Universal Serial Bus Communications Class Subclass Specifications for Socket Management Protocol

Revision 0.1

September 4, 2019

Revision History

Table 1: Revision History

Version	Date	Comments
1.0	TBD	Initial Release

Contributors

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1 Introduction

1.1 Purpose

The Socket Control Module (SCM) subclass is a protocol by which USB devices can efficiently manage and use Berkeley/POSIX-style sockets on the host.

The specification currently defines support for the INET (IPv4) and INET6 (IPv6) protocol families and the TCP and UDP protocols. Future versions may add support for additional families and protocols.

This protocol offers an alternative method for a device to communicate with remote servers. Existing approaches that operate at the L3 layer (IP/USB) or L2 layer (CDC ECM, EEM, NCM) have several disadvantages. In particular, they require the device to be assigned an IP address. Since many networks will assign only a single IP address to a host, this requires implementing some form of network address translation (NAT) on the host. Setting up the NAT requires userspace configuration in most operating systems, so the USB device is no longer truly plug and play.

1.2 Scope

This document specifies new device subclasses intended for use with Communication devices, based on the Universal Serial Bus Class Definitions for Communication Devices specification [USBCDC].

The intention of this specification is that all material presented here be upwards-compatible extensions of the [USBCDC] specification. New numeric codes are defined for subclass codes, protocol codes, management elements, and notification elements.

In some cases material from [USBCDC] is repeated for clarity. In such cases, [USBCDC] shall be treated as the controlling document.

In this specification, the word 'shall' or 'must' is used for mandatory requirements, the word 'should' is used to express recommendations and the word 'may' is used for options.

2 Overview

Socket Control Model (SCM) is a specification for efficent management of sockets on a host by its devices. SCM sends Application Layer traffic and internal socket management commands from the device to the host over USB. This module requires host implementaitons for each suported Network and Transport layer protocols, but other layers are beyond its scope.

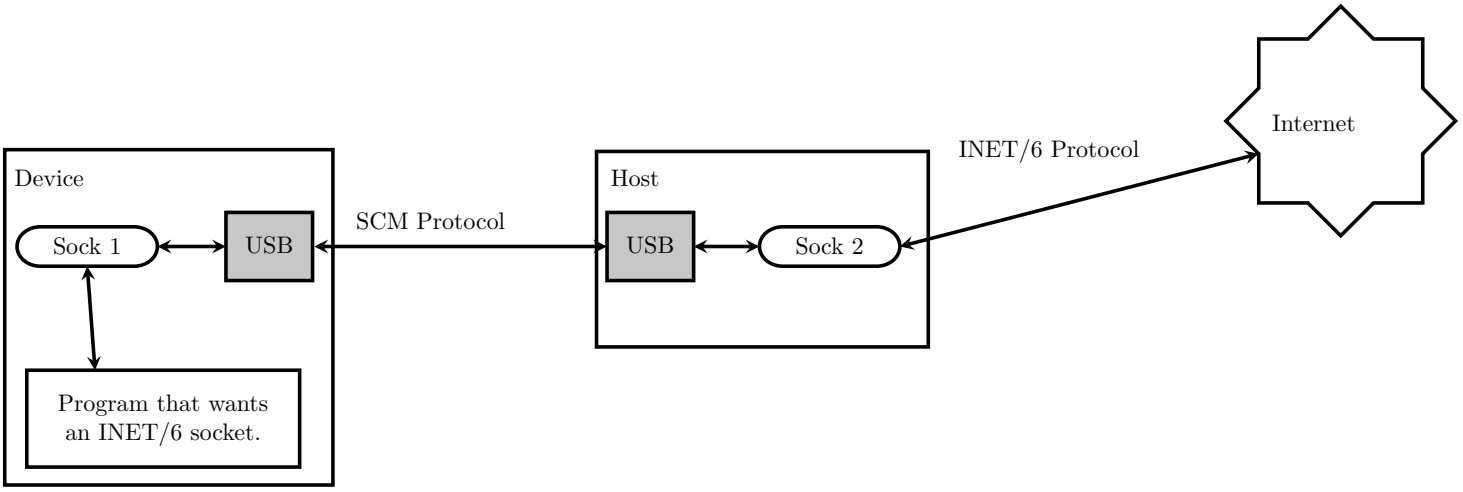
2.1 What is Socket Control Module (SCM)?

SCM allows a USB connected device to remotely create and control sockets on its host. A device may only control sockets it has created, and it shall expect exclusive control over this socket. Devices cannot control sockets created by other devices on the same host, and the host will not expose a devices socket for use by other applications.

Prior to SCM, connected devices would have to be assigned an IP address requiring the host to bridge the device or use NAT which also requires userspace configurations to the host. SCM allows a host to act on behalf of its device and provice it's network connection in a truly plug and play manner. This implicitly subjects the device to the same firewall rules and external network considerations without specific configuration.

The below figure illustrates a possible use case where a new socket type (Sock 1) is created on the device to interface with SCM. This allows userspace applications to interact with a standard protocol.

Figure 1: SCM Overview.



2.2 USB Endpoints

SCM's endpoint requirements consist of a bulk pair (In and Out) and command pair (In and Out). The SCM Device Class uses the standard Endpoint descriptor, as defined in chapter 9 of the USB Specification.
Additionally, SCM requires a pair of bulk-in/bulk-out endpoints and a control-in endpoint for recieving commands.

3 Socket Control Model (SCM)

The payload of the USB packet contains any combination of a single SCM packet, two or more SCM packets or a split SCM packet. SCM transfers can be split across USB packets but shall not be split across USB transfers.

3.1 SCM Packet Format

The packet format defines an SCM packet. For information regarding USB packets refer to [USB2.0] specification. Details packets formats can be found in section 8.4 of the [USB2.0] specification.

All SCM packets begin with a one-byte opcode (see Table 2), a one-byte message ID and a one-byte Socket ID.

While represented differently, both types of SCM packets will indicate the length of data being sent and then the data being sent. A packets data segment will always immediately proceed the header and this packet will always be sent in one USB transfer (although USB may split the SCM packet into many USB packets).

Figure 2: SCM Packet header and data.

3.2 SCM Packet Types

SCM has two different types of commands: Command and Payload. Command supports quickly sending short messages and Payload supports sending large messages.

3.2.1 Common Fields

All SCM packets begin with the following three bytes:

1. **Opcode**: 8-bit unsigned integer identifying what type of packet follows. All Op Codes are defined as either a Command or Data type so this field is sufficient to decide which type of structure to expect.

2. **Message ID**: 8-bit unsigned integer provided to allow the receiver to identify the received message when replying. This is always genrated by the sender, and the receiver may only reply using the given ID once. Sending an ACK or REPLY to an unknown Message ID causes undefiend behavior.

3. **bSockID**: 8-bit unsigned integer identifying which sock is being sent to. Sock IDs are always created by the device during an OPEN command.

While represented differently, both packets also include a length parameter indicating how much data follows the header. Both length fields are the length of the payload, not including the header.

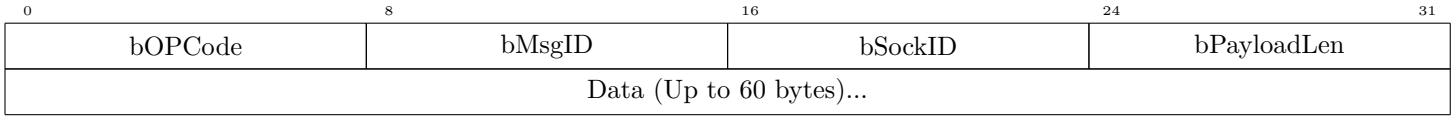
3.2.2 Op Codes

Table 2: OP Codes

Opcode	Name	Type	Purpose
0x00	OPEN	Cmd	Open a socket on the host
0x01	CONNECT	Cmd	Connect an open socket to a given address
0x02	SHUTDOWN	Cmd	Indicates that the sender will not send any more traffic.
0x03	TRANSMIT	Data	Write data to a connected socket
0x04	ACK	Cmd	Acknowledge a command and indicate success
0x05	ACKDATA	Data	Similar to ACK but contains data.
0x06	CLOSE	Cmd	Close the socket.

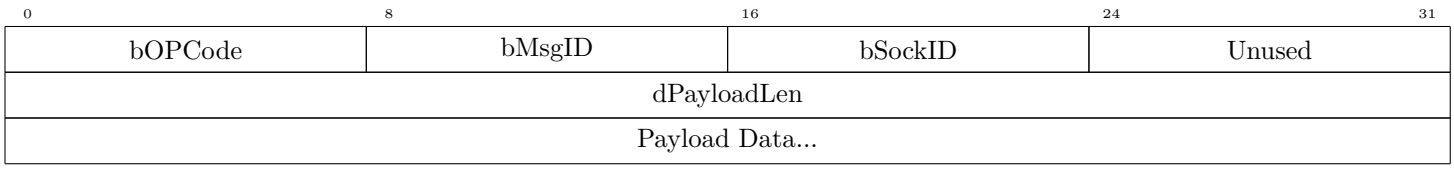
3.2.3 Command

SCM Command operations relate to opening, closing and managing sockets across USB. These requests are infrequent and short in length so they do not need to be mixed with larger data transmissions that can take a long time to process. Command packets are always sent over the USB Control EP and have a maximum length of 64 bytes including the header.



3.2.4 Data

SCM Data packets are meant for forwarding data across USB bulk endpoints. These requests can contain large amounts of data. These requests are either for sending data transmitted across sockets or acknowledging messages with a response longer than 64 bytes.



3.3 SCM Packets

All values in SCM packets are little endian unless otherwise noted. All IDs and integer values are unsigned unless otherwise noted.

3.3.1 SCM Command Packet Formats

3.3.1.1 OPEN

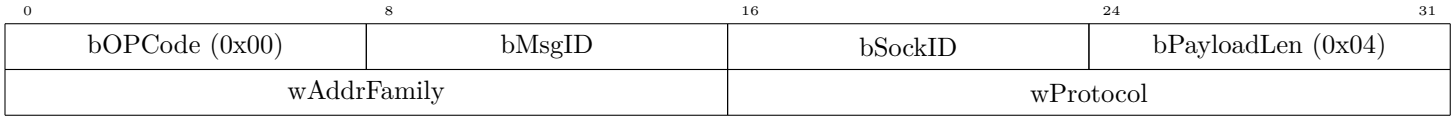
The OPEN command is awlays initiated by the device to the host. The device will create a new message ID and new sock ID so the device can identify future operations on these objects.

Table 3: Values for Family.

ID	Name
0x01	IP
0x02	IP6

Table 4: Values for Protocol.

ID	Name
0x01	TCP
0x02	UDP



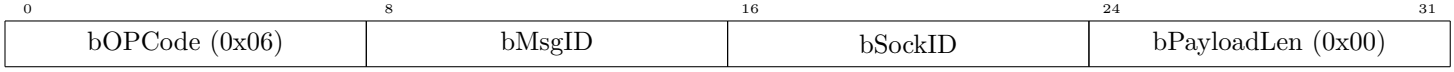
ACK will return with a 1-byte unsigned integer.

Table 5: ACK Codes for OPEN

ID	Name	Description
0	ESUCCESS	Success
1	EHOSTERR	An error has occured on the host
2	EINVAL	Host does not understand protocol or protocol family
3	EPROTONOSUPPORT	The protocol type is not supported on the domain.

3.3.1.2 CLOSE

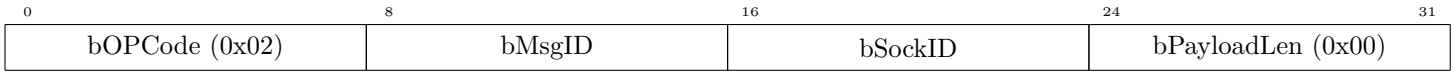
When sent from device to host, this command disconnects (if connected) and closes a socket using the ID given during creation. If sent from host to device this will serve as a notification that the socket has been closed by the remote peer.



Upon completion an ACK command will be sent witn no return data.

3.3.1.3 SHUTDOWN

Shutdown indicates that the sender will no longer transmit data to the reiever, but the reciever may still send messages.



Upon completion an ACK command will be sent witn no return data.

3.3.1.4 ACK

Upon completion of a message the receiver will send this back to acknowledge reciept and indicate whether the operation

was a succes or a failure. Once USB has acknowledged reciept, the sender of an ACK will not wait for further confirmation that the recipient has received the message.

0	8	16	24 31
bOPCode (0x04)	bMsgID	bSockID	bPayloadLen
bOrigOpCode	Reserved	Return data (Up to 56 bytes)	

3.3.1.5 CONNECT

Connect tells the host to connect a created socket to a given address. The address information passed will vary by protocol, the host and device should know which structs the other side will send and process those (these are typically the same on both ends).

IP Connect Packet

0	8	16	24 32
bOPCode (0x01)	bMsgID	bSockID	bPayloadLen (0x08)
bFamily (0x00)	bProtocol	wPort (in Network Byte Order[1])	
IP Address in Network Byte Order			

IP6 Connect Packet

0	8	16	24 32
bOPCode (0x01)	bMsgID	bSockID	bPayloadLen (0x24)
bFamily (0x01)	bProtocol	wPort (in network byte order)	
dFlowInfo			
dScopeID			
IP6 Addr In Network Byte Order...			
...IP6 Addr In Network Byte Order...			
...IP6 Addr In Network Byte Order...			
...IP6 Addr In Network Byte Order			

Both connect types will send an ACK with a 1-byte unsigned integer as a response.

Table 6: ACK Codes for CONNECT

Value	Name	Description
0	ESUCCESS	Success
1	EHOSTERR	An error has occured on the host
2	ECONNREFUSED	No one is listening on remote address
3	ENETUNREACH	Network is unreachable
4	ETIMEDOUT	Timeout while attempting connection
5	EMISMATCH	Family or protocol for CONNECT to not match socks type on OPEN.

3.3.2 SCM Data Packet Formats

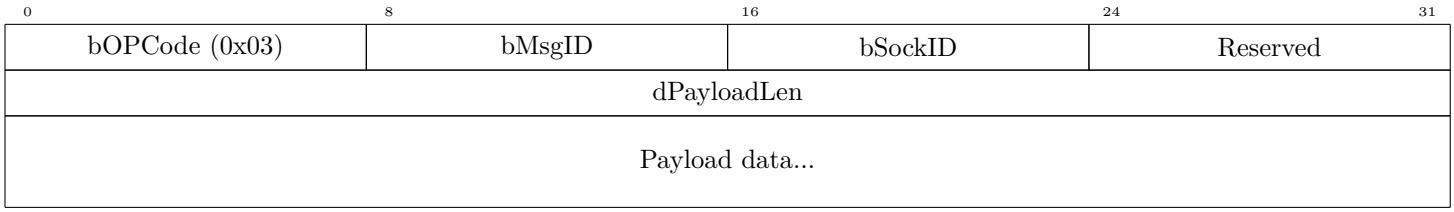
Data packets contain arbitrary data immediately after the header of whatever length is contained in the headers length field.

Data Length will always be an unsigned 32-bit integer.

[1] POSIX.1-2017 expects the address and port to be in network byte order regardless of the host byte order.

3.3.2.1 TRANSMIT

Sends data over the Bulk endpoint containing an arbitrary amount of data for a connected socket.



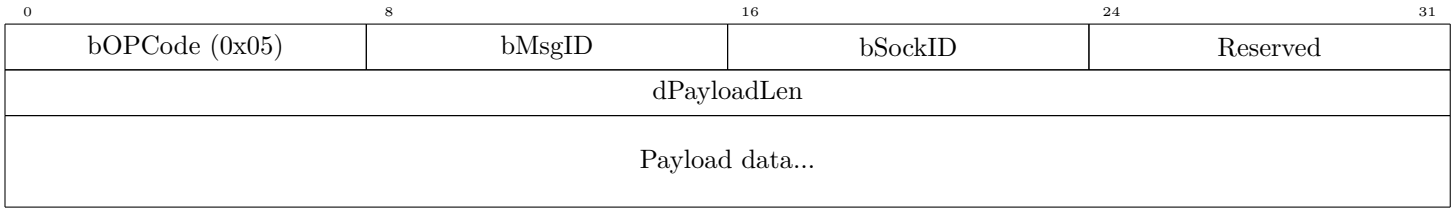
ACK will return as a 4-byte signed integer. On error the a negative number will be returned. Nonnegative return codes indicate a succesful trasnfer while positive return codes also indicate flow indicators (TODO: IMPLEMENT POSITIVE CODE BEHAVIOR).

Table 7: ACK Codes for TRANSMIT

Value	Name	Description
0	ESUCCESS	Success
-1	EHOSTERR	An error has occured on the host
-2	ENOTCONN	The socket on the remote side is not open and connected

3.3.2.2 REPLY

Similar to ACK but is a DATA type command. This should only be used for commands that can expect more than 60 bytes of data back.



3.4 SCM Packet Ordering

Synchronization must be maintained to ensure that all commands arrive at the detinsation in the order they were requested. In particular, CLOSE commands shall not be transmitted while there is still unsent data and more data shall not be queued to transmit while a CLOSE is waiting to be sent.

4 Packet Processing

Fig A describes the process for the receiver on both ends to assemble and transmit packets from USB to their respective proxies. The Send Command To Proxy procedure can be assumed to be nonblocking, after which the data passed in can be safely freed.

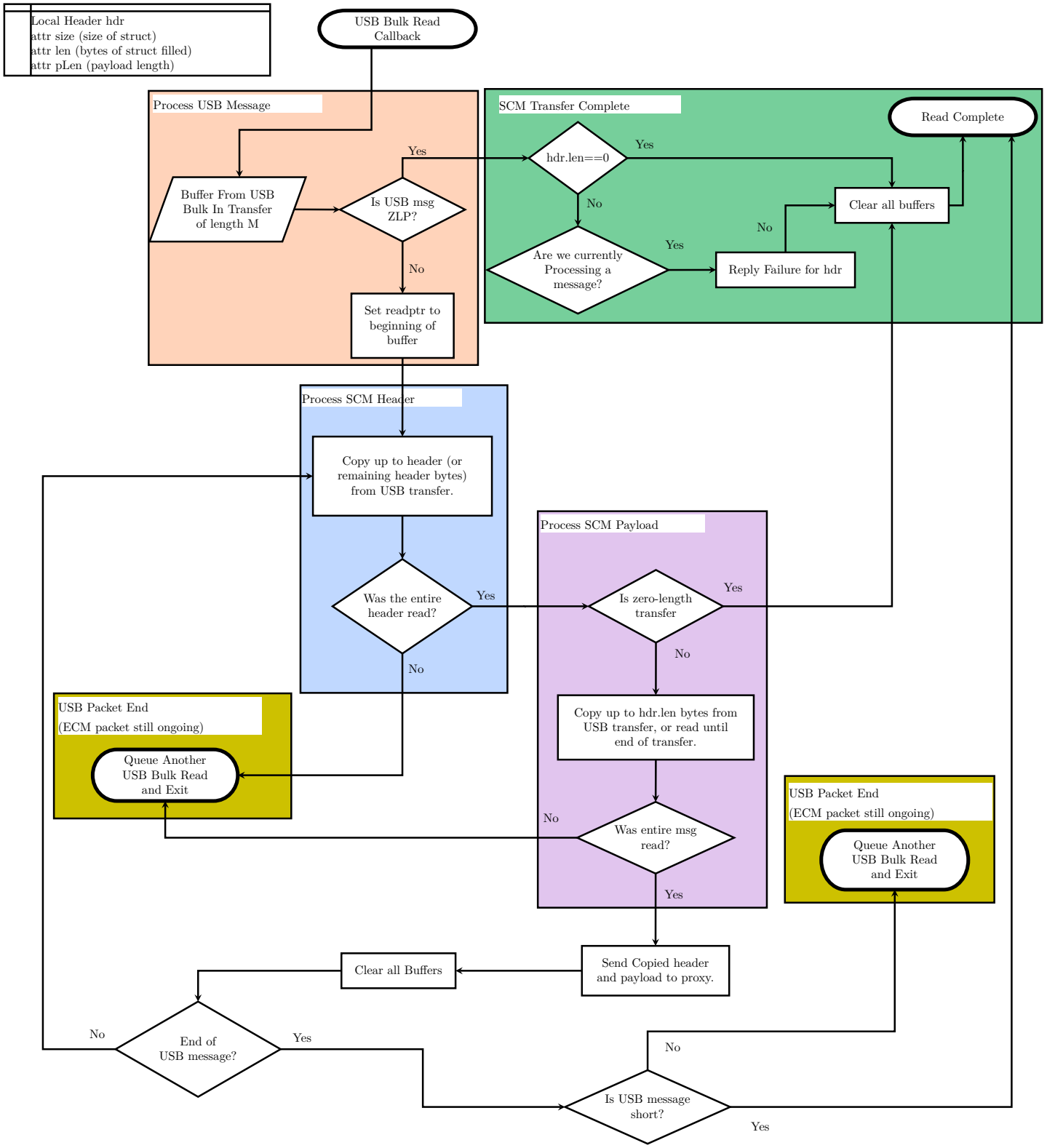
4.1 Processing Flow

4.1.1 Receiving SCM Packets From USB

SCM transmission packets are sent over USB bulk transfers. SCM transfers may not be split over multiple bulk transfers, but may be split over USB Bulk Packets within a single transfers. Many SCM tranmission packets may be sent in one bulk transfer. This means that SCM packet headers may also be split between SCM packets.

SCM transfers will end with one of a short USB packet, zero-length packet over USB (if supported) or a zero-length SCM transfer. Sending a zero-length USB packet when the reciever is expecting the continuation of a SCM packet causes undefined behavior.

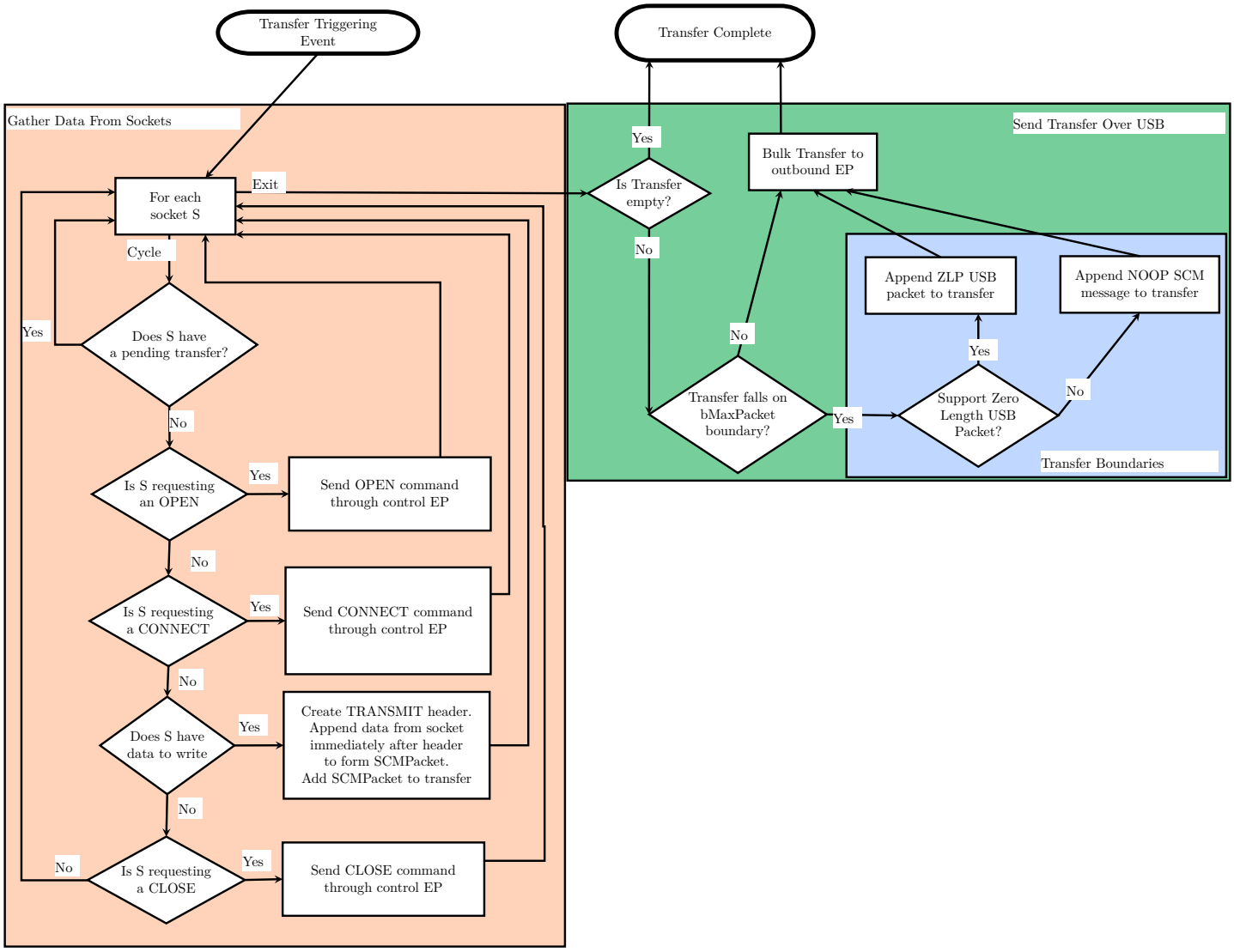
Figure 3: SCM Packet receive Flow.



4.1.2 Transmitting Data

The figure below illustrates how the host and device should send messages to eachother.

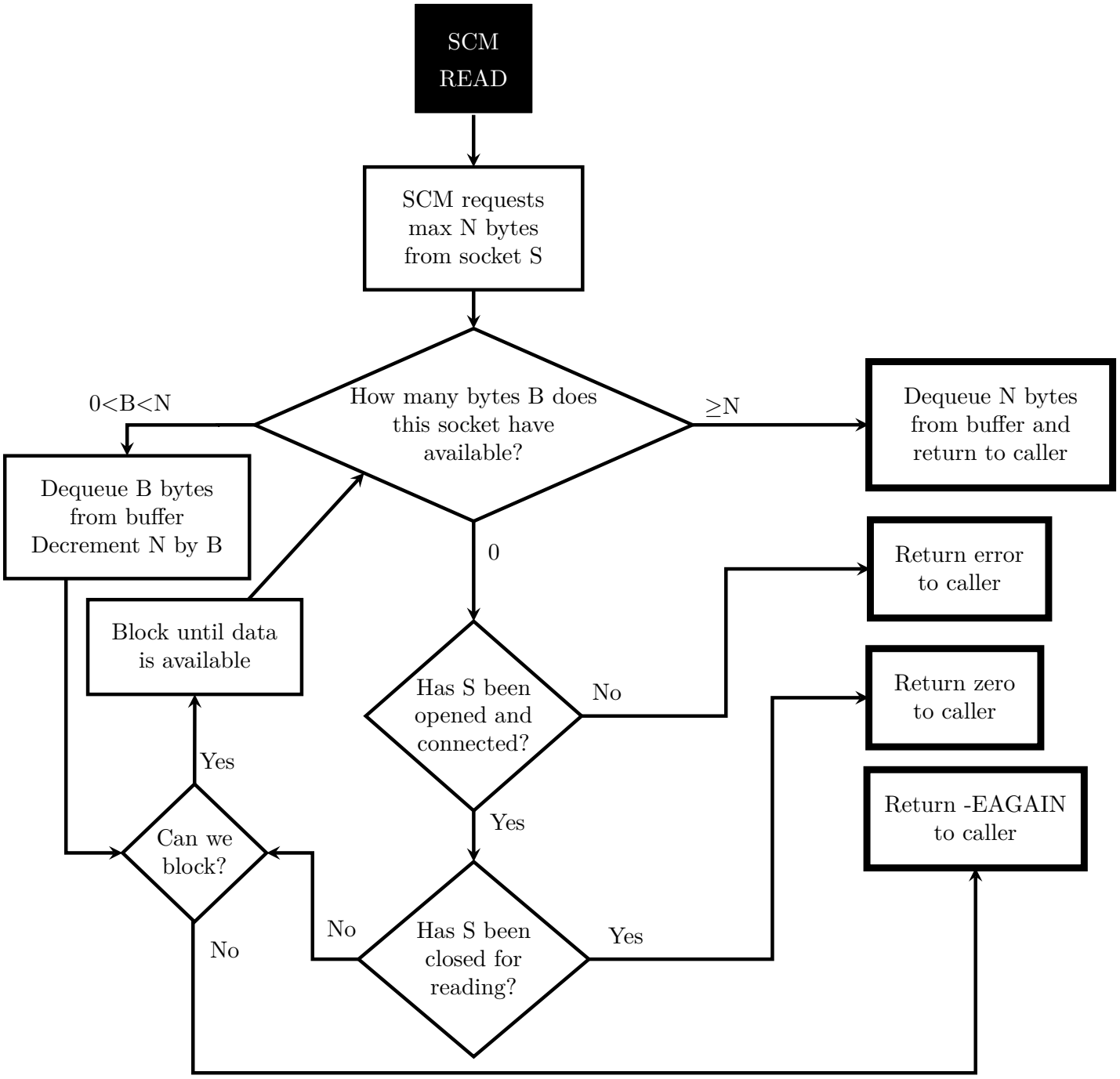
Figure 4: Sending To Peer.



4.1.3 Reading Transmitted Data

The figure below illustrates how either the host or device should its read functions. Read can only work with data that has already been transmitted, it does not ask for data from its peer since any sendable data will be sent automatically.

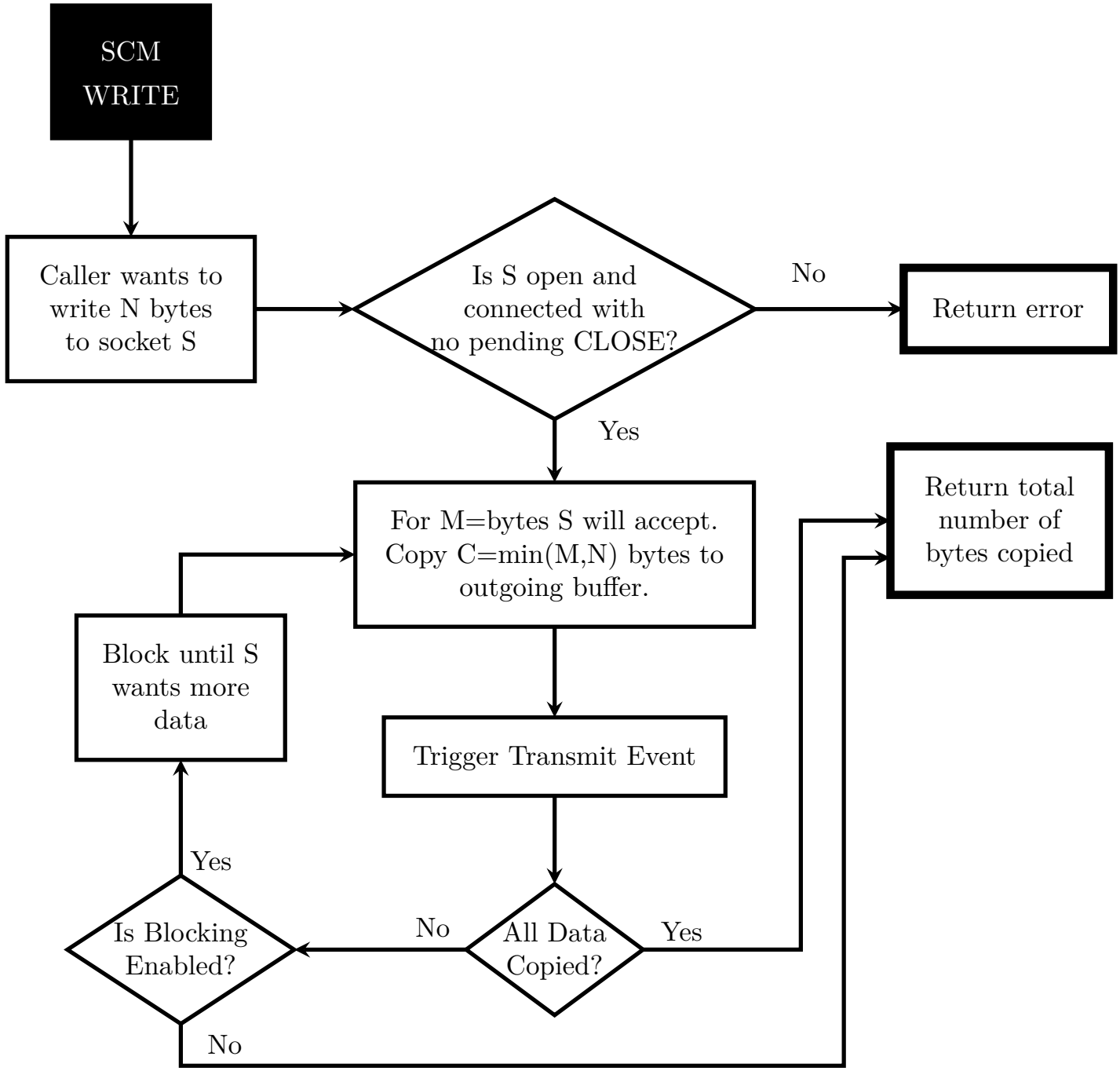
Figure 5: Reading Transmitted Data.



4.1.4 Writing Data

The figure below illustrates how either the host or device should its handle socket write calls.

Figure 6: Writing Data to SCM.



4.1.5 Command Flow

Commands involve controlling sockets and sending ACKs for commands.

Open and Connect require confirmation from the host before the device can change its behavior. Disconnect and Close take effect regardless of acknowledgement, subsequent writes on a closed channel will return an error.

Figure 7: Command Flow.