OpenLCB	**OpenLCB Standard**	
	BLE Transfer	
	August 18, 2024	**Concept**

1 Introduction (Informative)

The OpenLCB suite of protocols can be used on multiple physical transports; this document defines the specifics that relate to using Bluetooth Low Energy (BLE) as a transport layer. The BLE protocol uses broadcast messages and connection based transfer of attribute data. This Standard defines unique broadcast messages called advertisements to identify the presence of OpenLCB nodes supporting BLE and the exchange of data using attributes over connections.

2 Intended Use (Informative)

This Standard is intended for use whenever OpenLCB nodes are communicating using BLE. It is not intended to cover OpenLCB communications over other types of communications links.

3 References and Context

This specification is in the context of the following OpenLCB-CAN Standards:

- The OpenLCB Message Network Standard, which specifies the general OpenLCB message format

For more information about BLE, please refer to the Bluetooth Special Interest Group.

For the purposes of this standard, a BLE "device" implements the BLE Peripheral role and uses BLE Advertisements to both announce itself and accept connections. A "client" implements the BLE Central role and uses BLE scanning to find BLE devices to establish connections to.

4 Message Formats

There exists two possible ways in which a node using BLE transport can join the network.

1. The Streaming method utilizes the general OpenLCB message format transported over a pair of BLE attributes. This method requires a full OpenLCB stack implementation on the BLE device.

2. The Simplified method assumes that the BLE device implements one or more very specific applications. It uses one or more BLE attributes to exchange information specific to the given application. This method does not require a full OpenLCB stack implementation on the BLE device.

All multi-byte advertising fields are in little-endian format, consistent with BLE conventions.

4.1 BLE UUIDs

30 Version 4 BLE UUIDs are used by OpenLCB services and characteristics. A Version 4 UUID is a 128-bit universally unique identifier that is generated using random numbers.

OpenLCB BLE UUIDs	
Description	**UUID**
Streaming Service	0ff45220-84a9-4daf-83e7-da4c828d1851
Streaming Active Characteristic	
Streaming Data In Characteristic	b029e1ba-47bc-4d8a-a28e-fbe167fc06cb
Streaming Data Out Characteristic	c4fed917-55d9-485d-bf30-2eb3c095a90f
Simplified Services	
Node Information Service	
Node Manufacturer Name	
Node Model Name	
Node Hardware Version	
Node Software Version	
Node User Name	
Node User Description	
Memory Configuration Service	
Memory Configuration Command	
Memory Configuration Reply	
Train Service	
Train Incoming Message	
Train Outgoing Message	

4.2 Streaming

If a node supports streaming protocol, it shall implement the following advertising format to announce itself and accept connections.

Legacy Advertising Payload (Connectable Undirected)		
Bytes	**Field**	**Payload**
1	flags length	2
1	flags type	
1	flags	
1	local name length	2-27
1	local name type	Use "short" type if the OpenLCB Node user name does not fit. Use "complete" type if the OpenLCB Node user name does fit.
1-26	local name	Up to the first 26 bytes of the OpenLCB Node user name, null terminated if length is less than 26 bytes. Shall not contain a ':' or ';' character. ':' or ';' characters shall be replaced by spaces.
Legacy Scan Response Payload		
Bytes	**Field**	**Payload**
1	service data 128 length	27
1	service data 128 type	
16	128-bit UUID	Unique Identifier identifying this as having an OpenLCB Streaming Service (and more). 0ff45220-84a9-4daf-83e7-da4c828d1851
6	OpenLCB Node ID	48-bit OpenLCB Node ID.
4	OpenLCB PIP	If PIP exceeds four bytes, then a connection is required to get the rest.

35

OpenLCB BLE Transfer Standard

If a node supports streaming protocol, it shall implement the following BLE GATT Service.

UUID Length (bits)	UUID	Permissions	Size (bytes)	Value
OpenLCB Streaming Service Attribute Table				
16	Primary Service	Read	16	Streaming Service UUID 0ff45220-84a9-4daf-83e7-da4c828d1851
16	Characteristic Declaration	Read	1	Characteristic Property write
128	Streaming Active Characteristic	Write	1	0: Streaming connection not active 1: Streaming connection active
16	Characteristic Declaration	Read	1	Characteristic Property write
128	Streaming Data In Characteristic b029e1ba-47bc-4d8a-a28e-fbe167fc06cb	Write	244	OpenLCB message data to the device.
16	Characteristic Declaration	Read	1	Characteristic Property read notify ack
128	Streaming Data out Characteristic c4fed917-55d9-485d-bf30-2eb3c095a90f	Read	244	OpenLCB message date from the device

16	Client Characteristic Configuration Descriptor	Read/Write	2	

40 *4.3 Simplified*

If a node supports one or more of the simplified protocols, it shall implement the following advertising format to announce itself and accept connections.

Legacy Advertising Payload (Connectable Undirected)		
Bytes	**Field**	**Payload**
1	flags length	2
1	flags type	
1	flags	
1	local name length	2-27
1	local name type	Use "short" type if the OpenLCB Node user name does not fit. Use "complete" type if the OpenLCB Node user name does fit.
1-26	local name	Up to the first 26 bytes of the OpenLCB Node user name, null terminated if length is less than 26 bytes.
Legacy Scan Response Payload		
Bytes	**Field**	**Payload**
1	service data 128 length	27 - 30
1	service data 128 type	
16	128-bit UUID	Unique Identifier identifying this as having one or more OpenLCB Simplified Services (and more).
6	OpenLCB Node ID	48-bit OpenLCB Node ID.
4	OpenLCB PIP	If PIP exceeds four bytes, then a connection is required to get the rest.

OpenLCB BLE Transfer Standard

45 If a node supports one or more of the simplified protocols, it shall implement one or more of the following BLE GATT Services.

OpenLCB Node Information Attribute Table

UUID Length (bits)	UUID	Permissions	Size (bytes)	Value
16	Primary Service	Read	16	Node Information Service UUID
16	Characteristic Declaration	Read	1	Characteristic Property read
128	Manufacturer Name	Read	41	Null terminated string
16	Characteristic Declaration	Read	1	Characteristic Property read
128	Model Name	Read	41	Null terminated string
16	Characteristic Declaration	Read	1	Characteristic Property read
128	Hardware Revision Characteristic	Read	21	Null terminated string
16	Characteristic Declaration	Read	1	Characteristic Property read
128	Software Version Characteristic	Read	21	Null terminated string
16	Characteristic Declaration	Read	1	Characteristic Property read
128	Node User Name Characteristic	Read	63	Null terminated string

16	Characteristic Declaration	Read	1	Characteristic Property read
128	Node User Description Characteristic	Read	64	Null terminated string

OpenLCB Memory Configuration Attribute Table

UUID Length (bits)	UUID	Permissions	Size (bytes)	Value
16	Primary Service	Read	16	Memory Configuration Service UUID
16	Characteristic Declaration	Read	1	Characteristic Property write
128	Command	Write	72	
16	Characteristic Declaration	Read	1	Characteristic Property read notify ack
128	Reply	Read	72	
16	Client Characteristic Configuration Descriptor	Read/Write	2	

OpenLCB Train Attribute Table

OpenLCB BLE Transfer Standard

UUID Length (bits)	UUID	Permissions	Size (bytes)	Value
16	Primary Service	Read	16	Train Service UUID
16	Characteristic Declaration	Read	1	Characteristic Property write
128	Incoming Message	Write	11	Train Control Message
16	Characteristic Declaration	Read	1	Characteristic Property read notify ack
128	Outgoing Message	Read	11	Train Control Message
16	Client Characteristic Configuration Descriptor	Read/Write	2	

5 States

5.1 General

2.5 ±0.5 seconds after a connection is established, the device shall request an update of the connection parameters within the bounds provided in Section 6.2 below. The client shall respond with one of the following:

1. Rejection of connection parameter update.

2. Request to update connection parameters within the bounds requested by the device.

3. Request to update connection parameters outside the bounds requested by the device.

    1. In this case, the connection parameters must still fall within the bounds provided in Section 6.2 below.

The client may skip the connection parameter update request if the initial connection parameters are already acceptable to it.

Upon initiation of a connection, a device shall disable all advertisements and not accept new connections until either:

1. All connections are terminated.

2. At least 5 seconds has past since the last connection initiation.

5.2 Streaming

A connection is not required for basic device interaction. A client may "proxy" information contained in the advertising and scan response payload over the OpenLCB network without an active connection having been established. A client may initiate a connection with a device if:

1. The device is sent an addressed message (routed through the client).

A client is only required to initiate a connection with a device if it has the capacity to establish more BLE connections and one of:

1. The device is sent an addressed message (routed through the client) and the client is previously paired to the device.

2. The client is paired to the device and configured to force connect upon discovery.

The client may automatically terminate connections to devices if a timeout occurs with no OpenLCB messages exchanged between the device and client, and the client is not paired to the device and also configured to force connect upon discovery.

A client shall not proxy information contained in the advertising and scan response payload over the OpenLCB network if does not have the capacity to establish any more BLE connections.

A device shall only support one active streaming connection at any given time. The lifetime of an active streaming connection is as follows:

1. Device starts advertising.

2. Client scans for and receives device advertisement.

3.[2.] Client initiates a BLE connection to the device, device stops advertising.

4. Client exchanges MTU with device.

5. Client discovers OpenLCB Streaming Service handles.

6. Client enables notifications on Streaming Data Out characteristic.

7. Client writes a value of 1 to the Streaming Active characteristic.

8.[3.] Device sends Streaming Active characteristic write response.

9. Device moves node to the initialized state upon write of value 1 to Streaming Active characteristic and begins sending OpenLCB messages over the Streaming Data Out characteristic.

10. Upon receiving Streaming Active characteristic write response from the device, client begins sending OpenLCB messages over the Streaming Data In characteristic.

If any errors occur during the above sequence, the connection shall be terminated. The connection may be terminated by either device or client side. The device shall not enable a streaming advertisement and scan response payload as long as it has an active streaming connection.

When an active streaming connection is terminated, the device shall force the Streaming Active characteristic value to 0.

If a client requests a write of value 1 to the Streaming Active characteristic when the value is already set to 1, the client connection shall be immediately terminated by the device.

5.3 Simplified

6 Interactions

This section applies to all client/device interactions.

6.1 Scanning and Advertising

For all device advertising, the recommended interval is 20 milliseconds. The maximum advertising interval is 152.5 milliseconds.

There are no specific requirements on client scanning. The recommended scanning interval is 100 milliseconds maximum. The recommended scanning window is 20 milliseconds. Passive and active scanning may be utilized.

The values in this section are "nominal". Because scanning and advertising are asynchronous activities, many BLE protocol stack implementations will defer and/or skip scanning and advertising activities if a higher priority activity conflicts and preempts a scanning or advertising activity.

All scanning and advertising shall be at 1M PHY rates.

6.2 Connections

Parameter	Minimum	Recommended	Maximum
Interval (milliseconds)	30	30 to 60	500
Latency (intervals)	0		30
Timeout (seconds)	6	6	10

The device requests the connection parameters. The client makes the final choice of connection parameters. The device connection parameter request must also meet the following criteria:

1. Interval minimum shall be a multiple of 30 milliseconds.

2. Interval maximum shall be at least 30 milliseconds greater than interval minimum.

3. Interval maximum * (Peripheral Latency + 1) <= 6 seconds

4. Timeout shall be greater than interval maximum * (Peripheral Latency + 1) * 3

The minimum MTU size shall be 27. It is recommended that the client request the maximum supported MTU size supported by both client and device, up to the max of 251 supported by the BLE Data Packet Length Extension.

6.3 Privacy

The device should be able to resolve a Resolvable Private Address in all situations. The device shall use a Random Device Address as defined in the Bluetooth 4.0 specification Volume 3, Part C Section 10.8.

6.4 Permissions

The accessory should not require special permissions, such as pairing, authentication, or encryption to discover services and characteristics. It may require special permissions only for access to a characteristic value or a descriptor value. See the Bluetooth 4.0 specification, Volume 3, Part G, Section 8.1, fifth paragraph.

6.5 Pairing

The accessory should not request pairing until an ATT request is rejected using the Insufficient Authentication error code. See the Bluetooth 4.0 specification, Volume 3, Part F, Section 4 for details.

If, for security reasons, the accessory requires a bonded relationship with the Central, the Peripheral should reject the ATT request using the Insufficient Authentication error code, as appropriate. As a result, the device may proceed with the necessary security procedures.

Similarly, if the device acts as a Central and a GATT server, it may reject an ATT request using the Insufficient Authentication error code. The accessory should initiate the security procedure for pairing in response.

145 Pairing may require user authorization depending on device. Once an accessory is paired with a device, the accessory shall retain the distributed keys of both central and peripheral for future use. If the pairing is no longer required, the accessory shall delete both sets of keys.

6.6 PHY Modes

150 All clients and devices shall support the 1M PHY. If a client and device both support 2M, 500K, and/or 125K PHY modes, the PHY may be dynamically upgraded or down graded upon request by the client in order to maximize throughput or maximize range. The PHY selection criteria may be based on Receive Signal Strength Initiator (RSSI) of the link, however other selection criteria may also be used. The device may also initiate a request for a PHY mode change, but the client is not required to honor the request.

155

Table of Contents