By Mostafa El-koumy

Introduction to USB ?

ORIGINAL MOTIVATION

- merging of computing and communication.
- Flexibility.
- Ease of using by an end user.
- High speed.
- Port expansion.

USB Speeds

- High Speed - 480 Mbits/s.
- Full Speed - 12 Mbits/s.
- Low Speed - 1.5 Mbits/s.

- USB version 1 supports Low and Full speeds.

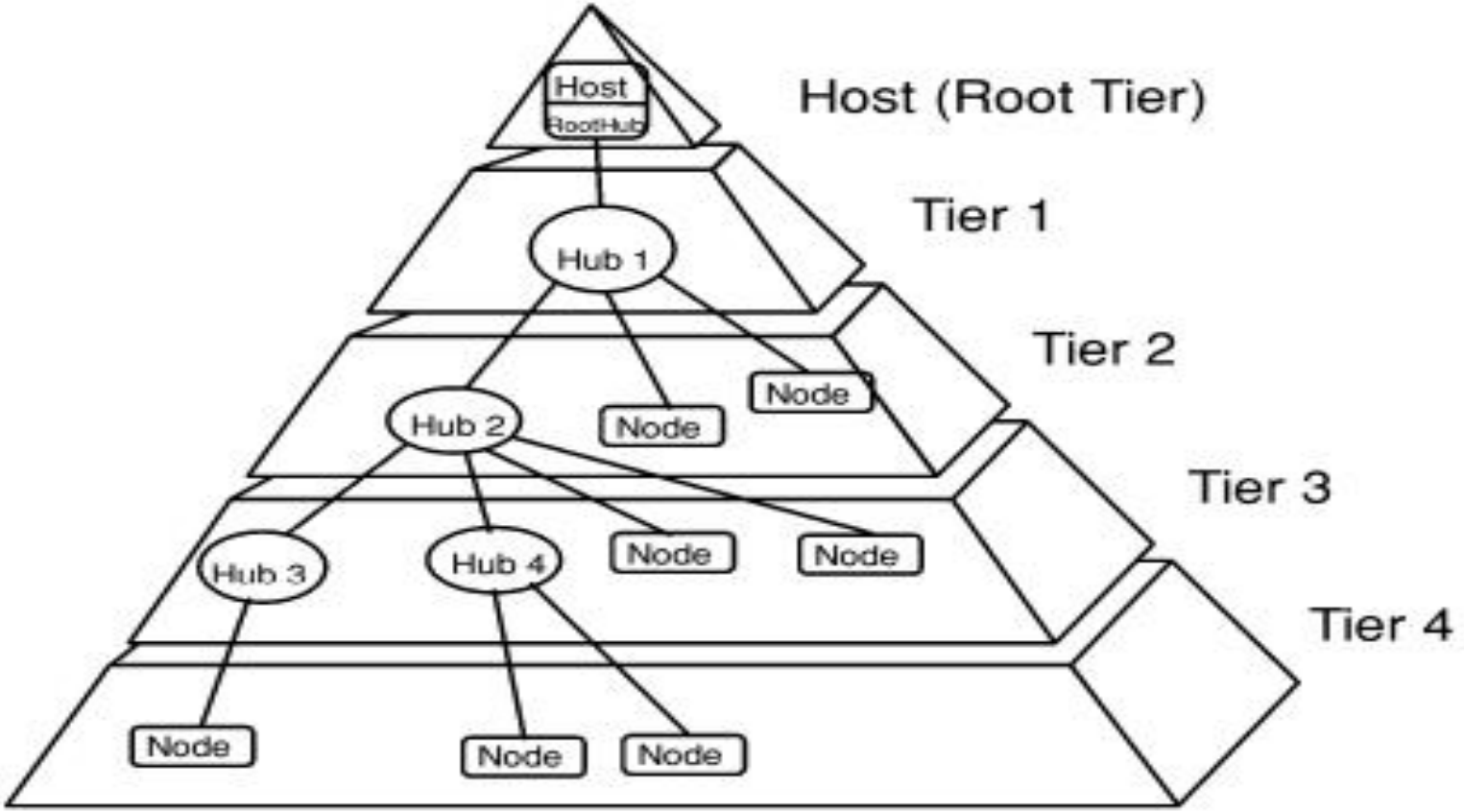
- USB 2.0 that in our hands today supports the three speeds.

USB BUS

- USB is host controlled so only one host can per bus and does not support any form of multi-master arrangement.
- The USB host is responsible for undertaking all transactions and scheduling bandwidth.
- Data can be sent by various transaction methods using a token-based protocol.
- The starting of implementation of USB idea was by Apple As Apple Desktop Bus (ADB).

USB TOPOLOGY

- Star topology



- Host is responsible for powering the nodes if there is no alternate power source.
- Up to 127 devices can be attached to USB bus at once.
- It uses 4 shielded wires such that two are power (+5v & GND) and The remaining two are twisted pair differential data signals.
- USB supports plug & play with dynamically loadable and unloadable drivers.

- The loading of the appropriate driver is done using a PID/VID (Product ID/Vendor ID) combination.
- The VID is supplied by the USB Implementer's forum.
- Some organizations provide a extra VID for non-commercial activities such as teaching, research.
- USB supports Control, Interrupt, Bulk and Isochronous transfers.
- Data on the USB bus is transmitted LSb first.

Connection

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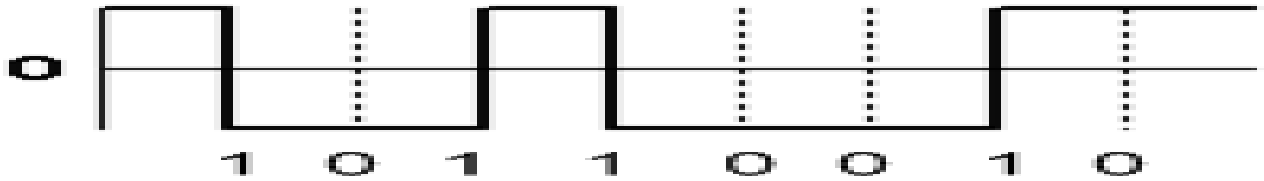
- All devices have an upstream connection to the host or hub and all hosts and hubs have a downstream connection to the device.

- There are commonly two types of connectors, called type A and type B which are shown below.
- Type A plugs always face upstream and Type B sockets are found on devices.
- Type Mini was made for handheld devices (A&B).

- USB uses a differential transmission pair for data. This is encoded using **NRZI** and is **bit stuffed** to ensure adequate transitions in the data stream.



- The speed of USB bus is known by the applied voltage on the bus using built in pull-up resistor.

- A USB device will enter suspend state when there is no activity on the bus for greater than 3.0 ms. It then has a further 7 ms to shutdown the device.
- so USB has a start of frame packet or keep alive sent periodically on the bus. This prevents an idle bus from entering suspend mode in the absence of data.

Suspend sorts

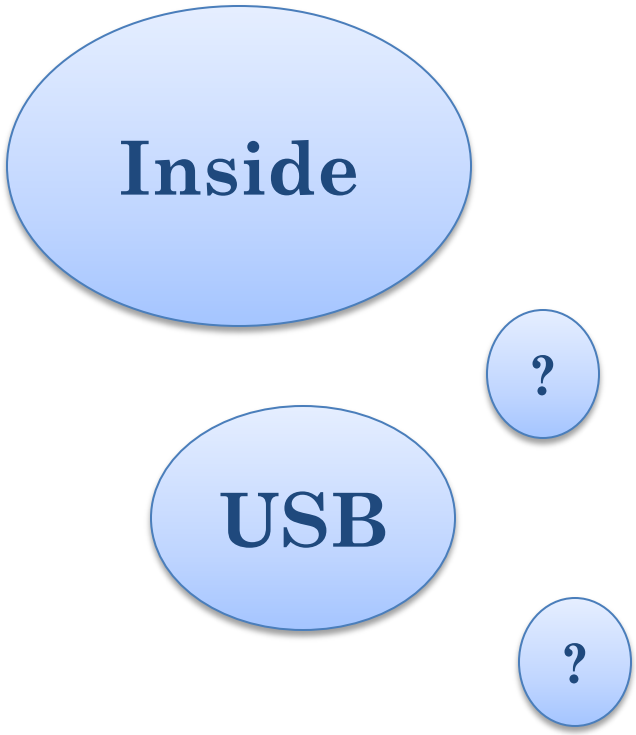
- **Global Suspend**

  used when the entire USB bus enters suspend mode collectively.

- **Selective suspend**

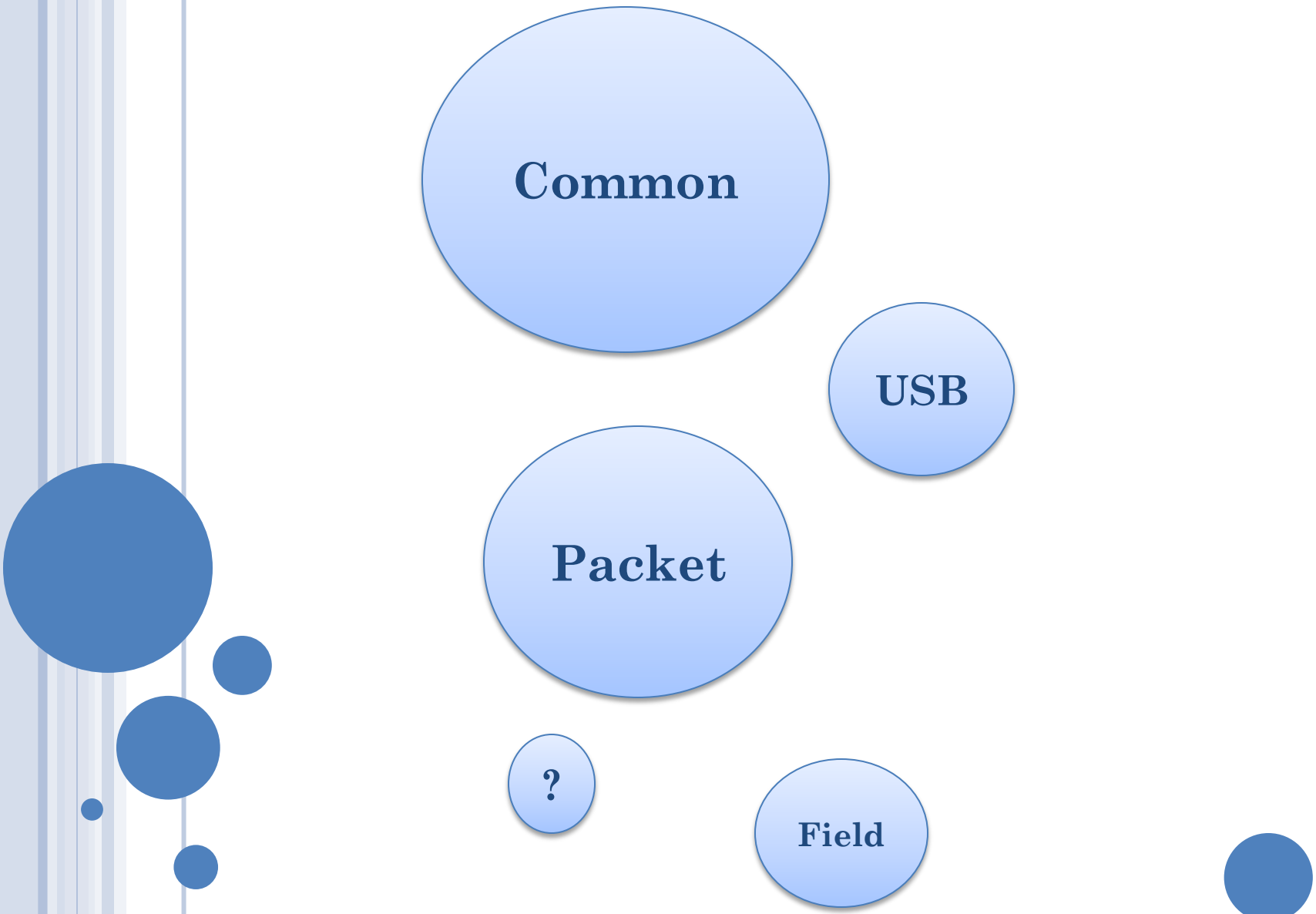
  selected devices can be suspended by sending a command to the hub.

The device will resume operation when it receives any non idle signaling. If a device has remote wakeup enabled then it may signal to the host to resume from suspend.


Inside
?
USB
?

USB TRANSACTION

- Each one consists of :-
  - ✓ Token Packet (Header defining).
  - ✓ Optional Data Packet, (Containing the data payload).
  - ✓ Status Packet (Used to acknowledge transactions and to provide a means of error correction).
- Because of the USB bus is a host centric bus. The host initiates all transactions.
- The first packet, also called a token is generated by the host to describe what is to follow and whether the data transaction will be a read or write and what the device's address and designated endpoint is.
- The next packet is generally a data packet carrying the payload and is followed by an handshaking packet, reporting if the data or token was received successfully, or if the endpoint is stalled or not available to accept data.


Common
USB
Packet
?
Field

Sync

- All packets must start with a sync field.
- The sync field is 8 bits long at low and full speed or 32 bits long for high speed and it may be shorter.
- It is used to synchronize the clock of the receiver with that of the transmitter.
- The last two bits indicate to the end of the SYNC field and, by inference, the start of the PID

PID

- PID stands for Packet Identifier and This field is used to identify the type of packet that is being sent.

- There are 4 bits to the PID and to insure it is received correctly, the 4 bits are complemented and repeated, making an 8 bit PID in total. The resulting format is shown below.

ADDR

- The address field specifies which device the packet is designated for.
- It is 7 bits long that means 127 devices can be supported.
- Address 0 is not valid and any attached device that not yet has an address must respond to packets sent to address zero.

ENDP

- The endpoint field is made up of 4 bits, allowing 16 possible endpoints.

- Low speed devices have only 4 possible endpoint max.

Frame Number

- Frame number is 11-bit field that is incremented by the host on a per-frame.
- Max number is 7FF H (2047).
- It is sent only in SOF tokens at the start of each frame.

Data Field (Payload)

- The data field may range from zero to 1024 bytes and must be an integral number of bytes.

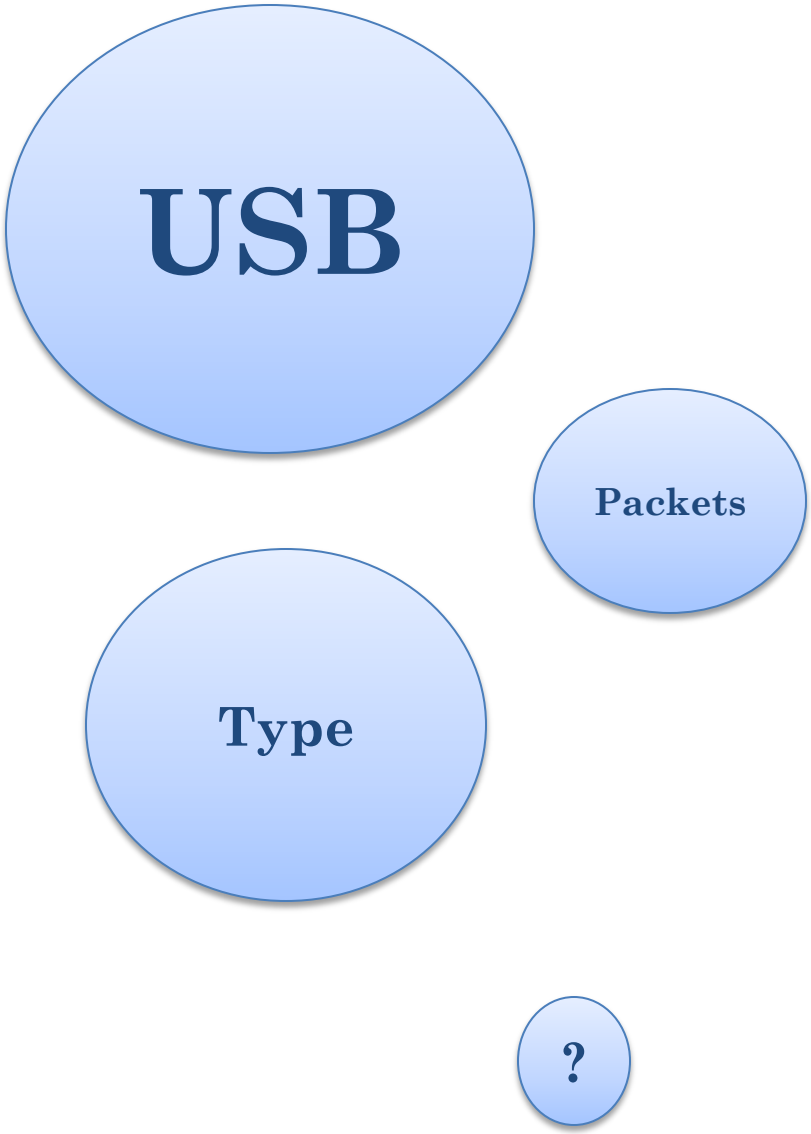
- Data bits within each byte are shifted out LSb first.

CRC

- Cyclic Redundancy Checks are performed on the data within the packet payload.
- All token packets have a 5 bit CRC.
- Data packets have a 16 bit CRC.

EOP

- End of packet is Signaled by a Single Ended Zero (SE0) for approximately 2 bit times followed by a J for 1 bit time.


USB
Packets
Type
?

USB HAS FOUR DIFFERENT PACKET TYPES

- *Token packets* - indicate the type of transaction to follow.
- *Data packets* - contain the payload.
- *Handshake packets* - are used for acknowledging data or reporting errors.
- *Start of frame packets* - indicate the start of a new frame.

Token Packets

- There are three types of token packets:-
  - ✓ **In** - Informs the USB device that the host wishes to read information.
  - ✓ **Out** - Informs the USB device that the host wishes to send information.
  - ✓ **Setup** - Used to begin control transfers.
- Token Packets must conform to the following format.

SYNC	PID	ADDR	ENDP	CRC	EOP
8 bits (low/full)/32 bits (high)	8 bits	7 bits	4 bits	5 bits	n/a

Data Packets

- There are two types of data packets each capable of transmitting up to 1024 bytes of data.
  - ✓ *DATA0*
  - ✓ *DATA1*
- High Speed mode defines another two data PIDs, *DATA2* and *MDATA*.
- Data packets have the following format

Data Packets (con't)

- Maximum data payload size for low-speed devices is 8 bytes.
- Maximum data payload size for full-speed devices is 1023 bytes.
- Maximum data payload size for high-speed devices is 1024 bytes.
- Data must be sent in multiples of bytes (integral number).

Handshake Packets

- There are 3 types of handshake packets which consist simply of the PID
  - ✓ **ACK** - Acknowledgment that the packet has been successfully received.
  - ✓ **NAK** - Reports that the device temporary cannot send/receive data. Also used during interrupt transactions to inform the host there is no data to send.
  - ✓ **STALL** - The device finds its in a state that it requires intervention from the host.
- Handshake Packets have the following format

Start of Frame Packets (SOF)

- The SOF packet consisting of an 11-bit frame number is sent by the host every 1ms ± 500ns on a full speed bus or every 125 µs ± 0.0625 µs on a high speed bus.

USB

Functions

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- USB devices which provide a capability or function such as a Printer, Zip Drive, Scanner, Modem or other peripheral called a function.

- Most functions will have a series of buffers, Each buffer will belong to an endpoint - EP0 IN, EP0 OUT etc.
- For example, the host sends a device descriptor request. The function hardware will read the setup packet and determine from the address field ,it will copy the payload of the following data packet to the appropriate endpoint buffer dedicated by the value in the endpoint field of the setup token.
- It will then send a handshake packet to acknowledge the reception of the byte and generate an internal interrupt within the semiconductor/micro-controller for the appropriate endpoint signifying it has received a packet. This is typically all done in hardware.
- The software now gets an interrupt, and should read the contents of the endpoint buffer and parse the device descriptor request.

USB

Endpoints

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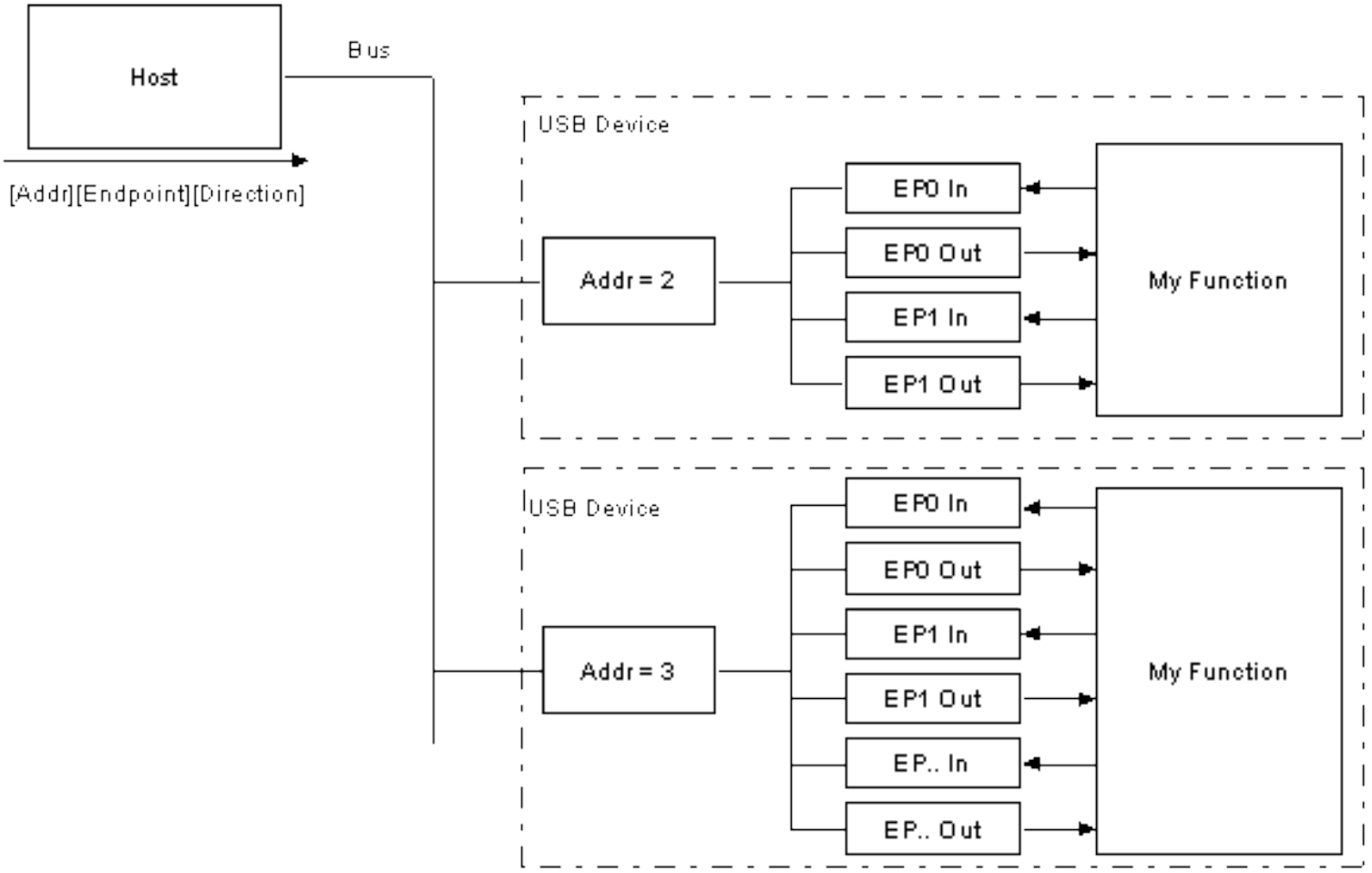
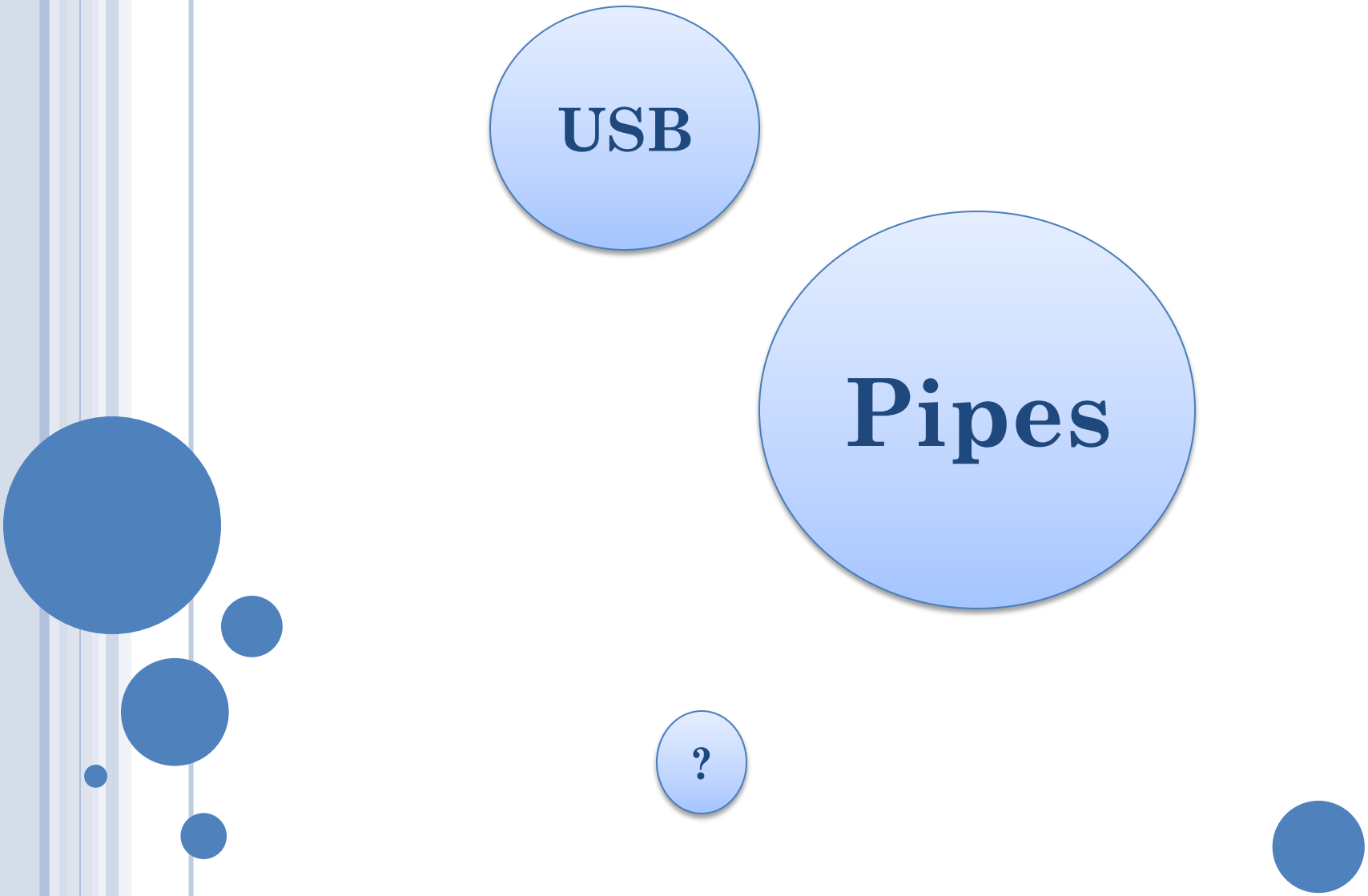
- Endpoints can be described as sources or sinks of data.
- Endpoints can also be seen as the interface between the hardware of the function device and the firmware running on the function device.
- For example, data is flowing out from the host, it will end up in the EP1 OUT buffer. Your firmware will then read this data. If it wants to return data, the function cannot simply write to the bus as the bus is controlled by the host. Therefore it writes data to EP1 IN which sits in the buffer until such time when the host sends a IN packet to that endpoint requesting the data.
- All devices must support endpoint zero. This is the endpoint which receives all of the devices control and status requests during enumeration and if the device not yet has an address.

Relationship between function and Endpoint



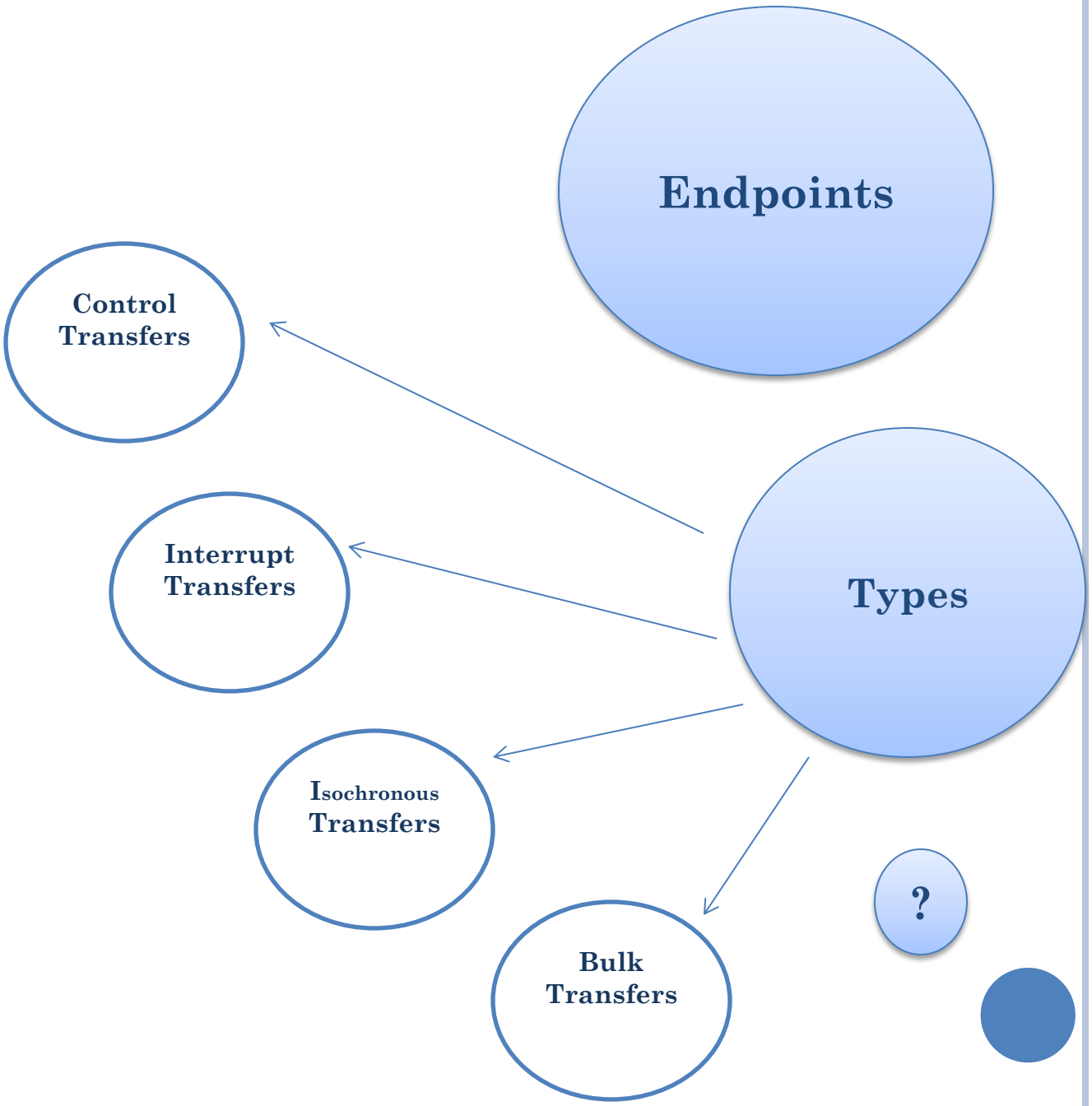

USB
Pipes
?

- While the device sends and receives data on a series of endpoints, the client software transfers data through pipes.
- A pipe is a logical connection between the host and endpoint(s).
- Pipes will also have a set of parameters associated with them such as:

  - ✓ Bandwidth allocated to it.
  - ✓ Transfer type (Control, Bulk, Isochronous or Interrupt) it uses,
  - ✓ Direction of data flow.
  - ✓ maximum packet/buffer sizes.

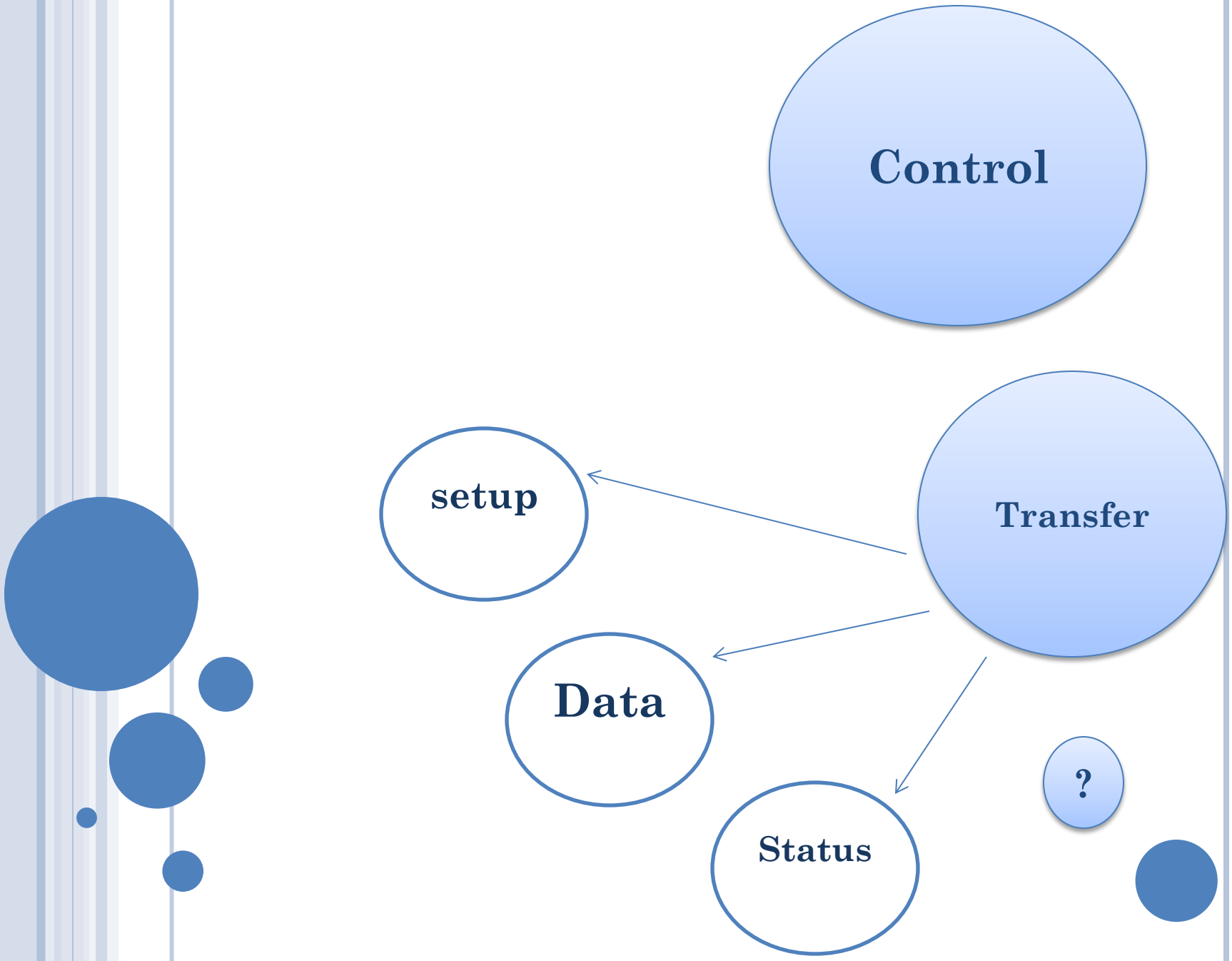
USB DEFINES TWO TYPES OF PIPES

- ***Stream Pipes***
  - ✓ have no defined USB format, that is you can send any type of data down a stream.
  - ✓ Data flows sequentially and has a pre-defined direction, either in or out.
  - ✓ Stream pipes supports bulk, isochronous and interrupt transfer types.
  - ✓ Stream pipes can either be controlled by the host or device.
- ***Message Pipes***
  - ✓ have a defined USB format.
  - ✓ host controlled, which are initiated by a request sent from the host.
  - ✓ Data is then transferred in the desired direction, dictated by the request.
  - ✓ Message pipes allow data to flow in both directions but will only support control transfers.

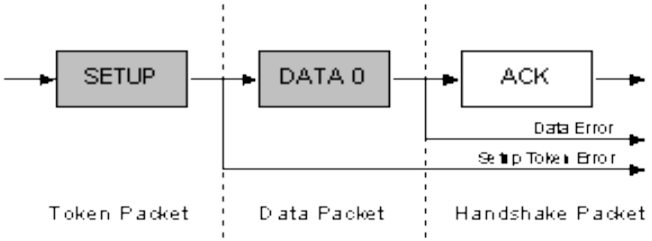

Endpoints
Types
Control Transfers
Interrupt Transfers
Isochronous Transfers
Bulk Transfers
?

Control Transfers

- Control transfers are typically used for command and status operations.
- They are essential to setup a USB device with all enumeration functions being performed using control transfers.
- They are typically bursty, initiated by the host and use best effort delivery.
- The packet length of control transfers in low speed devices must be 8 bytes, high speed devices allow a packet size of 8, 16, 32 or 64 bytes and full speed devices must have a packet size of 64 bytes.


Control
setup
Transfer
Data
?
Status

1- Setup Stage



- Held when the request is sent.
- consists of three packets.
- The setup token is sent first which contains the address and endpoint number.
- The data packet is sent next and always has a PID type of DATA0 and includes a setup packet which details the type of request.
- The last packet is a handshake used for acknowledging successful receipt or to indicate an error.
- If the function successfully receives the setup data (CRC and PID etc OK) it responds with ACK, otherwise it ignores the data and doesn't send a handshake packet.
- Functions cannot issue a STALL or NAK packet in response to a setup packet.

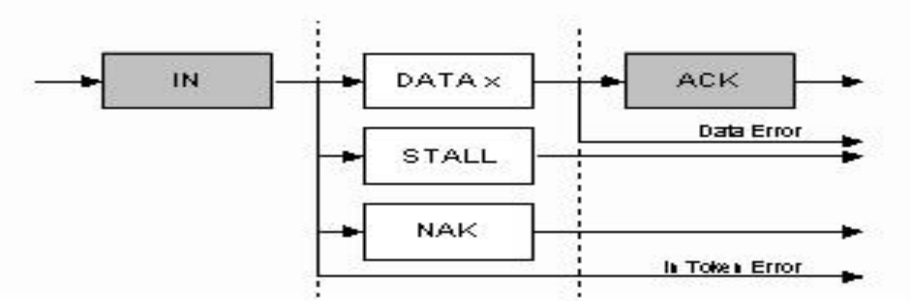
2- Data Stage

- Optional and consists of one or multiple IN or OUT transfers.

- The setup request indicates the amount of data to be transmitted in this stage, If it exceeds the maximum packet size, data will be sent in multiple transfers each being the maximum packet length except for the last packet.

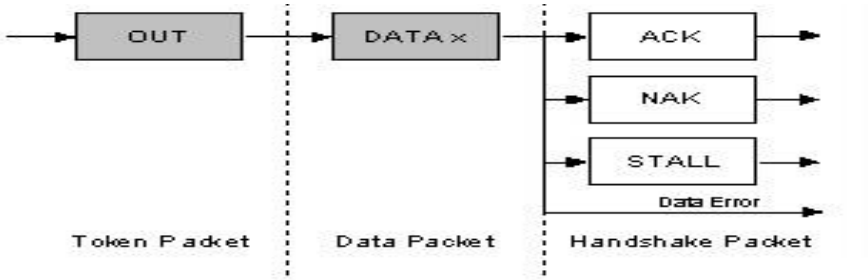
- Data stage has two different scenarios depending upon the direction of data transfer (IN / OUT).

IN-TRANSFER



- When the host is ready to receive control data it issues an IN Token.
- If the function receives the IN token with an error e.g. the PID doesn't match the inverted PID bits, then it ignores the packet.
- If the token was received correctly, the device can either reply with a DATA packet containing the control data to be sent, a stall packet indicating the endpoint cannot send and needs help or a NAK packet indicating to the host that the endpoint is working, but temporarily has no data to send.

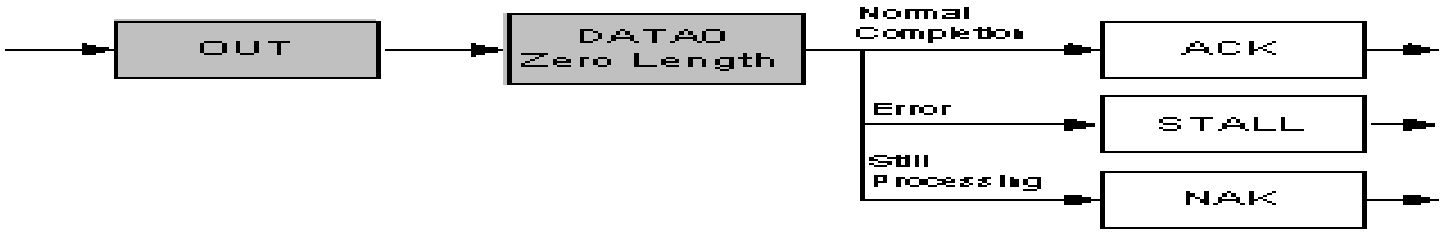
OUT-TRANSFER



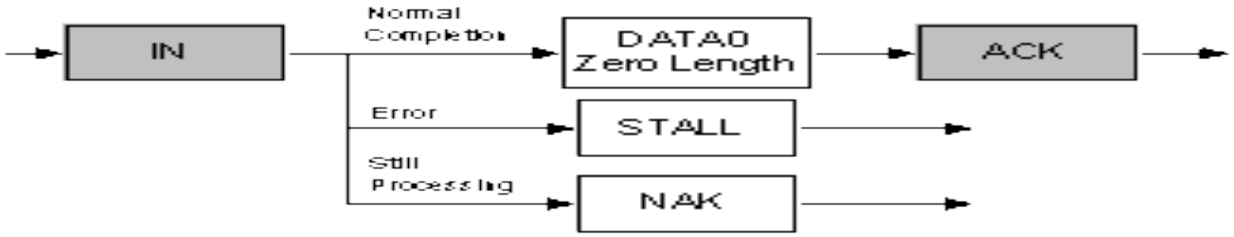
- When the host needs to send the device a control data packet, it issues an OUT token followed by a data packet containing the control data as the payload.
- If any part of the OUT token or data packet is corrupt then the function ignores the packet.
- If the function's endpoint buffer was empty and it has clocked the data into the endpoint buffer it issues an ACK informing the host it has successfully received the data.
- If the endpoint buffer is not empty due to processing of the previous packet, then the function returns a NAK.

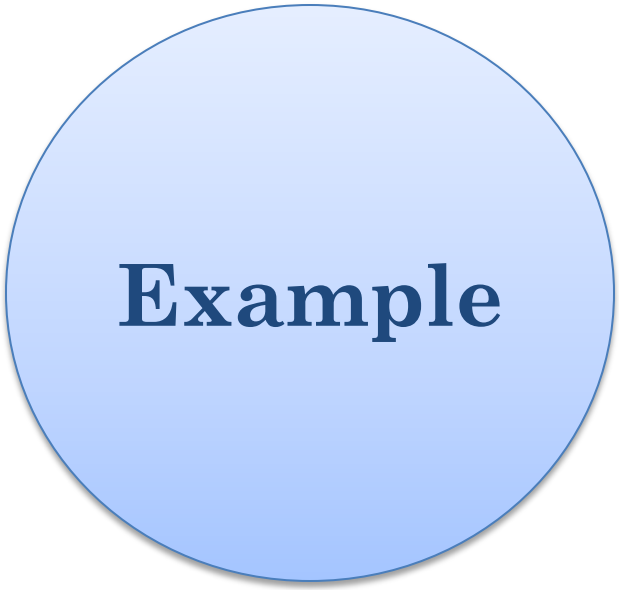
3- Status Stage

- reports the status of the overall request and this once again varies due to direction of transfer.
- Status reporting is always performed by the function.
- **IN:** If the host sent IN token(s) during the data stage to receive data, then the host must acknowledge the successful receipt of this data.
- This is done by the host sending an OUT token followed by a zero length data packet.
- The function can now report its status in the handshaking stage.
- An ACK indicates the function has completed the command is now ready to accept another command. If an error occurred during the processing of this command, then the function will issue a STALL.



- **OUT:** If the host sent OUT token(s) during the data stage to transmit data, the function will acknowledge the successful receipt of data by sending a zero length packet in response to an IN token.
- However if an error occurred, it should issue a STALL or if it is still busy processing data, it should issue a NAK asking the host to retry the status phase later.





THE HOST WANTS TO REQUEST A DEVICE DESCRIPTOR DURING ENUMERATION

Procedure

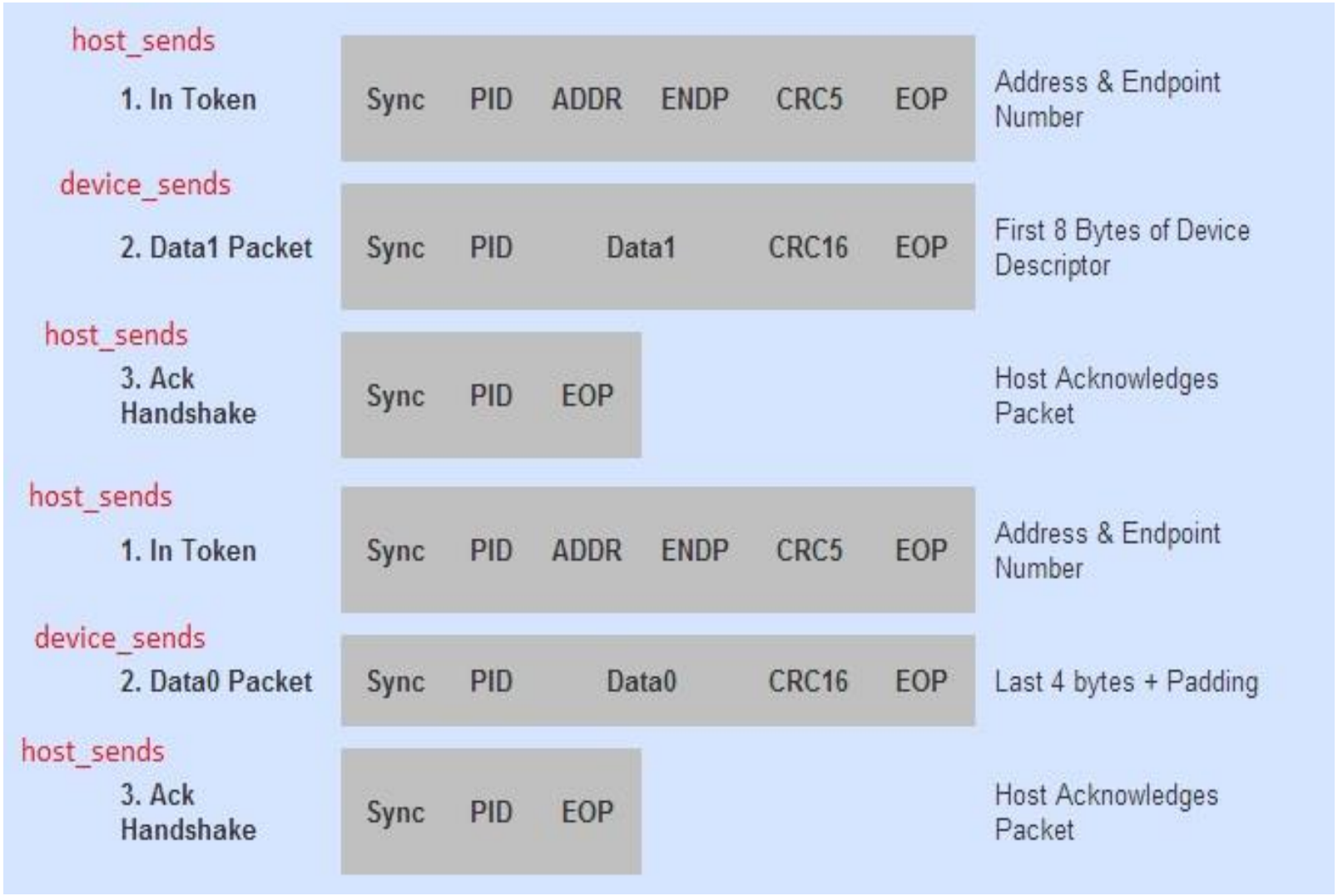
- The host will send the Setup token telling the function that the following packet is a Setup packet.
- The Address field will hold the address of the device which the host is requesting the descriptor from.
- The endpoint number should be zero, specifying the default pipe.
- The host will then send a DATA0 packet. This will have an 8 byte payload which is the Device Descriptor Request (Low Speed).
- The USB function then acknowledges the setup packet has been read correctly with no errors.
- If the packet was received corrupt, the device just ignores this packet and The host will then resend the packet after a short delay

- The above three packets represent the first USB transaction.
- The USB device will now decode the 8 bytes received, and determine if it was a device descriptor request.
- The device will then attempt to send the Device Descriptor, which will be the next USB transaction.

Data stage

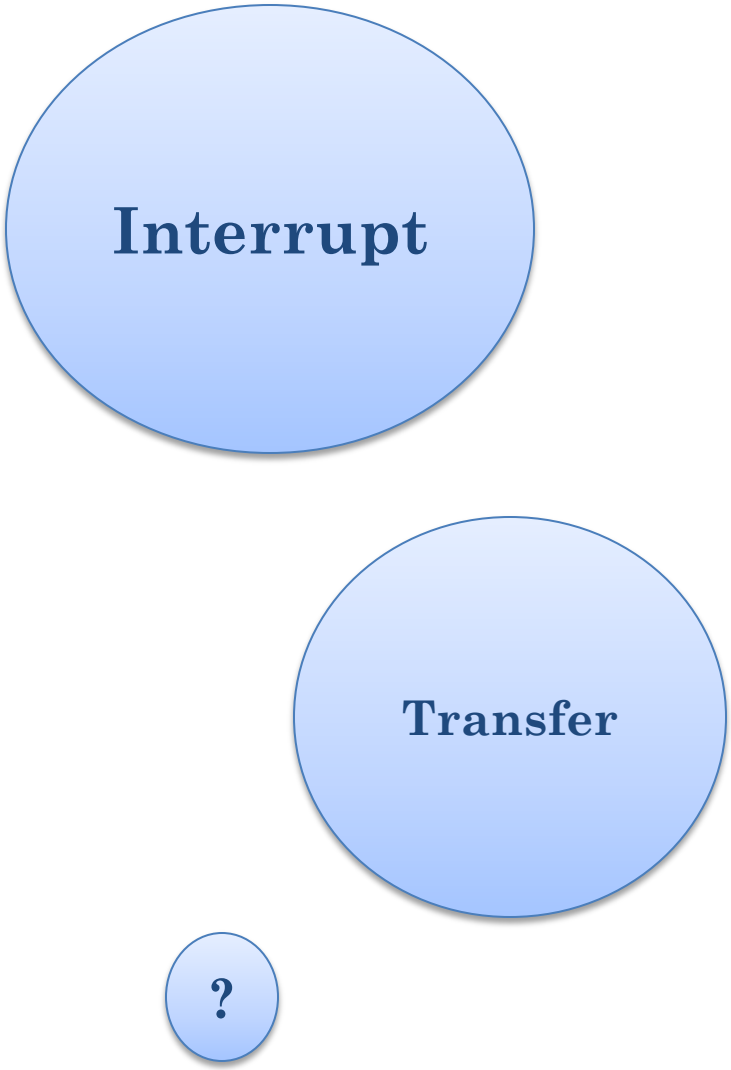
- In this case, we assume that the maximum payload size is 8 bytes.
- The host sends the IN token, telling the device it can now send data for this endpoint.
- As the maximum packet size is 8 bytes, we must split up the 12 byte device descriptor into chunks to send, Each chunk must be 8 bytes except for the last transaction.
- The host acknowledges every data packet we send it.

DATA STAGE (CON'T)

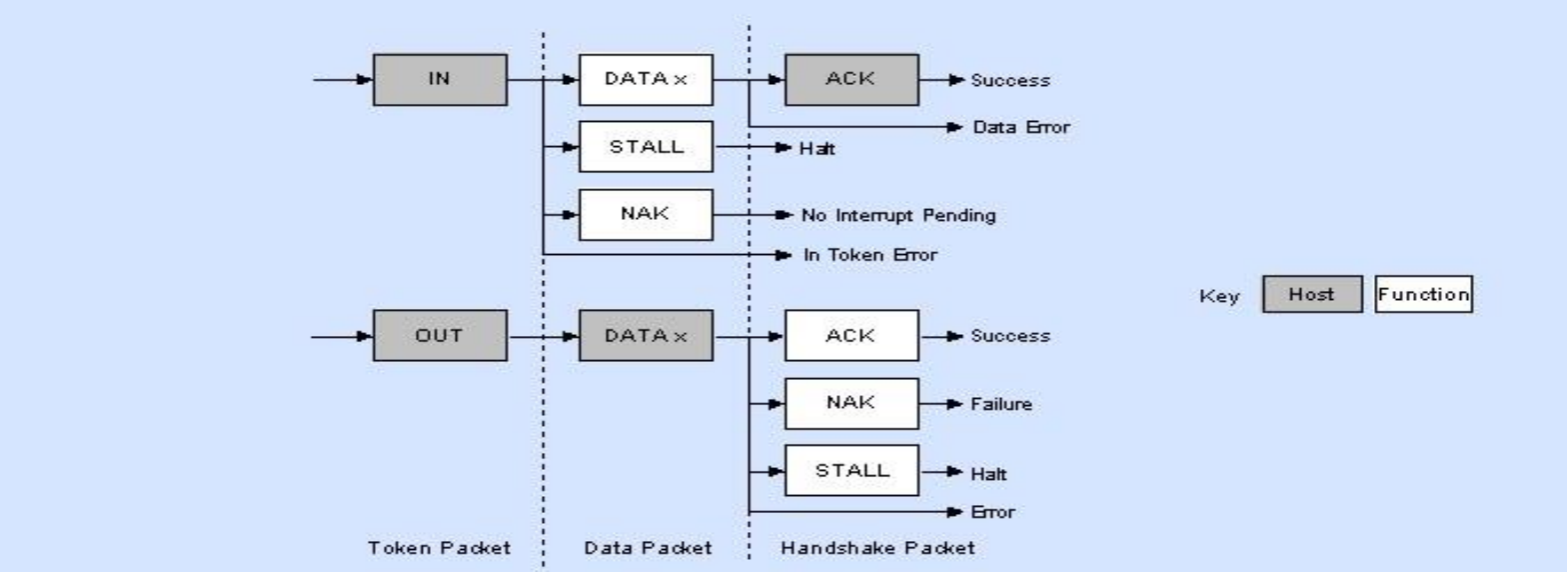


Status Stage

- Once the device descriptor is sent, a status transaction follows.
- If the transactions were successful, the host will send a zero length packet indicating the overall transaction was successful.
- The function then replies to this zero length packet indicating its status (ACK, STALL, NAK).


Interrupt
Transfer
?

- Through USB the device cannot take the attention of the Host, it must wait until the host polls it to tell it the urgent.
- Non-periodic communication.
- Interrupt request is queued by the device until the host polls the USB device asking for data.
- Max data payload size for low-speed devices is 8 bytes.
- Max data payload size for full-speed devices is 64 bytes.
- Max data payload size for high-speed devices is 1024 bytes

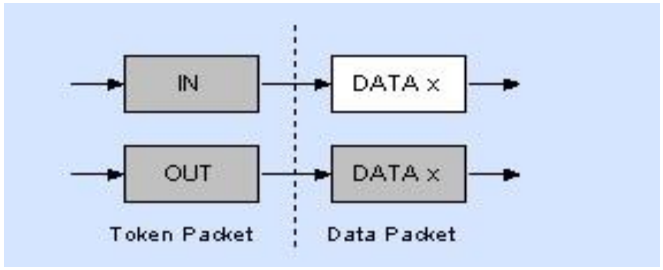


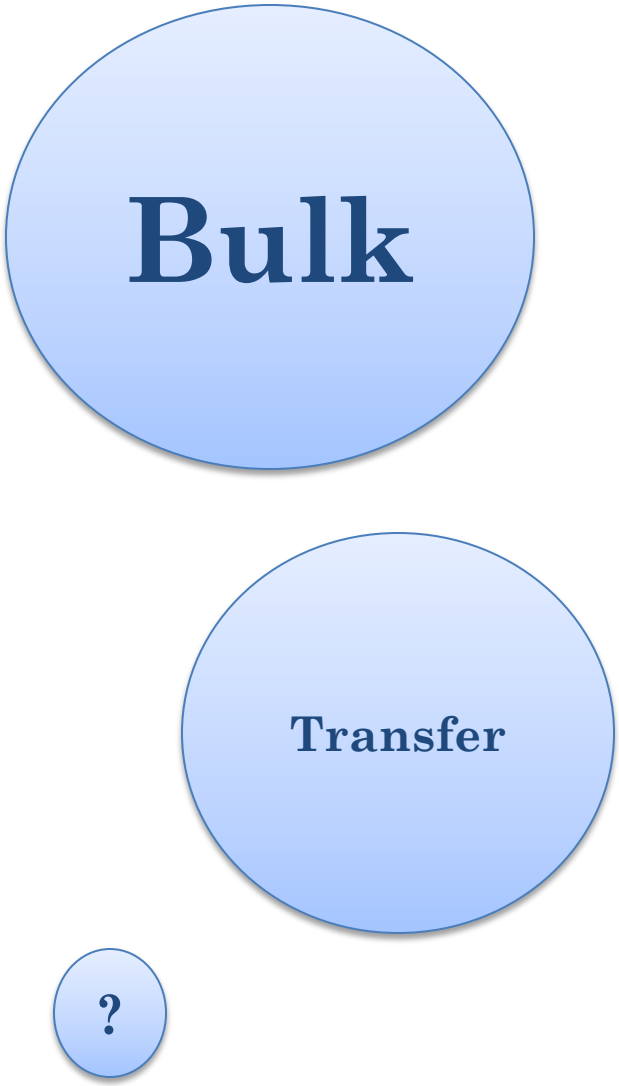
Isochronous

Transfer

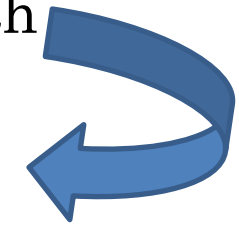
?

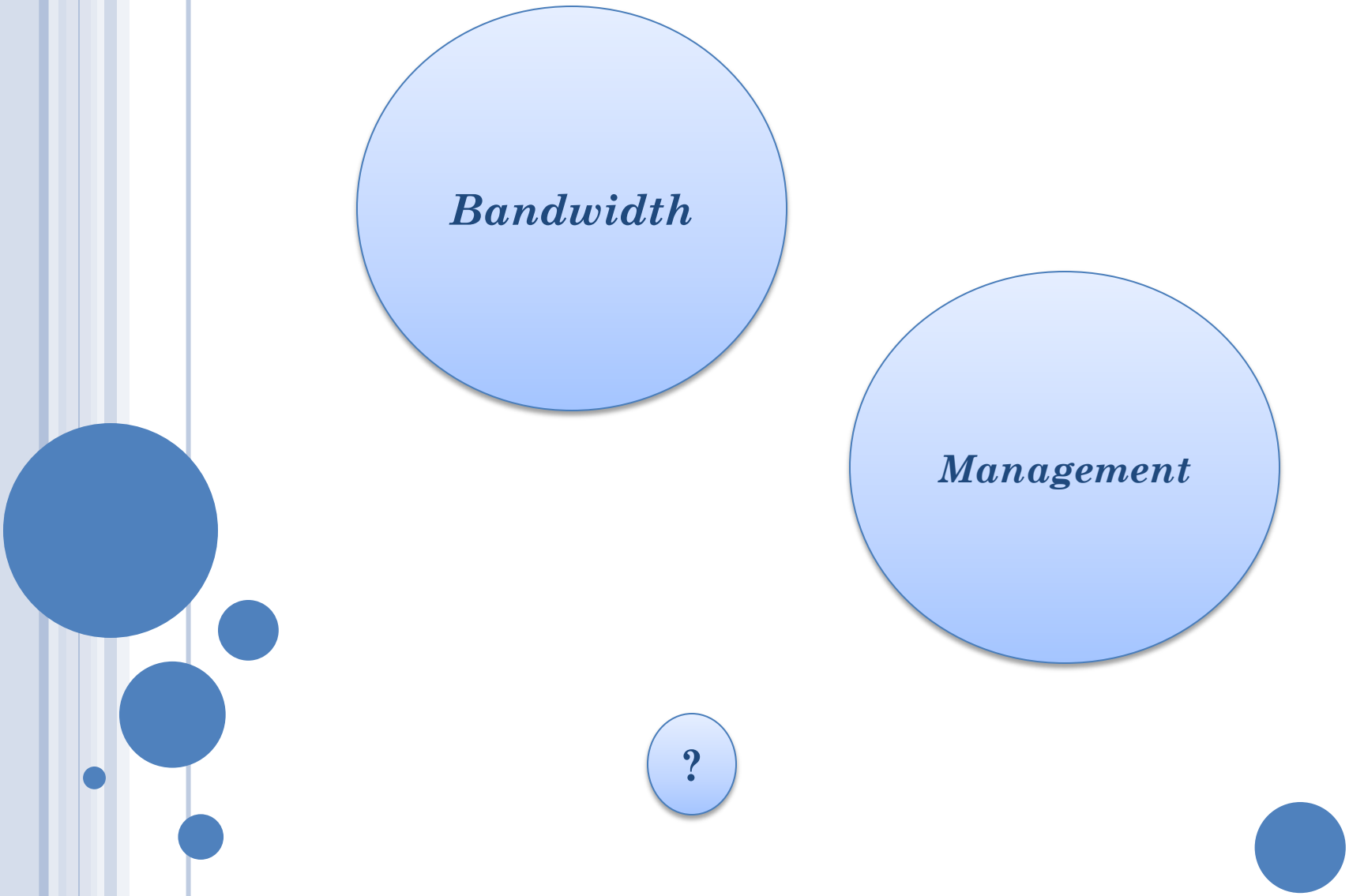
- Isochronous transfers occur continuously and periodically.
- They typically contain time sensitive information, such as an audio or video stream.
- Guaranteed access to USB bandwidth.
- Bounded latency.
- Stream Pipe – Unidirectional transfer.
- Error detection via CRC, but no retry or guarantee of delivery.
- Full & high speed modes only.
- No data toggling.
- Don't have a handshake stage.




Bulk
Transfer
?

- can be used for large bursty data, Such as print-job sent to a printer or an image generated from a scanner.
- It provides error correction in the form of a CRC16 field on the data payload and error detection/re-transmission mechanisms ensuring data is transmitted and received without error.
- Bulk transfers will use spare un-allocated bandwidth on the bus.
- It should only be used for time insensitive communication as there is no guarantee of latency.
- only supported by full and high speed devices.
- For full speed endpoints, max bulk packet size is 8, 16, 32 or 64 bytes long.
- For high speed endpoints, max packet size can be up to 512 bytes long.
- If the data payload falls short of the maximum packet size, it doesn't need to be padded with zeros.




Bandwidth
Management
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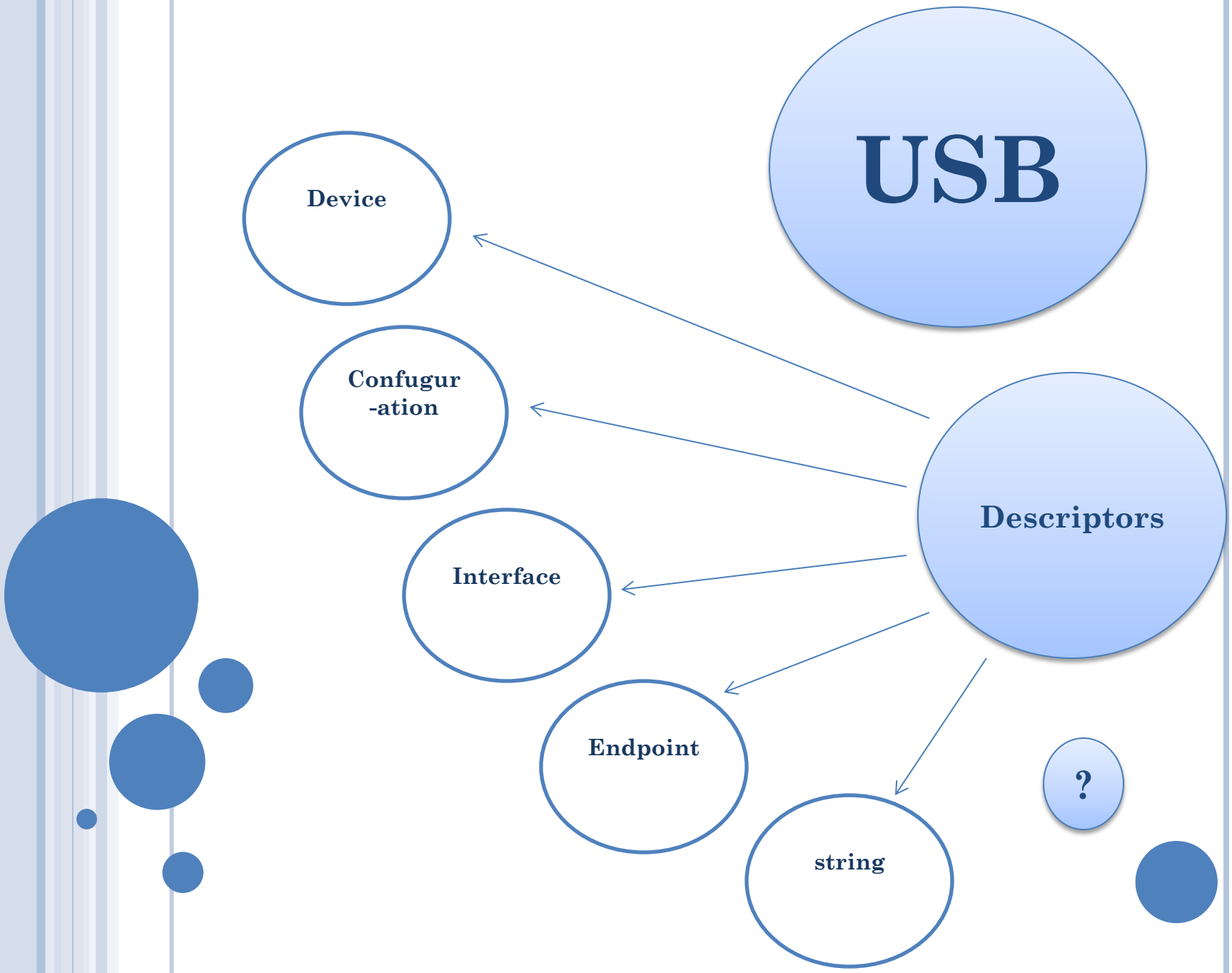
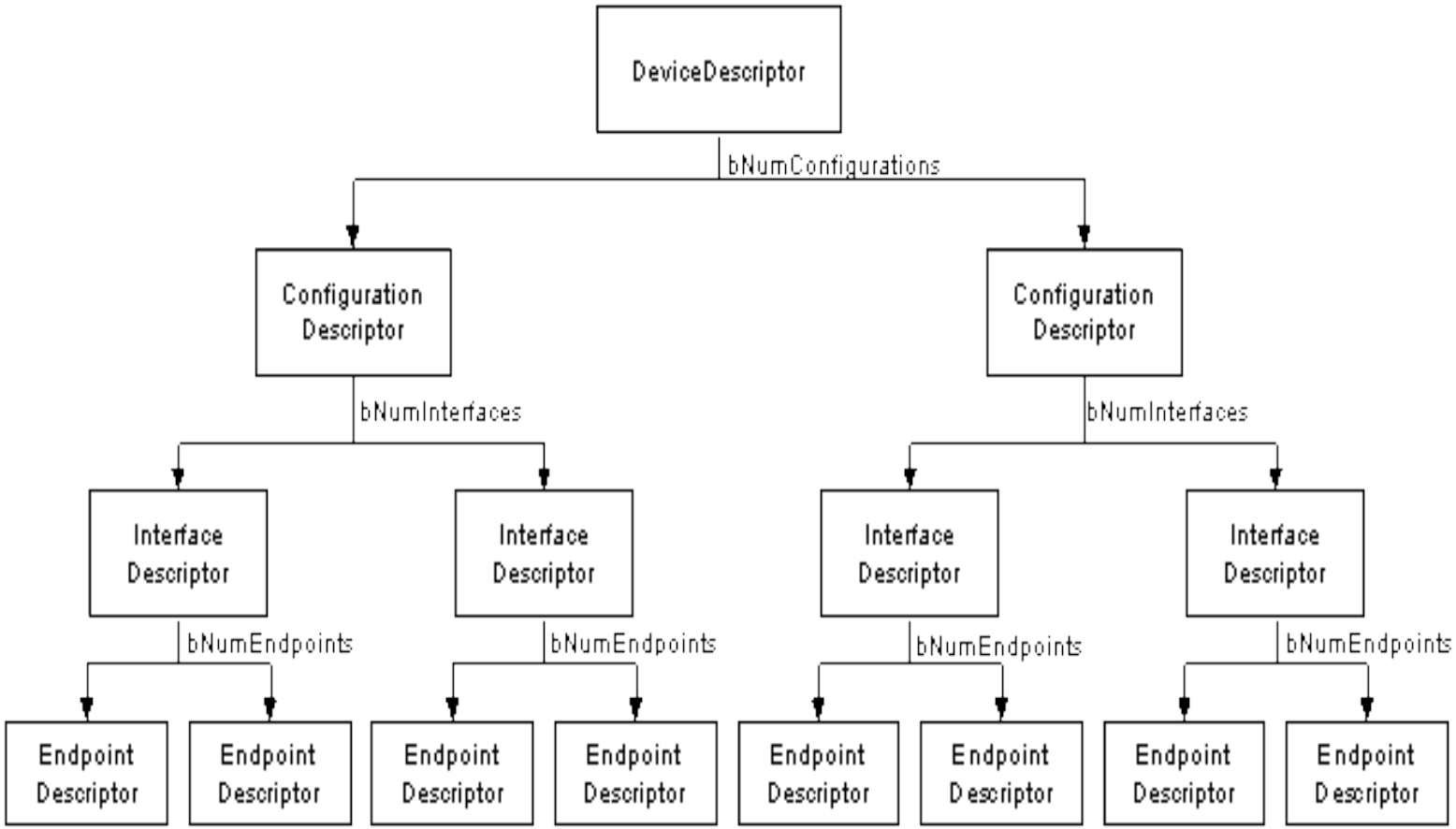
- The host is responsible for managing the bandwidth of the bus.
- This is done at enumeration when configuring Isochronous and Interrupt Endpoints and throughout the operation of the bus (if found).
- no more than 90% of any frame to be allocated for periodic transfers (Interrupt and Isochronous) on a full speed bus.
- On high speed buses this limitation gets reduced to no more than 80% of a micro-frame can be allocated for periodic transfers.
- So you can quite quickly see that if you have a highly saturated bus with periodic transfers, the remaining 10% is left for control transfers and once those have been allocated, bulk transfers will get their slice of what is left.


USB
Device
Confugur
-ation
Interface
Endpoint
string
Descriptors
?


DeviceDescriptor
bNumConfigurations
Configuration Descriptor
Configuration Descriptor
bNumInterfaces
bNumInterfaces
Interface Descriptor
Interface Descriptor
Interface Descriptor
Interface Descriptor
bNumEndpoints
bNumEndpoints
bNumEndpoints
bNumEndpoints
Endpoint Descriptor
Endpoint Descriptor
Endpoint Descriptor
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Endpoint Descriptor
Endpoint Descriptor
Endpoint Descriptor

Device Descriptor

- Each device should have one device descriptor.
- Includes information about:-
  - ✓ USB revision number.
  - ✓ Product ID.
  - ✓ Vendor ID.
  - ✓ Number of configuration descriptor the device have.
- Product and vendor IDs of device descriptor helps to load the appropriate device driver to operate it.

Configuration Descriptor

- The configuration descriptor specifies values such as the amount of power this particular configuration uses.
- if the device is self or bus powered and the number of interfaces it has.
- When a device is enumerated, the host reads the device descriptors and can make a decision of which configuration to enable.
- It can only enable one configuration at a time.
- changing the configuration requires all activity on each endpoint to stop.
- very few devices have more than 1 configuration.

Example

- It is possible to have a high power bus powered configuration and a self powered configuration.
- If the device is plugged into a host with a mains power supply, the device driver may choose to enable the high power bus powered configuration enabling the device to be powered without a connection to the mains.
- If it is connected to a laptop or personal organizer it could enable the 2nd configuration (self powered) requiring the user to plug your device into the power source.

Interface Descriptor

- could be seen as a header or grouping of the endpoints into a functional group performing a single feature of the device.
- For example you could have a multi-function fax/scanner/printer device.
  - ✓ Interface descriptor 1 describe the endpoints of the fax function.
  - ✓ Interface descriptor 2 the scanner function.
  - ✓ Interface descriptor 3 the printer function.
- Unlike the configuration descriptor, there is no limitation to having only one interface enabled at a time.
- A device could have 1 or more interface descriptors enabled at once.

- Interface descriptors have a ***bInterfaceNumber*** field specifying the Interface number and a ***bAlternateSetting*** which allows an interface to change settings on the fly.

- For example we could have a device with two interfaces, interface 1 and interface 2.
  - ✓ Interface 1 has ***bInterfaceNumber*** = 0, ***bAlternateSetting*** = 0 (default).
  - ✓ Interface 2 has ***bInterfaceNumber*** = 0, ***bAlternateSetting*** = 0 (default).

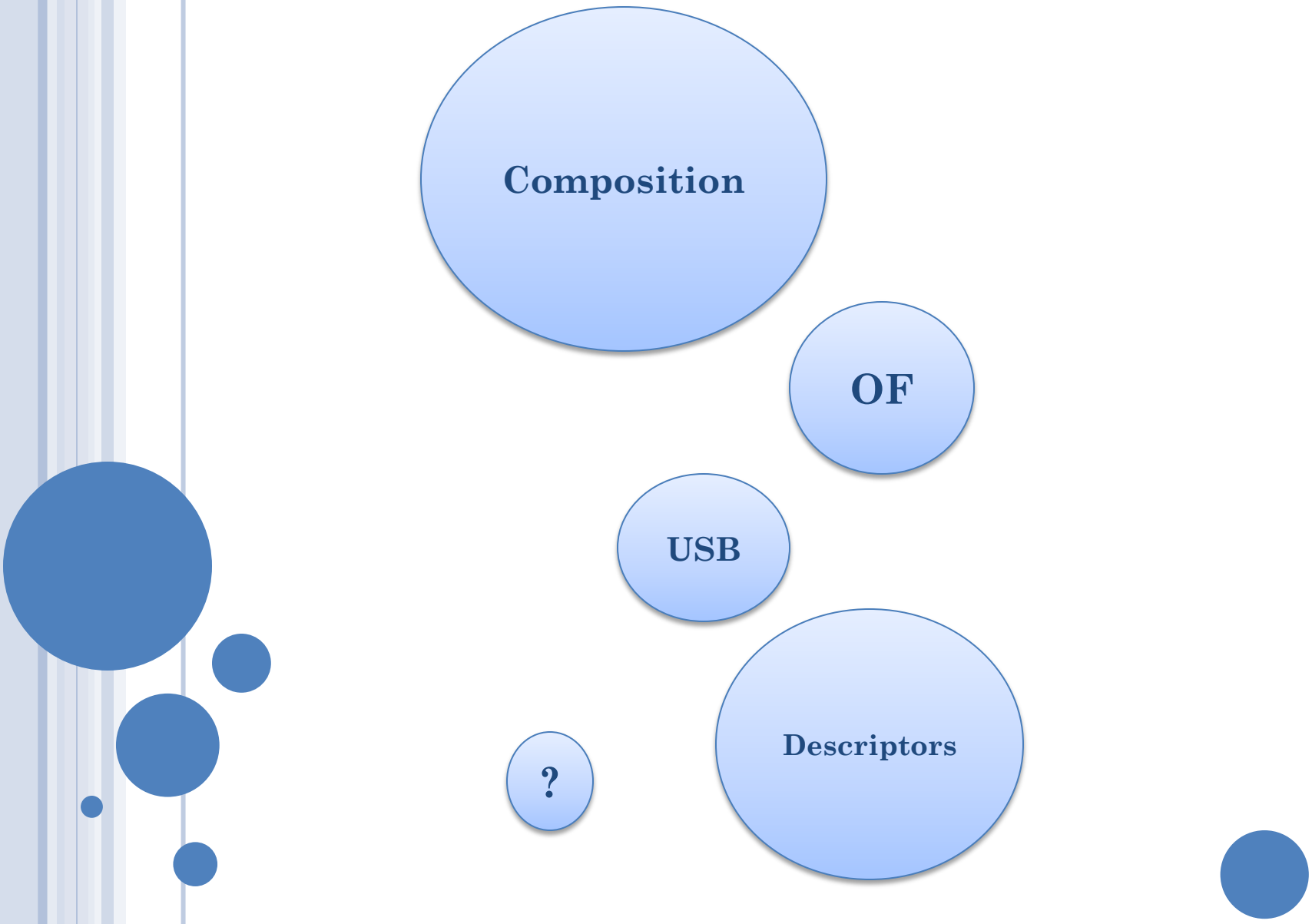
- Making ***bAlternateSetting*** = **1** means making an alternate settings to be applied on the configuration.

- In other words, having two configurations, in that we can be transmitting data over interface zero while we change the endpoint settings associated with interface one without affecting interface zero.

Endpoint Descriptor

- Each endpoint descriptor is used to specify:-
  - ✓ type of transfer (control, bulk,…).
  - ✓ Direction (IN, OUT).
  - ✓ polling interval.
  - ✓ maximum packet size for each endpoint.

- Endpoint zero, the default control endpoint is always assumed to be a control endpoint and as such never has a descriptor.


Composition
OF
USB
Descriptors
?

- All descriptors are made up of a common format.
- The first byte specifies the length of descriptor.
- the second byte indicates the descriptor type.
- If the length of a descriptor is smaller than what the specification defines, then the host shall ignore it.
- if the length is greater than expected the host will ignore the extra bytes and start looking for the next descriptor at the end of actual length.

Offset	Field	Size	Value	Description
0	bLength	1	Number	Size of Descriptor in Bytes
1	bDescriptionType	1	Constant	DescriptorType
2	...	n		Start of parameters for descriptor

Device Descriptor

Offset	Field	Size	Value	Description
0	bLength	1	Number	Size of the Descriptor in Bytes (18 bytes)
1	bDescriptorType	1	Constant	Device Descriptor (0x01)
2	bcdUSB	2	BCD	USB Specification Number which device complies too.
4	bDeviceClass	1	Class	Class Code (Assigned by USB Org)
5	bDeviceSubClass	1	SubClass	Subclass Code (Assigned by USB Org)
6	bDeviceProtocol	1	Protocol	Protocol Code (Assigned by USB Org)
7	bMaxPacketSize	1	Number	Maximum Packet Size for Zero Endpoint. Valid Sizes are 8, 16, 32, 64
8	idVendor	2	ID	Vendor ID (Assigned by USB Org)
10	idProduct	2	ID	Product ID (Assigned by Manufacturer)
12	bcdDevice	2	BCD	Device Release Number
14	iManufacturer	1	Index	Index of Manufacturer String Descriptor
15	iProduct	1	Index	Index of Product String Descriptor
16	iSerialNumber	1	Index	Index of Serial Number String Descriptor
17	bNumConfigurations	1	Integer	Number of Possible Configurations

Configuration descriptor

Offset	Field	Size	Value	Description
0	bLength	1	Number	Size of Descriptor in Bytes
1	bDescriptorType	1	Constant	Configuration Descriptor (0x02)
2	wTotalLength	2	Number	Total length in bytes of data returned
4	bNumInterfaces	1	Number	Number of Interfaces
5	bConfigurationValue	1	Number	Value to use as an argument to select this configuration
6	iConfiguration	1	Index	Index of String Descriptor describing this configuration
7	bmAttributes	1	Bitmap	D7 Reserved, set to 1. (USB 1.0 Bus Powered) D6 Self Powered D5 Remote Wakeup D4..0 Reserved, set to 0.
8	bMaxPower	1	mA	Maximum Power Consumption in 2mA units

Interface Descriptor

Offset	Field	Size	Value	Description
0	bLength	1	Number	Size of Descriptor in Bytes (9 Bytes)
1	bDescriptorType	1	Constant	Interface Descriptor (0x04)
2	bInterfaceNumber	1	Number	Number of Interface
3	bAlternateSetting	1	Number	Value used to select alternative setting
4	bNumEndpoints	1	Number	Number of Endpoints used for this interface
5	bInterfaceClass	1	Class	Class Code (Assigned by USB Org)
6	bInterfaceSubClass	1	SubClass	Subclass Code (Assigned by USB Org)
7	bInterfaceProtocol	1	Protocol	Protocol Code (Assigned by USB Org)
8	iInterface	1	Index	Index of String Descriptor Describing this interface

Endpoint Descriptor

Offset	Field	Size	Value	Description
0	bLength	1	Number	Size of Descriptor in Bytes (7 bytes)
1	bDescriptorType	1	Constant	Endpoint Descriptor (0x05)
2	bEndpointAddress	1	Endpoint	Endpoint Address Bits 0..3b Endpoint Number. Bits 4..6b Reserved. Set to Zero Bits 7 Direction 0 = Out, 1 = In (Ignored for Control Endpoints)
3	bmAttributes	1	Bitmap	Bits 0..1 Transfer Type 00 = Control 01 = Isochronous 10 = Bulk 11 = Interrupt Bits 2..7 are reserved. If Isochronous endpoint, Bits 3..2 = Synchronisation Type (Iso Mode) 00 = No Synchonisation 01 = Asynchronous 10 = Adaptive 11 = Synchronous Bits 5..4 = Usage Type (Iso Mode) 00 = Data Endpoint 01 = Feedback Endpoint 10 = Explicit Feedback Data Endpoint 11 = Reserved
4	wMaxPacketSize	2	Number	Maximum Packet Size this endpoint is capable of sending or receiving
6	bInterval	1	Number	Interval for polling endpoint data transfers. Value in frame counts. Ignored for Bulk & Control Endpoints. Isochronous must equal 1 and field may range from 1 to 255 for interrupt endpoints.

String Descriptors

- provide optional human readable information.
- If they are not used, any string index fields of descriptors must be set to zero.
- The strings are encoded in the Unicode format and products can be made to support multiple languages.
- A list of USB Language IDs can be found in USB Language Identifiers (LANGIDs) on USB.org.
- The host should read this descriptor to determine what languages are available.
- If a language is supported, it can then be referenced by sending the language ID in the wIndex field of a Get Descriptor(String) request.

Offset	Field	Size	Value	Description
0	bLength	1	Number	Size of Descriptor in Bytes
1	bDescriptorType	1	Constant	String Descriptor (0x03)
2	wLANGID[0]	2	number	Supported Language Code Zero (e.g. 0x0409 English - United States)
4	wLANGID[1]	2	number	Supported Language Code One (e.g. 0x0c09 English - Australian)
n	wLANGID[x]	2	number	Supported Language Code x (e.g. 0x0407 German - Standard)

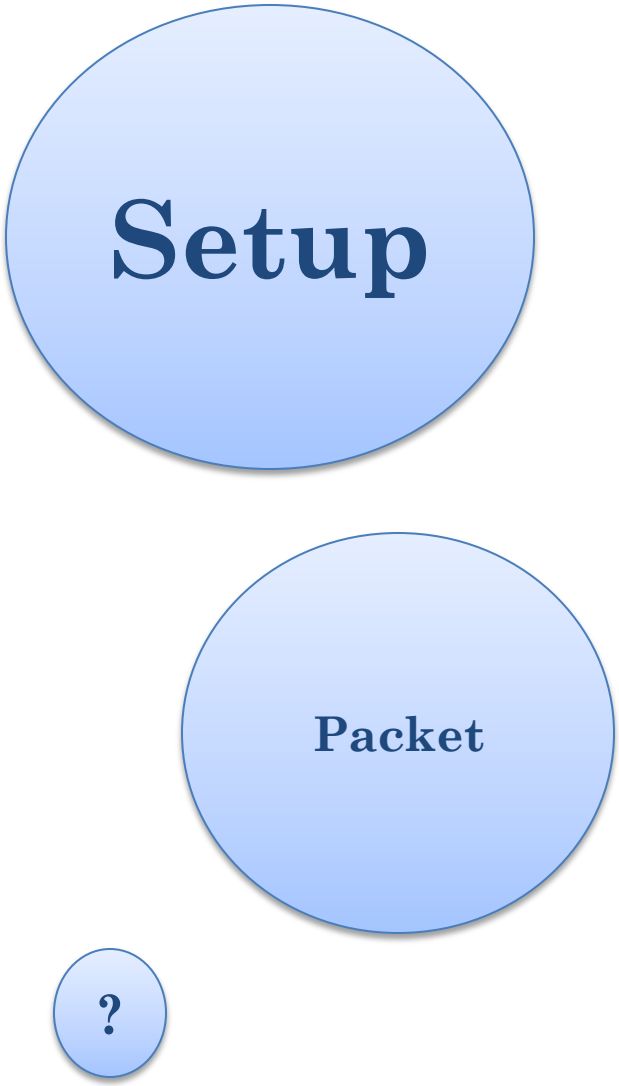
- The above String Descriptor shows the format of String Descriptor Zero.
- All subsequent strings take on the format below

Offset	Field	Size	Value	Description
0	bLength	1	Number	Size of Descriptor in Bytes
1	bDescriptorType	1	Constant	String Descriptor (0x03)
2	bString	n	Unicode	Unicode Encoded String


USB


Requests

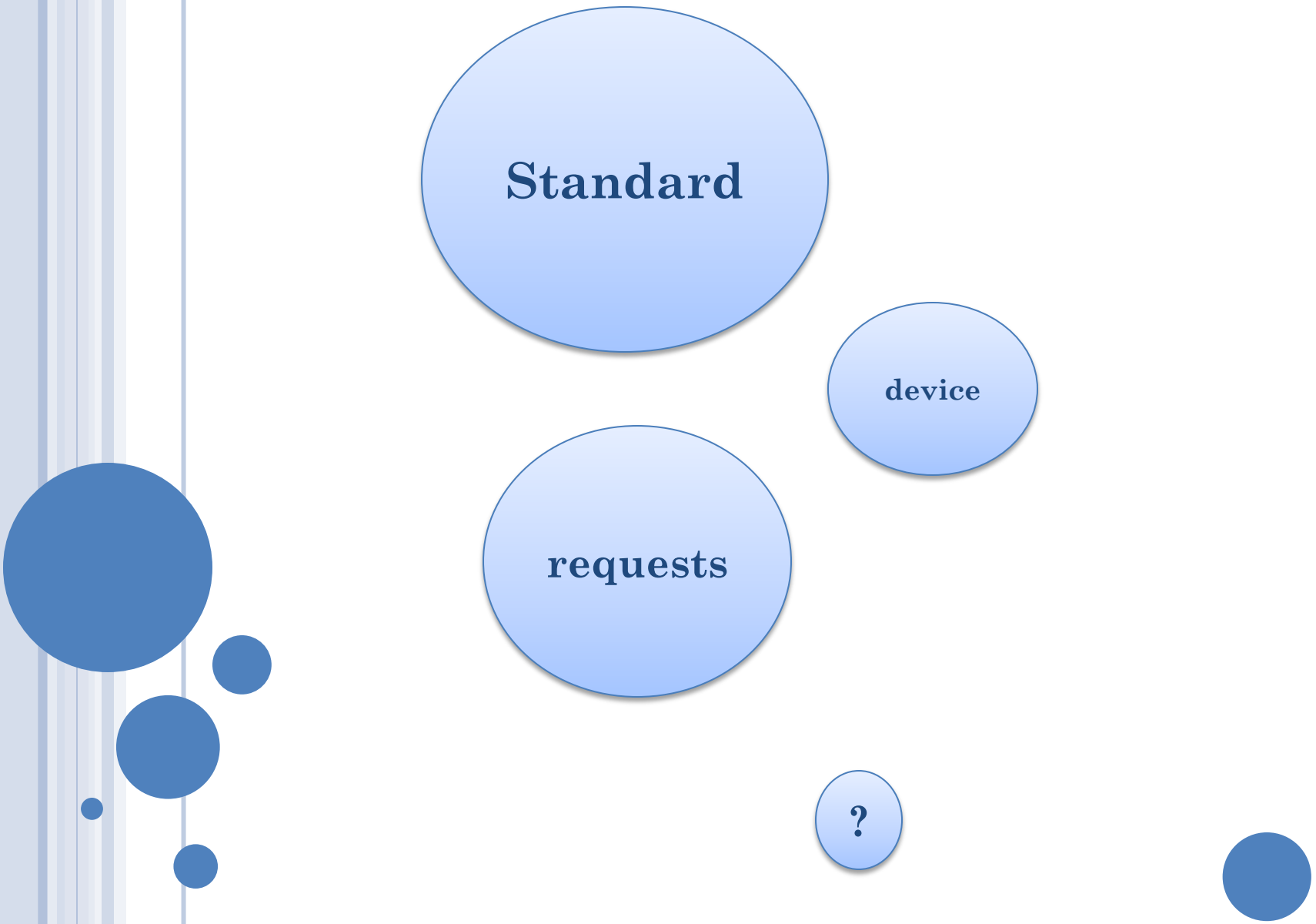

?


Setup
Packet
?

- Every USB device must respond to setup packets on the default pipe.
- The setup packets are used for detection and configuration of the device and carry out common functions such as setting the USB device's address, requesting a device descriptor or checking the status of a endpoint.
- A USB compliant Host expects all requests to be processed within a maximum period of 5 seconds.
- Standard Device requests without a data stage must be completed in 50 ms.
- Standard Device requests with a data stage must start to return data 500 ms after the request.

- Each data packet must be sent within 500 ms of the successful transmission of the previous packet.
- The status stage must complete within 50 ms after the transmission of the last data packet.
- Each request starts with a 8 byte long Setup data Packet which has the following format

Offset	Field	Size	Value	Description
0	bmRequestType	1	Bit-Map	**D7 Data Phase 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	Request
2	wValue	2	Value	Value
4	wIndex	2	Index or Offset	Index
6	wLength	2	Count	Number of bytes to transfer if there is a data phase


Standard
device
requests
?

There are currently eight Standard Device requests.

bmRequestType	bRequest	wValue	wIndex	wLength	Data
1000 0000b	GET_STATUS (0x00)	Zero	Zero	Two	Device Status
0000 0000b	CLEAR_FEATURE (0x01)	Feature Selector	Zero	Zero	None
0000 0000b	SET_FEATURE (0x03)	Feature Selector	Zero	Zero	None
0000 0000b	SET_ADDRESS (0x05)	Device Address	Zero	Zero	None
1000 0000b	GET_DESCRIPTOR (0x06)	Descriptor Type & Index	Zero or Language ID	Descriptor Length	Descriptor
0000 0000b	SET_DESCRIPTOR (0x07)	Descriptor Type & Index	Zero or Language ID	Descriptor Length	Descriptor
1000 0000b	GET_CONFIGURATION (0x08)	Zero	Zero	1	Configuration Value
0000 0000b	SET_CONFIGURATION (0x09)	Configuration Value	Zero	Zero	None

EXAMPLE

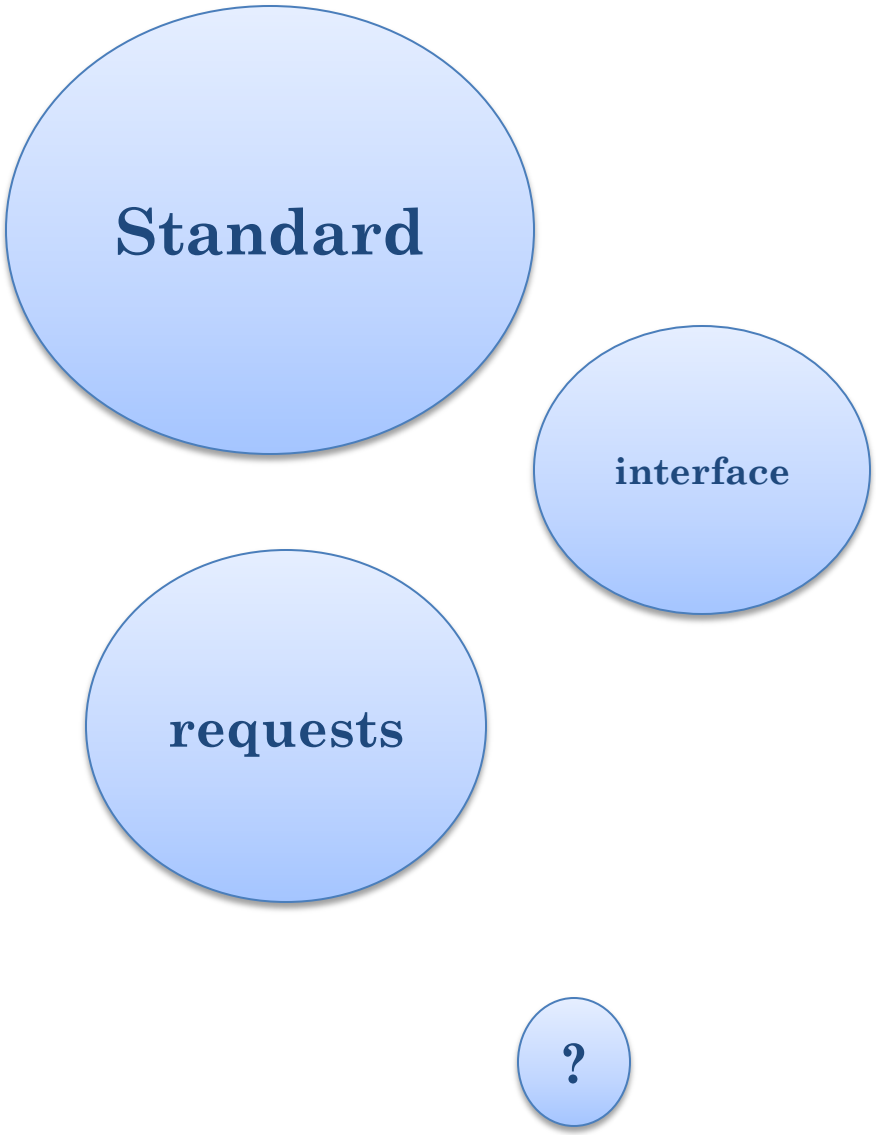
- The *Get_Status* request directed at the device will return two bytes during the data stage with the following format.

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Reserved														Remote Wakeup	Self Powered

- If D0 is set, then this indicates the device is self powered. If clear, the device is bus powered. If D1 is set, the device has remote wakeup enabled and can wake the host up during suspend.

- The remote wakeup bit can be by the SetFeature and ClearFeature requests with a feature selector.

- Set_Address is used during enumeration to assign a unique address to the USB device.
- The address is specified in wValue and can only be a maximum of 127. This request is unique in that the device does not set its address until after the completion of the status stage.
- This request is unique in that the device does not set its address until after the completion of the status stage, but All other requests must complete before the status stage.
- Set_Descriptor/Get_Descriptor is used to set/return the specified descriptor in wValue.
- Get_Configuration/Set_Configuration is used to request or set/return the current device configuration.


Standard
interface
requests
?

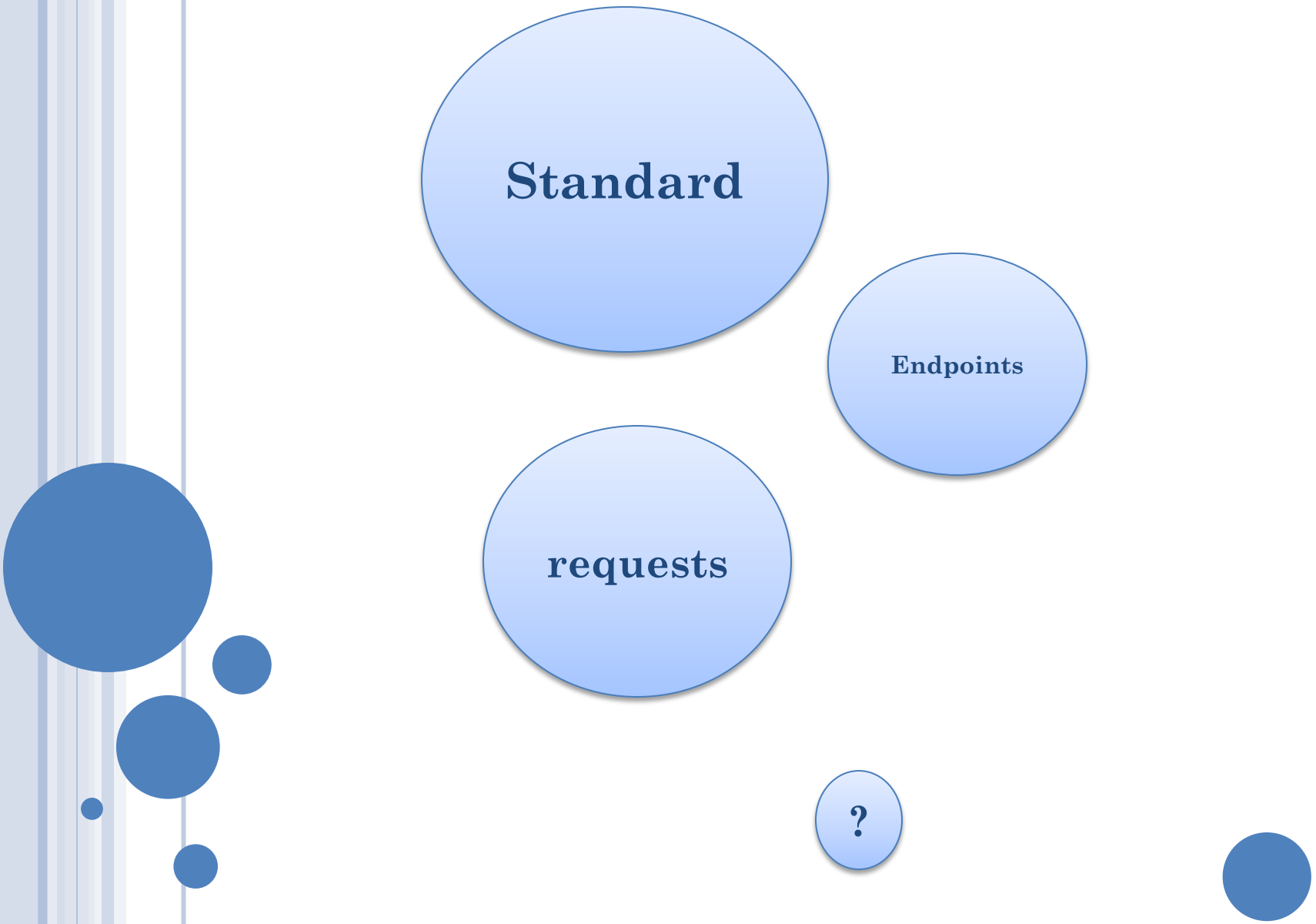
The specification currently defines five Standard Interface requests

bmRequestType	bRequest	wValue	wIndex	wLength	Data
1000 0001b	GET_STATUS (0x00)	Zero	Interface	Two	Interface Status
0000 0001b	CLEAR_FEATURE (0x01)	Feature Selector	Interface	Zero	None
0000 0001b	SET_FEATURE (0x03)	Feature Selector	Interface	Zero	None
1000 0001b	GET_INTERFACE (0x0A)	Zero	Interface	One	Alternate Interface
0000 0001b	SET_INTERFACE (0x11)	Alternative Setting	Interface	Zero	None

- ***wIndex*** *is normally used to specify the referring interface for requests directed at the interface. Its format is shown below.*

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Reserved								Interface Number							

- *the current USB Specification Revision 2 specifies no interface features.*


Standard
Endpoints
requests
?

bmRequestType	bRequest	wValue	Windex	wLength	Data
1000 0010b	GET_STATUS (0x00)	Zero	Endpoint	Two	Endpoint Status
0000 0010b	CLEAR_FEATURE (0x01)	Feature Selector	Endpoint	Zero	None
0000 0010b	SET_FEATURE (0x03)	Feature Selector	Endpoint	Zero	None
1000 0010b	SYNCH_FRAME (0x12)	Zero	Endpoint	Two	FrameNumber

- *The **wIndex** field is normally used to specify the referring endpoint and direction for requests directed to an endpoint. Its format is shown below.*

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Reserved								Dir	Reserved			Endpoint Number			

- ***Get Status** returns two bytes indicating the status (Halted/Stalled) of a endpoint. The format of the two bytes returned is illustrated below.*

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
Reserved															Halt

- ***Clear Feature** and **Set Feature** are used to set Endpoint Features. The standard currently defines one endpoint feature selector, ENDPOINT_HALT (0x00) which allows the host to stall and clear an endpoint. Only endpoints other than the default endpoint are recommended to have this functionality.*
- *A **Synch Frame** request is used to report an endpoint synchronisation frame.*

Enumeration

Steps

?

- 1. The system has a new device.
- 2. The hub detects the device
- 3. The host learns of the new device.
- 4. The hub detects whether a device is low or full speed.
- 5. The hub resets the device.
- 6. The host learns if a full-speed device supports high speed.
- 7. The hub establishes a signal path between the device and the bus.
- 8. The host sends a Get Descriptor request to learn the maximum packet size of the default pipe.
- 9. The host assigns an address.
- 10. The host learns about the device's abilities.
- 11. The host assigns and loads a device driver (client).
- 12. The host's device driver selects a configuration.

Item	Device	Payload
Reset (2.3 s)		
Suspended (114.0 ms)		
Reset (10.0 ms)		
High speed Detection Handshake		
GetDescriptor (Device)	0 (5)	8 bytes (12 01 00 02 FF 00 00 08)
Reset (10.0 ms)		
High speed Detection Handshake		
SetAddress (5)	0 (5)	No data
GetDescriptor (Device)	5	18 bytes (12 01 00 02 FF 00 00 08 ...
GetDescriptor (Configuration)	5	9 bytes (09 02 2E 00 01 01 00 A0 32)
GetDescriptor (Configuration)	5	46 bytes (09 02 2E 00 01 01 00 A0 ...
GetDescriptor (String lang IDs)	5	4 bytes (04 03 09 04)
GetDescriptor (String iProduct)	5	24 bytes (18 03 57 00 69 00 6E 00 ...
GetDescriptor (String lang IDs)	5	4 bytes (04 03 09 04)
GetDescriptor (String iProduct)	5	24 bytes (18 03 57 00 69 00 6E 00 ...
GetDescriptor (Device)	5	18 bytes (12 01 00 02 FF 00 00 08 ...
GetDescriptor (Configuration)	5	9 bytes (09 02 2E 00 01 01 00 A0 32)
GetDescriptor (Configuration)	5	46 bytes (09 02 2E 00 01 01 00 A0 ...
GetStatus (Device)	5	2 bytes (00 00)
SetConfiguration (1)	5	No data

Figure 4-1. To enumerate a newly attached device, the host sends a series of requests to obtain descriptors and set the device's bus address and configuration. (Screen capture from Ellisys USB Explorer analyzer.)

References

- Universal Serial Bus Specification 2.0.
- Wikipedia.
- www.usb.org.
- beyondlogic.org.
- USB Overview by Silicon Labs.

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