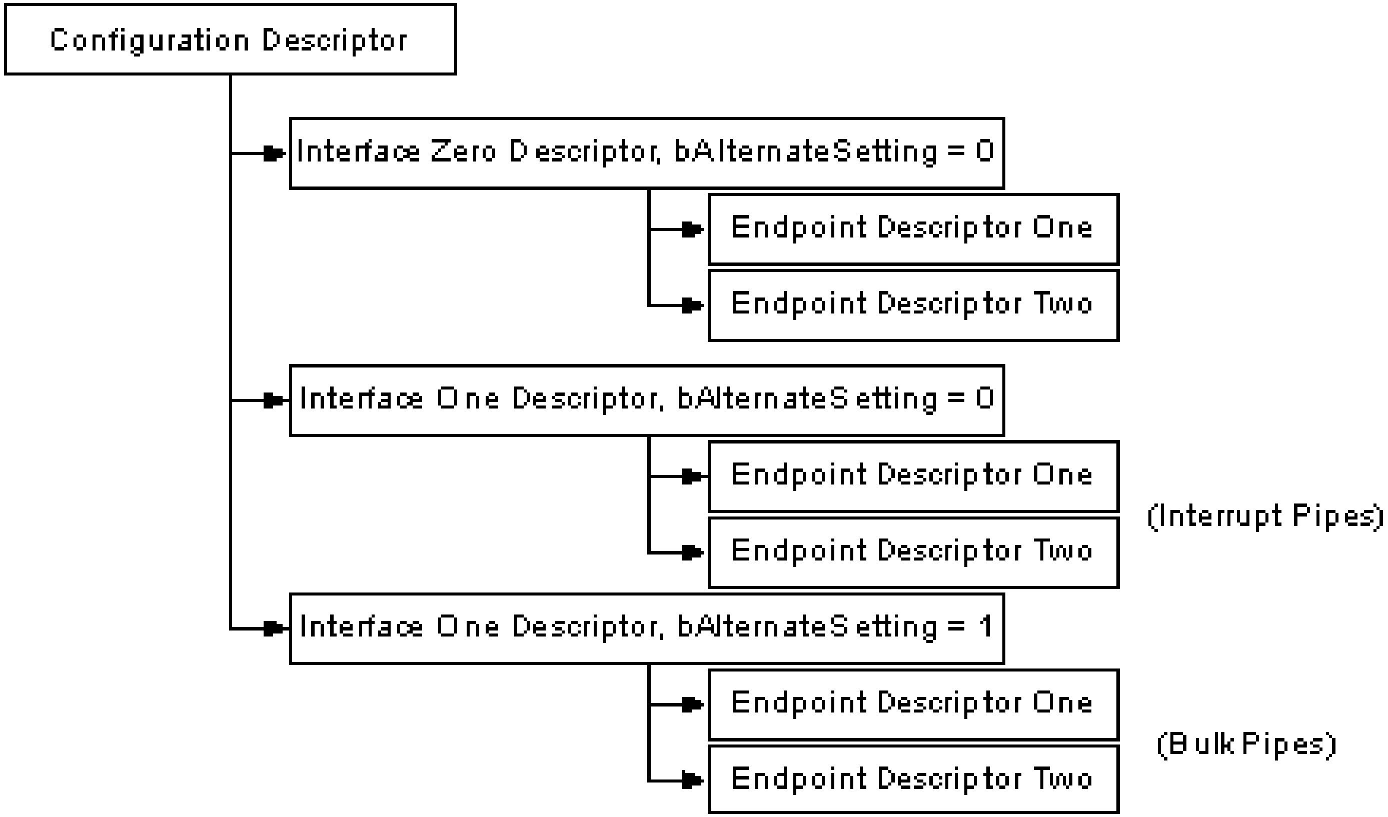
D7: Reserved (Set to 1)
D6: Self-powered
D5: Remote Wakeup
D4-0: Reserved (reset to 0)

bMax Power (mA)
8
Power

9.6.5 Interface Descriptor

- The interface descriptor describes a specific interface within a configuration.
  - A configuration provides one or more interfaces, each with zero or more endpoint descriptors describing a unique set of endpoints within the configuration.
  - When a configuration supports more than one interface, the endpoint descriptors for a particular interface follow the interface descriptor in the data returned by the GetConfiguration() request.
  - An interface descriptor is always returned as part of a configuration descriptor.
  - Interface descriptors cannot be directly accessed with a GetDescriptor() or SetDescriptor() request.

9.6.5 Interface Descriptor



Configuration Descriptor

Interface Zero Descriptor, bAlternateSetting = 0

Endpoint Descriptor One

Endpoint Descriptor Two

Interface One Descriptor, bAlternateSetting = 0

Endpoint Descriptor One

Endpoint Descriptor Two

(Interrupt Pipes)

Interface One Descriptor, bAlternateSetting = 1

Endpoint Descriptor One

Endpoint Descriptor Two

(Bulk Pipes)

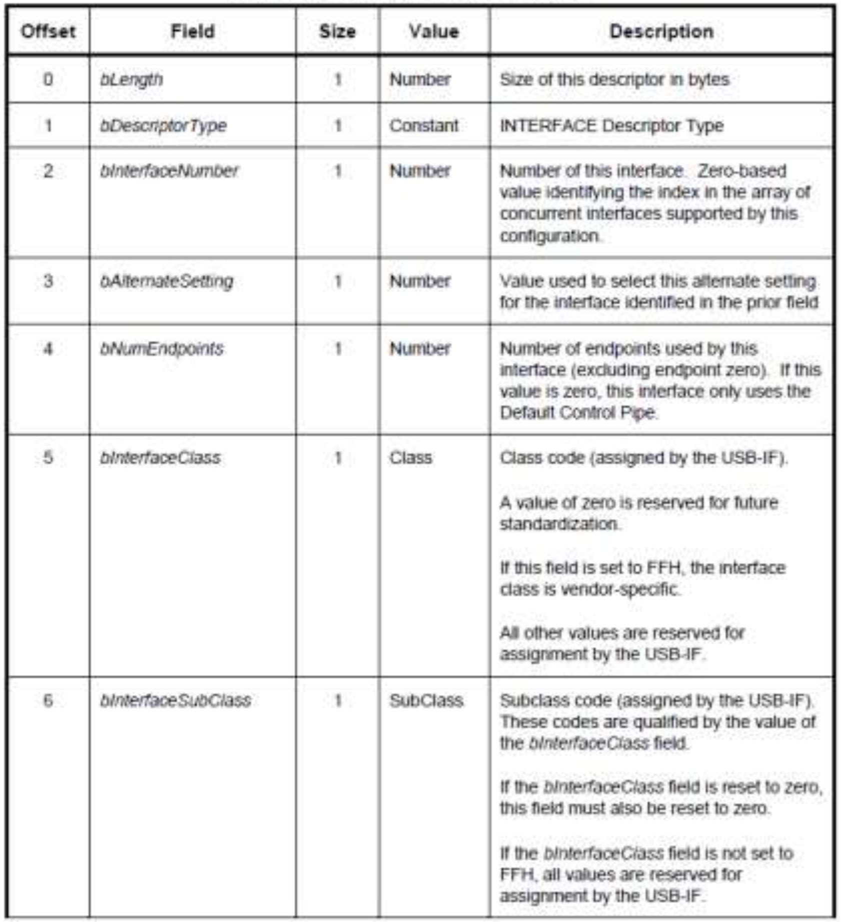
USB in a NutShell, http://www.beyondlogic.org/usbnutshell/usb5.shtml

9.6.5 Interface Descriptor

- An interface descriptor is always returned as part of a configuration descriptor.
- Interface descriptors cannot be directly accessed with a GetDescriptor() or SetDescriptor() request.

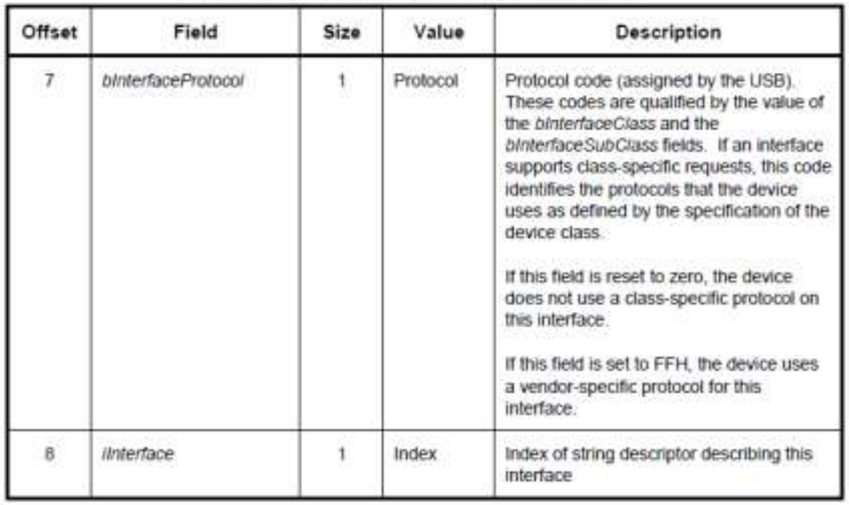
9.6.5 Interface Descriptor

Table 9-12. Standard Interface Descriptor



Offset	Field	Size	Value	Description
0	*bLength*	1	Number	Size of this descriptor in bytes
1	*bDescriptorType*	1	Constant	INTERFACE Descriptor Type
2	*bInterfaceNumber*	1	Number	Number of this interface. Zero-based value identifying the index in the array of concurrent interfaces supported by this configuration.
3	*bAlternateSetting*	1	Number	Value used to select this alternate setting for the interface identified in the prior field
4	*bNumEndpoints*	1	Number	Number of endpoints used by this interface (excluding endpoint zero). If this value is zero, this interface only uses the Default Control Pipe.
5	*bInterfaceClass*	1	Class	Class code (assigned by the USB-IF). A value of zero is reserved for future standardization. If this field is set to FFH, the interface class is vendor-specific. All other values are reserved for assignment by the USB-IF.
6	*bInterfaceSubClass*	1	SubClass	Subclass code (assigned by the USB-IF). These codes are qualified by the value of the *bInterfaceClass* field. If the *bInterfaceClass* field is reset to zero, this field must also be reset to zero. If the *bInterfaceClass* field is not set to FFH, all values are reserved for assignment by the USB-IF.

Table 9-12. Standard Interface Descriptor (Continued)



Offset	Field	Size	Value	Description
7	*bInterfaceProtocol*	1	Protocol	Protocol code (assigned by the USB). These codes are qualified by the value of the *bInterfaceClass* and the *bInterfaceSubClass* fields. If an interface supports class-specific requests, this code identifies the protocols that the device uses as defined by the specification of the device class. If this field is reset to zero, the device does not use a class-specific protocol on this interface. If this field is set to FFH, the device uses a vendor-specific protocol for this interface.
8	*iInterface*	1	Index	Index of string descriptor describing this interface

9.6.5 Interface Descriptor

	bLength	bDescriptor Type	bInterface Number	bAlternate Setting	bNum Endpoints	bInterface Class	bInterface SubClass	bInterface Protocol
bytes	0	1	2	3	4	5	6	7
	Number 0x09	Interface 0x04	Number	Number	Number	Class	SubClass	Protocol

iInterface
8
Index

9.6.5 Interface Descriptor

- Alternate Settings
  - An interface may include alternate settings that allow the endpoints and/or their characteristics to be varied after the device has been configured.
  - The default setting for an interface is always alternate setting zero.
  - The SetInterface() request is used to select an alternate setting or to return to the default setting.
  - The GetInterface() request returns the selected alternate setting.

9.6.5 Interface Descriptor

- Alternate Settings
  - Alternate settings allow a portion of the device configuration to be varied while other interfaces remain in operation.
  - If a configuration has alternate settings for one or more of its interfaces, a separate interface descriptor and its associated endpoints are included for each setting.

9.6.5 Interface Descriptor

- Alternate Settings
  - If a device configuration supported a single interface with two alternate settings, the configuration descriptor would be followed by
    - The first interface descriptor with the *bInterfaceNumber and bAlternateSetting* fields set to zero and then the endpoint descriptors for that setting,
      - followed by another interface descriptor and its associated endpoint descriptors.
    - The second interface descriptor's *bInterfaceNumber field would* also be set to zero, but the *bAlternateSetting field of the second interface descriptor would be set to one.*

9.6.5 Interface Descriptor

- Endpoint
  - If an interface uses only endpoint zero, no endpoint descriptors follow the interface descriptor.
    - In this case, the *bNumEndpoints field must be set to zero.*
  - An interface descriptor never includes endpoint zero in the number of endpoints.

9.6.5 Interface Descriptor

- bInterfaceClass
  - A value of zero is reserved for future standardization.
  - If this field is set to FFH, the interface class is vendor-specific.
- bInterfaceSubClass
  - These codes are qualified by the value of the bInterfaceClass field.
  - If the bInterfaceClass field is reset to zero, this field must also be reset to zero.
  - If the bInterfaceClass field is not set to FFH, all values are reserved for assignment by the USB-IF.

9.6.5 Interface Descriptor

- bInterfaceProtocol
  - These codes are qualified by the value of the bInterfaceClass and the bInterfaceSubClass fields.
  - If an interface supports class-specific requests, this code identifies the protocols that the device uses as defined by the specification of the device class.
  - Zero
    - the device does not use a class-specific protocol on this interface.
  - 0xFF
    - the device uses a vendor-specific protocol for this interface.
- iInterface
  - Index of string descriptor describing this interface.

9.6.6 Endpoint Descriptor

- Each endpoint used for an interface has its own descriptor.
  - This descriptor contains the information required by the host to determine the bandwidth requirements of each endpoint.
  - An endpoint descriptor is always returned as part of the configuration information returned by a GetDescriptor(Configuration) request.
  - An endpoint descriptor cannot be directly accessed with a GetDescriptor() or SetDescriptor() request.
  - There is never an endpoint descriptor for endpoint zero.

9.6.6 Endpoint Descriptor

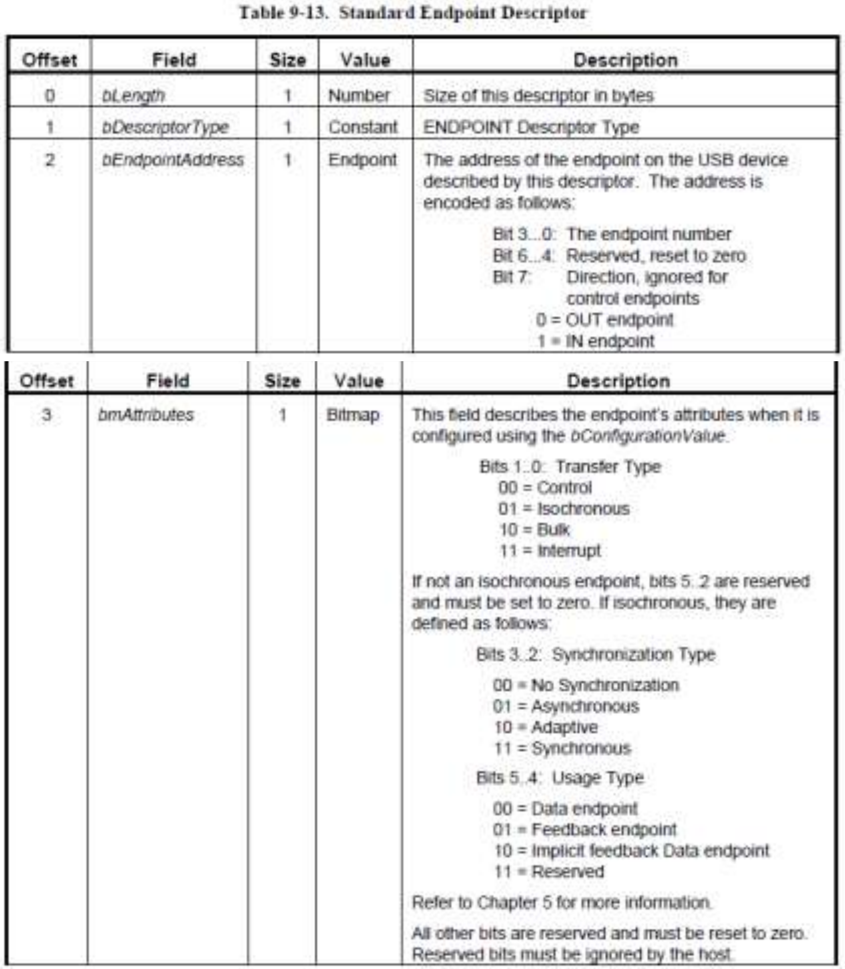


Table 9-13. Standard Endpoint Descriptor

Offset	Field	Size	Value	Description
0	*bLength*	1	Number	Size of this descriptor in bytes
1	*bDescriptorType*	1	Constant	ENDPOINT Descriptor Type
2	*bEndpointAddress*	1	Endpoint	The address of the endpoint on the USB device described by this descriptor. The address is encoded as follows: Bit 3...0: The endpoint number Bit 6...4: Reserved, reset to zero Bit 7: Direction, ignored for control endpoints 0 = OUT endpoint 1 = IN endpoint

Offset	Field	Size	Value	Description
3	*bmAttributes*	1	Bitmap	This field describes the endpoint's attributes when it is configured using the *bConfigurationValue*. Bits 1..0: Transfer Type 00 = Control 01 = Isochronous 10 = Bulk 11 = Interrupt If not an isochronous endpoint, bits 5..2 are reserved and must be set to zero. If isochronous, they are defined as follows: Bits 3..2: Synchronization Type 00 = No Synchronization 01 = Asynchronous 10 = Adaptive 11 = Synchronous Bits 5..4: Usage Type 00 = Data endpoint 01 = Feedback endpoint 10 = Implicit feedback Data endpoint 11 = Reserved Refer to Chapter 5 for more information. All other bits are reserved and must be reset to zero. Reserved bits must be ignored by the host.

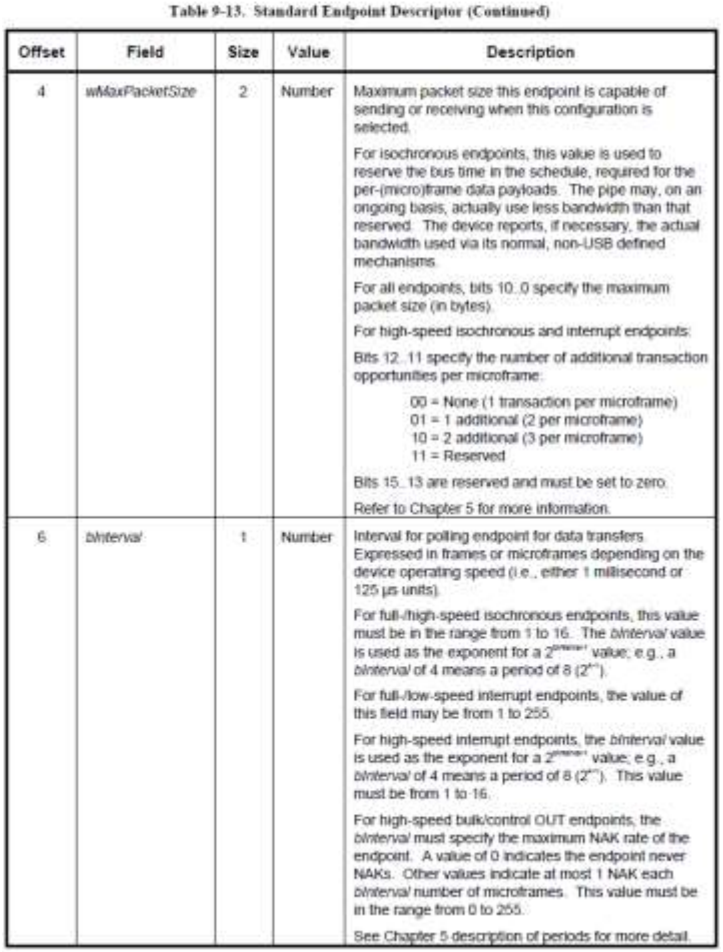
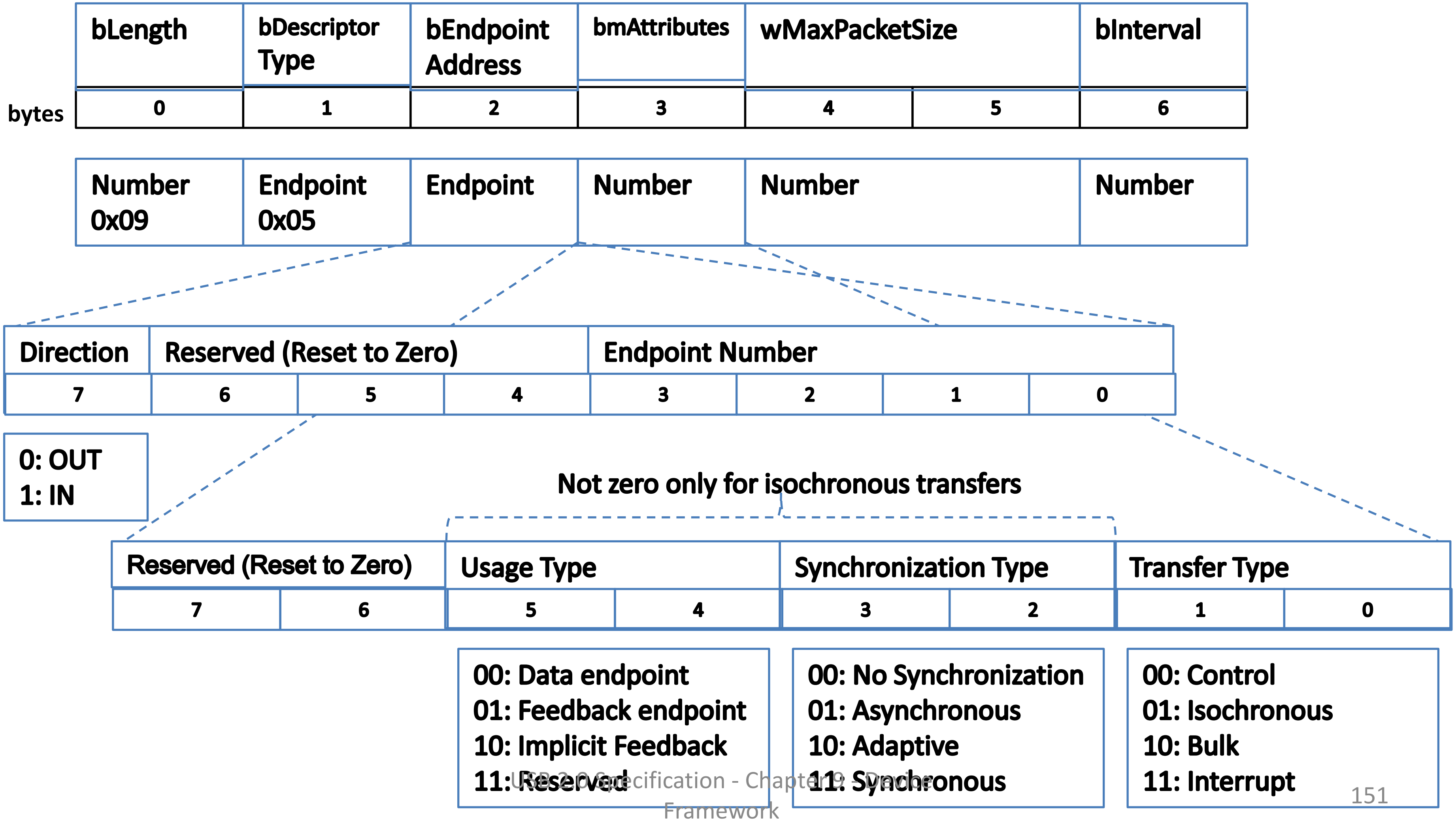


Table 9-13. Standard Endpoint Descriptor (Continued)

Offset	Field	Size	Value	Description
4	*wMaxPacketSize*	2	Number	Maximum packet size this endpoint is capable of sending or receiving when this configuration is selected. For isochronous endpoints, this value is used to reserve the bus time in the schedule, required for the per-(micro)frame data payloads. The pipe may, on an ongoing basis, actually use less bandwidth than that reserved. The device reports, if necessary, the actual bandwidth used via its normal, non-USB defined mechanisms. For all endpoints, bits 10..0 specify the maximum packet size (in bytes). For high-speed isochronous and interrupt endpoints: Bits 12..11 specify the number of additional transaction opportunities per microframe: 00 = None (1 transaction per microframe) 01 = 1 additional (2 per microframe) 10 = 2 additional (3 per microframe) 11 = Reserved Bits 15..13 are reserved and must be set to zero. Refer to Chapter 5 for more information.
6	*bInterval*	1	Number	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 µs units). For full-/high-speed isochronous endpoints, this value must be in the range from 1 to 16. The *bInterval* value is used as the exponent for a $2^{bInterval-1}$ value; e.g., a *bInterval* of 4 means a period of 8 (2^{4-1}). For full-/low-speed interrupt endpoints, the value of this field may be from 1 to 255. For high-speed interrupt endpoints, the *bInterval* value is used as the exponent for a $2^{bInterval-1}$ value; e.g., a *bInterval* of 4 means a period of 8 (2^{4-1}). This value must be from 1 to 16. For high-speed bulk/control OUT endpoints, the *bInterval* must specify the maximum NAK rate of the endpoint. A value of 0 indicates the endpoint never NAKs. Other values indicate at most 1 NAK each *bInterval* number of microframes. This value must be in the range from 0 to 255. See Chapter 5 description of periods for more detail.

9.6.6 Endpoint Descriptor



	bLength	bDescriptor Type	bEndpoint Address	bmAttributes	wMaxPacketSize		bInterval
bytes	0	1	2	3	4	5	6
	Number 0x09	Endpoint 0x05	Endpoint	Number	Number		Number

Direction	Reserved (Reset to Zero)			Endpoint Number			
7	6	5	4	3	2	1	0

0: OUT
1: IN

Not zero only for isochronous transfers

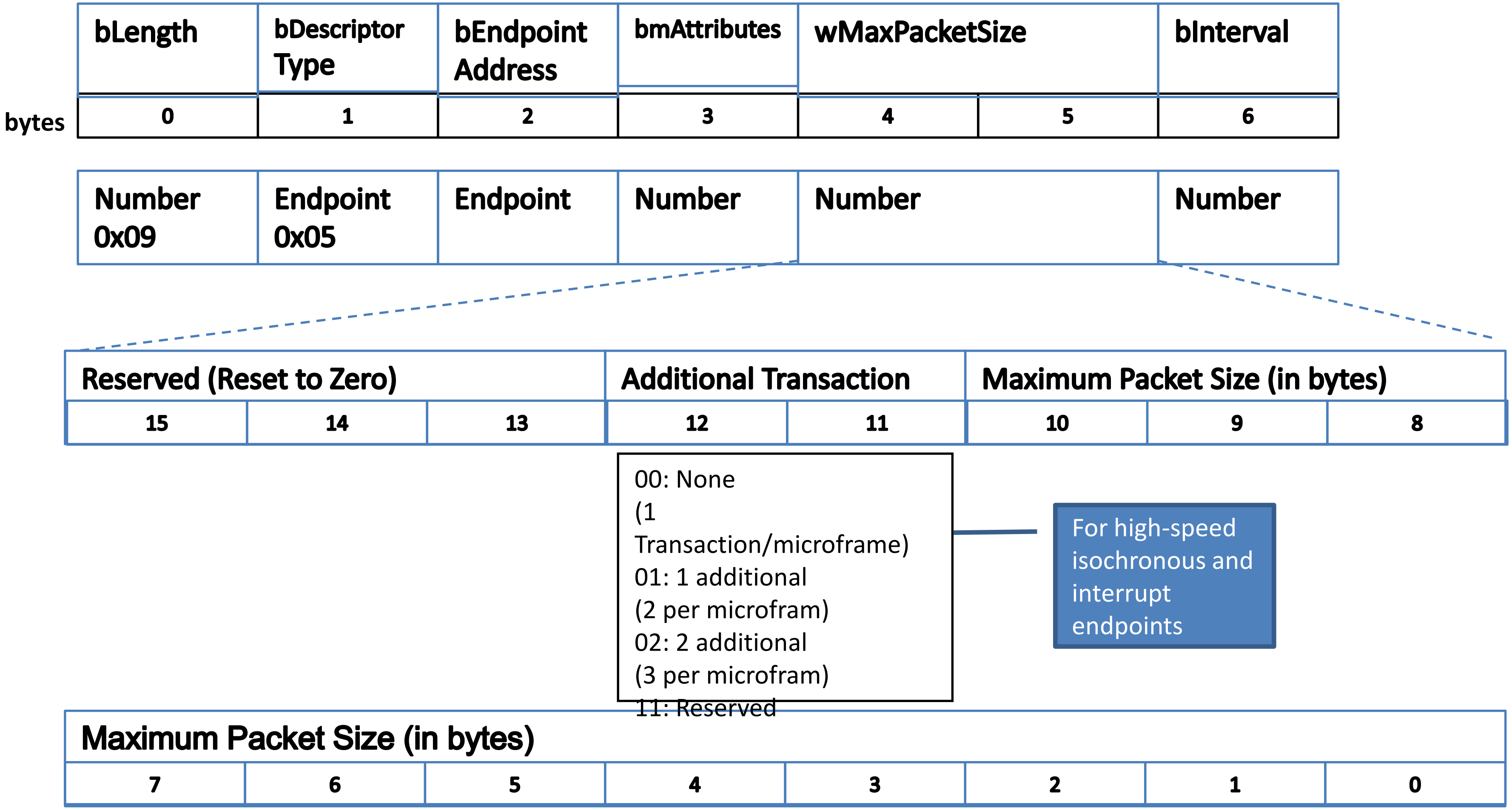
Reserved (Reset to Zero)		Usage Type		Synchronization Type		Transfer Type	
7	6	5	4	3	2	1	0

00: Data endpoint
01: Feedback endpoint
10: Implicit Feedback
11: Reserved

00: No Synchronization
01: Asynchronous
10: Adaptive
11: Synchronous

00: Control
01: Isochronous
10: Bulk
11: Interrupt

9.6.6 Endpoint Descriptor



	bLength	bDescriptor Type	bEndpoint Address	bmAttributes	wMaxPacketSize		bInterval
bytes	0	1	2	3	4	5	6
	Number 0x09	Endpoint 0x05	Endpoint	Number	Number		Number

Reserved (Reset to Zero)			Additional Transaction		Maximum Packet Size (in bytes)		
15	14	13	12	11	10	9	8

00: None
(1 Transaction/microframe)
01: 1 additional
(2 per microfram)
02: 2 additional
(3 per microfram)
11: Reserved

For high-speed isochronous and interrupt endpoints

Maximum Packet Size (in bytes)							
7	6	5	4	3	2	1	0

wMAXPacketSize

9.6.6 Endpoint Descriptor

	bLength	bDescriptor Type	bEndpoint Address	bmAttributes	wMaxPacketSize		bInterval
bytes	0	1	2	3	4	5	6
	Number 0x09	Endpoint 0x05	Endpoint	Number	Number		Number

For full-/high-speed isochronous endpoints, this value must be in the range from 1 to 16.

The bInterval value is used as the exponent for a $2^{\text{bInterval-1}}$ value; e.g., a bInterval of 4 means a period of 8 (2^{4-1}).

For full-/low-speed interrupt endpoints, the value of this field may be from 1 to 255.

For high-speed interrupt endpoints, the bInterval value is used as the exponent for a $2^{\text{bInterval-1}}$ value; e.g., a bInterval of 4 means a period of 8 (2^{4-1}).

This value must be from 1 to 16.

For high-speed bulk/control OUT endpoints, the bInterval must specify the maximum NAK rate of the endpoint. A value of 0 indicates the endpoint never NAKs. Other values indicate at most 1 NAK each bInterval number of microframes. This value must be in the range from 0 to 255.

9.6.6 Endpoint Descriptor

- bmAttribute
  - Isochronous
    - (B5..2) are only meaningful for isochronous endpoints and must be reset to zero for all other transfer types.
    - If the endpoint is used as an explicit feedback endpoint (bits 5..4=01B),
      - then the Transfer Type must be set to isochronous (bits1..0 = 01B)
      - and the Synchronization Type must be set to No Synchronization (bits 3..2=00B).

9.6.6 Endpoint Descriptor

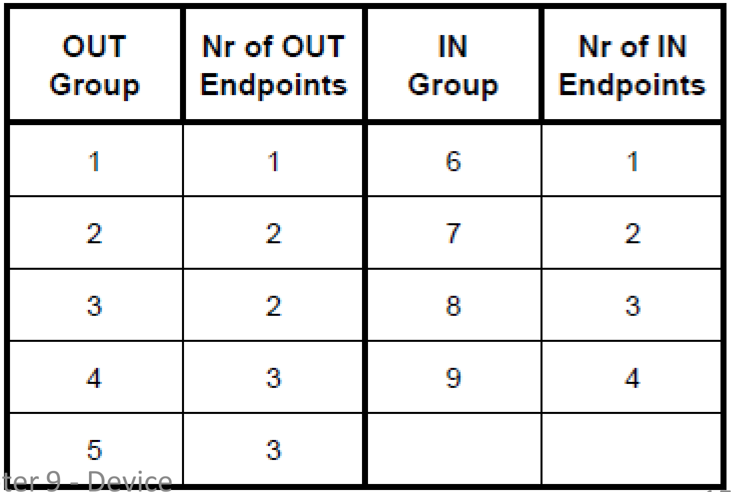
- bmAttribute
  - This field describes the endpoint's attributes when it is configured using the bConfigurationValue.
    - Transfer Type (B1..0)
    - Synchronization Type (B3..2)
    - Usage Type (B5..4)
  - If not an isochronous endpoint, (B5..2) are reserved and must be set to zero.

9.6.6 Endpoint Descriptor

- bmAttribute
  - Feedback
    - A feedback endpoint (explicit or implicit) needs to be associated with one (or more) isochronous data endpoints to which it provides feedback service.
      - The association is based on endpoint number matching.
    - A feedback endpoint always has the opposite direction from the data endpoint(s) it services.
      - If multiple data endpoints are to be serviced by the same feedback endpoint, the data endpoints must have ascending ordered–but not necessarily consecutive–endpoint numbers.
        - » The first data endpoint and the feedback endpoint must have the same endpoint number (and opposite direction).
        - » This ensures that a data endpoint can uniquely identify its feedback endpoint by searching for the first feedback endpoint that has an endpoint number equal or less than its own endpoint number.

9.6.6 Endpoint Descriptor

- bmAttribute
  - Feedback
    - Example:
      - Consider the extreme case where there is a need for five groups of OUT asynchronous isochronous endpoints and at the same time four groups of IN adaptive isochronous endpoints.
      - Each group needs a separate feedback endpoint and the groups are composed as shown in Figure 9-7.



OUT Group	Nr of OUT Endpoints	IN Group	Nr of IN Endpoints
1	1	6	1
2	2	7	2
3	2	8	3
4	3	9	4
5	3		

Figure 9-7. Example of Feedback Endpoint Numbers

9.6.6 Endpoint Descriptor

- bmAttribute
  - Feedback

The endpoint numbers can be intertwined as illustrated in Figure 9-8.

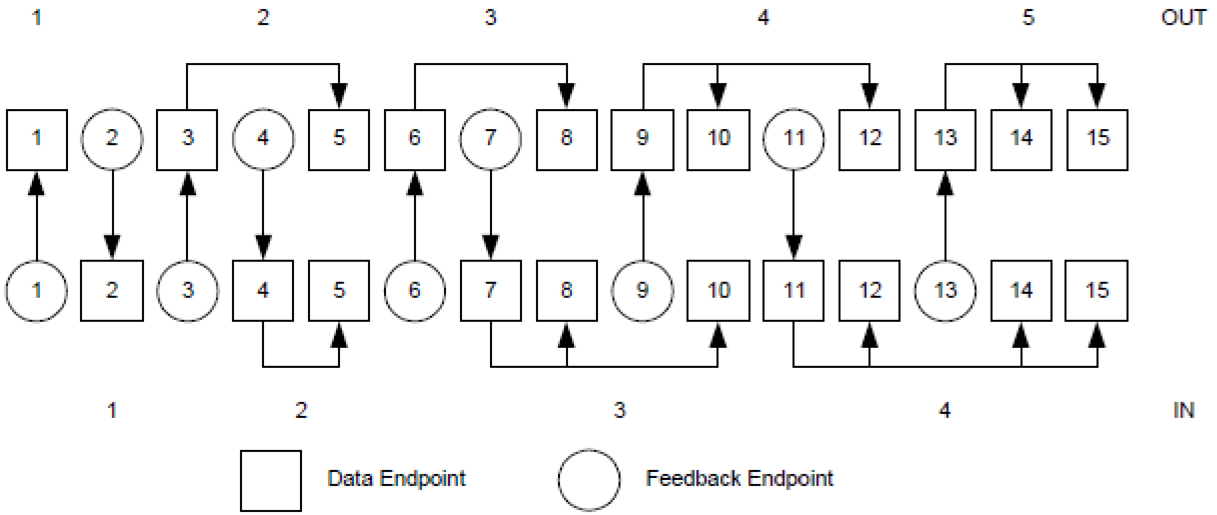


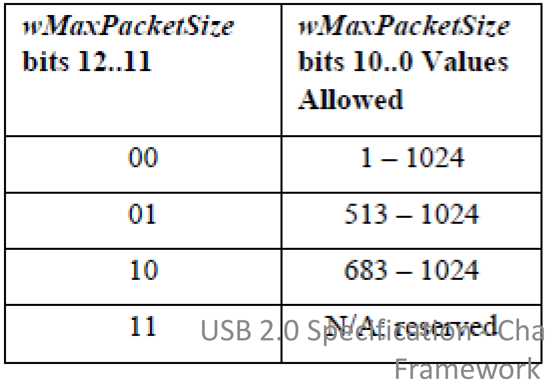
Figure 9-8. Example of Feedback Endpoint Relationships

9.6.6 Endpoint Descriptor

- wMaxPacketSize
  - Maximum packet size this endpoint is capable of sending or receiving when this configuration is selected.
    - For isochronous endpoints, this value is used to reserve the bus time in the schedule, required for the per-(micro)frame data payloads.
      - The pipe may, on an ongoing basis, actually use less bandwidth than that reserved.
      - The device reports, if necessary, the actual bandwidth used via its normal, non-USB defined mechanisms.

9.6.6 Endpoint Descriptor

- wMaxPacketSize
  - High-speed isochronous and interrupt endpoints use B(12..11) of wMaxPacketSize to specify multiple transactions for each microframe specified by bInterval.
    - If bits 12..11 of wMaxPacketSize are zero, the maximum packet size for the endpoint can be any allowed value (as defined in Chapter 5).
    - If bits 12..11 of wMaxPacketSize are not zero (0), the allowed values for wMaxPacketSize bits 10..0 are limited as shown in Table 9-14.



wMaxPacketSize bits 12..11	*wMaxPacketSize* bits 10..0 Values Allowed
00	1 – 1024
01	513 – 1024
10	683 – 1024
11	N/A; reserved

Table 9-14. Allowed wMaxPacketSize Values for Different Numbers of Transactions per Microframe

9.6.6 Endpoint Descriptor

- bInterval
  - 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 µs units).
    - For high-speed bulk and control OUT endpoints,
      - the bInterval field is only used for compliance purposes;
      - the host controller is not required to change its behavior based on the value in this field.

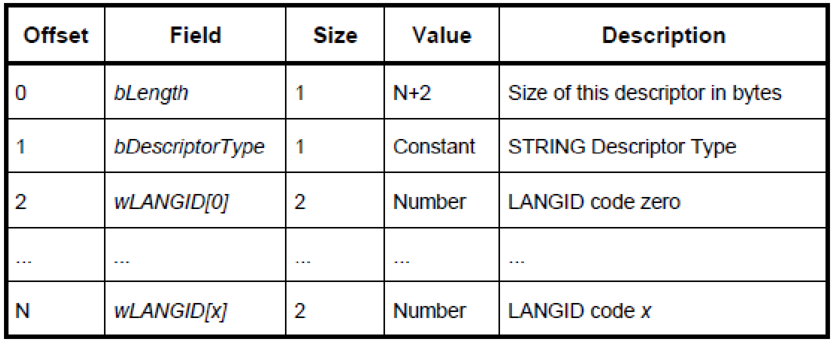
9.6.7 String Descriptor

- String descriptors are optional.
  - If a device does not support string descriptors, all references to string descriptors within device, configuration, and interface descriptors must be reset to zero.

9.6.7 String Descriptor

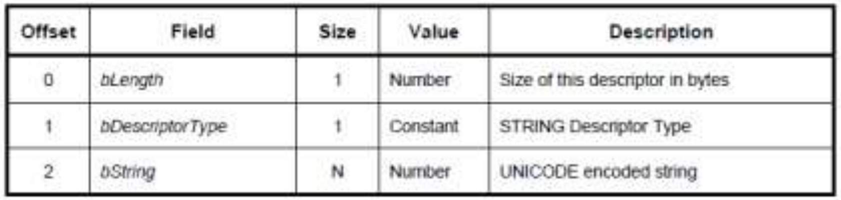
- String descriptors use UNICODE encodings as defined by The Unicode Standard, V3.0
  - The strings in a USB device may support multiple languages.
  - When requesting a string descriptor, the requester specifies the desired language using a 16 bits language ID (LANGID) defined by the USB-IF.

Table 9-15. String Descriptor Zero, Specifying Languages Supported by the Device



Offset	Field	Size	Value	Description
0	*bLength*	1	N+2	Size of this descriptor in bytes
1	*bDescriptorType*	1	Constant	STRING Descriptor Type
2	*wLANGID[0]*	2	Number	LANGID code zero
...	...	...	...	...
N	*wLANGID[x]*	2	Number	LANGID code *x*

Table 9-16. UNICODE String Descriptor



Offset	Field	Size	Value	Description
0	*bLength*	1	Number	Size of this descriptor in bytes
1	*bDescriptorType*	1	Constant	STRING Descriptor Type
2	*bString*	N	Number	UNICODE encoded string

9.6.7 String Descriptor

- String index zero for all languages returns a string descriptor that contains an array of two-byte LANGID codes supported by the device.
- A USB device may omit all string descriptors.
  - USB devices that omit all string descriptors must not return an array of LANGID codes.
- The array of LANGID codes is not NULL-terminated.
  - The size of the array (in bytes) is computed by subtracting two from the value of the first byte of the descriptor.
- The UNICODE string descriptor (shown in Table 9-16) is not NULL-terminated.
  - The string length is computed by subtracting two from the value of the first byte of the descriptor.

9.6.7 String Descriptor

	bLength	bDescriptor Type	wLANGID[0]		wLANGID[…]		wLANGID[X-1]	
bytes	0	1	2	3	4	5	6	7
	Number N+2 (2X+2)	Interface 0x03	Number		Number		Number	

Table 9-15. String Descriptor Zero, Specifying Languages Supported by the Device

	bLength	bDescriptor Type	wLANGID[0]					
bytes	0	1	2	3	4	5	6	7
	Number N+2	Interface 0x03	Number N					

Table 9-16. UNICODE String Descriptor

9.7 Device Class Definitions

- All devices must support the requests and descriptor definitions described in this chapter (Chapter 9).
- Most devices provide additional requests and, possibly, descriptors for device-specific extensions.
  - In addition, devices may provide extended services that are common to a group of devices.
  - In order to define a class of devices, the following information must be provided to completely define the appearance and behavior of the device class.
    - **9.7.1 Descriptors**
    - **9.7.2 Interface(s) and Endpoint Usage**
    - **9.7.3 Requests**

9.7.1 Descriptors

- If the class requires any specific definition of the standard descriptors, the class definition must include those requirements as part of the class definition.
  - In addition, if the class defines a standard extended set of descriptors, they must also be fully defined in the class definition.
  - Any extended descriptor definitions must follow the approach used for standard descriptors; for example, all descriptors must begin with a length field.

9.7.2 Interface(s) and Endpoint Usage

- When a class of devices is standardized, the interfaces used by the devices, including how endpoints are used, must be included in the device class definition.
- Devices may further extend a class definition with proprietary features as long as they meet the base definition of the class.

9.7.3 Requests

- All of the requests specific to the class must be defined.