OpenLCB Technical Note	
OpenLCB Event Transport	
Feb 2, 2013	Preliminary

1 Introduction

This Technical Note contains informative discussion and background for the corresponding "OpenLCB CAN Event Transport Standard". This explanation is not normative in any way.

OpenLCB nodes respond to local inputs and state changes by emitting Producer/Consumer Event Report (PCER) messages. When they do this, they are acting as "Producers". OpenLCB nodes receive these messages, and can act on them locally if desired. If they do so, they are acting as "Consumers". Together, this is called the Producer-Consumer Model of system control. In this model a particular concept, or event, is the sum of the inputs that trigger the production of the PCER by the producer(s) and the action(s) taken by the consumer(s).

Its main advantage is the knowledge independence it imparts between all of the nodes involved in an event. Expressed in more anthropomorphic terms, neither the producers nor consumers or a PCER are aware of each other. This adds flexibility to the system, since more producers or consumers of the PCER can be added to implement the associated event, without concern of side effects to the the other nodes involved in the event.[1][2]

The P/C Event ID included in a PCER message is a 8-byte unique identifier. The method for assigning these and ensuring their uniqueness is in the OpenLCB Event Identifiers Standard and Technical Note.

There are many possible ways to use these 64 bits, some of which are discussed as examples below. In particular, OpenLCB does not require or enforce any particular partitioning of the eight bytes. More than one node may emit the same P/C Event ID (note that the Node ID of the emitting node is available separately in the message). More than one node may receive and act on a PCER message with a specific P/C Event ID. The only requirement is that the 8-byte quantity be unique to the event.

2 Annotations to the Standard

This section provides background information on corresponding sections of the Standard document. It is expected that two documents will be read together.

2.1 Introduction

[1] D. Miorandi and S. Vitturi, "Performance analysis of producer/consumer protocols over IEEE 802.11 wireless links", *Proc. IEEE Workshop Factory Communication Systems (WFCS)*, 2004

[2] The Producer/Consumer Model and Control System Design ControlLogix 1999 https://cours.etsmtl.ca/gpa774/Cours/old-24-03-04/Documentations/Rockwell/articles/Producer_Consumer.html

2.2 Intended Use

A particular PCER may be produced in response to physical input or state change on a layout, for example a contact closure or the activation of a block occupancy detector, or it can be in response to a non-physical change such as the arrival of a certain time. The same PCER can be produced by several different state changes. That PCER may result in some action at consumers. The term 'event' includes the state changes, the PCER message, and the resulting actions, and represent a specific idea or concept, such as “Night has fallen”.

For example, the concept of an “Emergency stop” event might include the actions of turning off track power, turning on a fault-indicator, and sounding a buzzer. The PCER may be produced by any of: a panic button, a throttle button, an over-current detector, or an anti-collision system.

The aforementioned “Night has fallen” event might be triggered by a fast-clock time, a toggle switch, or a control program, and its actions might include illuminating street lights, house lights, and the dimming of overhead lighting.

In addition, ranges of PCERs can be used for specific purposes. For example, a fast clock's messages can be implemented as a range of PCERs, where the low order bytes code the time.

2.3 References and Context

For more information on format and presentation, see:

- OpenLCB Common Information Technical Note

For more information on MTI values and how they are laid out, see:

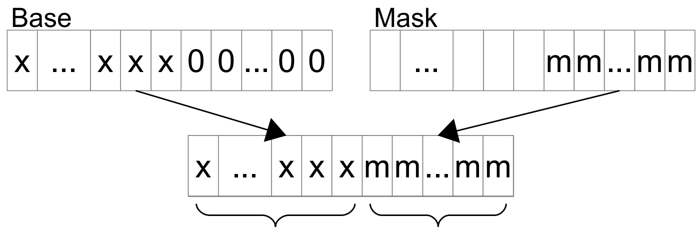
- OpenLCB Message Network Standard[3]
- MTI allocation table[4].

2.4 Message Formats

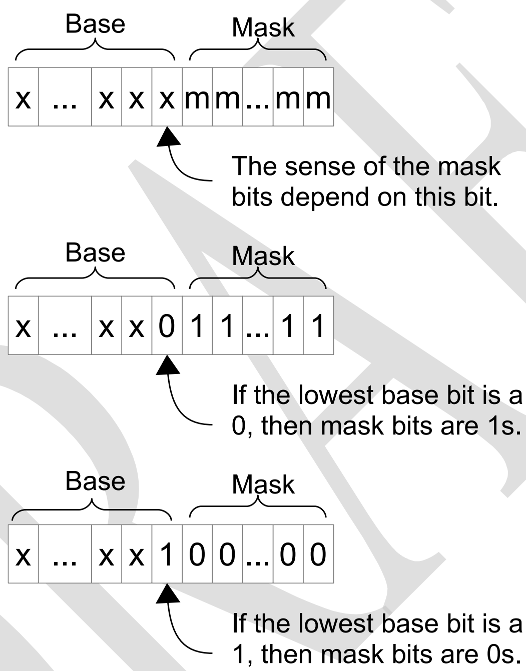
The range mask is implemented as a combined base value and mask in order to save space. The base value takes the form 0bv...0 and the mask 0b0...m. If the lowest bit of the base value is a one, then the combined form is 0bv...0. However, if the lowest bit of the base value is a zero, then the mask is inverted and the combined form becomes 0bv...1.

[3] As of the time of this writing, the OpenLCB Message Network Standard was still in preparation. See the OpenLCB web site documents page for current status: http://openlcb.org/trunk/specs/index.html

[4] http://openlcb.org/trunk/specs/MtiAllocations.pdf



Range Mask



Ranges can only be specified in powers of 2, ie they can specify ranges of 2, 4, 8, … .Therefore, if a range of n is required, then the next larger power of two is used. Ranges should not be over specified, so the standard requires that a range not extend past the next power of two by requiring that at least 50% of the EventIDs in the range be relevant.

Encoding a range is done by determining how many values are required, choosing the next higher power of two, choosing a base value and the mask, and finally combining the two, inverting the mask if necessary. For example, a range 0x1234xx would require a mask of the form 0x0000FF, and the combined form would be 0x1234FF. A range of 0x1235xx would also require a mask of 0x0000FF, but the combined form would be 0x123500, since the mask is inverted.

Decoding a range involves identifying the mask as lowest contiguous bits of the same value as the lowest bit. The base value is the remaining high order bits. For example, the combined form 0x987650 would yield a mask of 0x00000F and a base of 0x98765, whereas 0x98764F would yield a mask of 0x00000F (inverted) and a base of 0x987640.

2.4.1 Producer/Consumer Event Report (PCER)

This message transports an Event-number from a producer node(s) to zero or more unspecified consumer nodes. It is the backbone of the protocol, and forms most of the expected traffic.

The source node ID allows identification of which node sent the event. This can be used for diagnostic and status purposes, but nodes must act on the event without regard to where it came from.

2.4.2 Identify Consumer

This message is broadcast and requests every node to report if they consume this Event ID.

2.4.3 Consumer Identified

This message is broadcast, in response to a received Identify Consumer message, from each node that consumes the included Event ID. Nodes also send this as part of their startup so that other nodes know they want to consume particular events.

This is one of the messages that allows bridges to do automatic routing of event messages.

The "valid", "invalid", "unknown" subforms are used to attempt to recover the state of the overall system. In general, event transmission via PCER messages conveys state changes. If a node comes in during operation, it might want to determine the correct value of the distributed state. Producers can, but don't always, know that state. For example, consider "On" and "Off" events for a light. There might be two producers attached to toggle switch. In that case, one of them will still see their state as current, and will reply with valid. Alternately, the two producers might be set to produce when two separate pushbuttons are pressed. In that case, at some later time neither producer knows whether the distributed state corresponds to its event. They both have to report as unknown. Consumers can also know the state. The lamp controller that consumes the "On" and "Off" probably knows whether it is currently providing power to the lamp, and so can reply with valid for one event and invalid for the other.

2.4.4 Consumer Range Identified

This message broadcasts, in response to a received Identify Consumer message, from each node that consumes event is in the range specified by the included event-ID-with-mask. This is one of the messages that allows bridges to do automatic routing of event messages.

The requirement that 50% or more of the Event IDs in a range are consumed is to allow rounding the range up to the enclosing bit, but no further. This keeps the Event ID ranges in the complete OpenLCB system compact and is intended to make the task of gateways more manageable.

2.4.5 Identify Producer

This message is broadcast and requests every node to report whether they produce this Event ID.

2.4.6 Producer Identified

This message is broadcast, in response to a received Identify Producer message, from each node that produces the included Event ID. This is one of the messages that allows bridges to do automatic routing of event messages.

2.4.7 Producer Range Identified

The requirement that 50% or more of the Event IDs in a range are produced is to allow rounding the range up to the enclosing bit, but no further. This keeps the Event ID ranges in the complete OpenLCB system compact and is intended to make the task of gateways more manageable.

An example of a producer range would be a fast clock node that sends a range of events to indicate the time. Since there are 24*60*60 = 86,400 seconds in a day, it needs a range containing 86,400 events. That could be expressed in 17 bits, so if the range was to start with an Event ID of 0x12.34.56.78.00.00.00.00, the range could be expressed as 0x12.34.56.78.00.01.FF.FF using 1 bits to represent the mask. If the range had to start at 0x12.34.56.78.FF.FE.00.00 for some reason, 1 bits would not properly represent the mask because 0x12.34.56.78.FF.FF.FF.FF is actually a different range. Using a 0 bit for the mask would work, giving 0x12.34.56.78.FF.FE.00.00 as the representation.

This message is broadcast, in response to a received Identify Producer message, from each node that produces events in the range specified by the included event-ID-with-mask. This is one of the messages that allows bridges to do automatic routing of event messages.

2.4.8 Identify Events

Two forms of identify events; recommendation on uses for global form

In some cases, the node may want to query a specific node as to whether it produces or consumes that event, in these case the directed form is appropriate.

In other cases, the node producing the Identify Event will not know if any node uses that event, and therefore the global form is the more appropriate choice. Be aware that since this latter form is transmitted throughout the network, it can be relatively expensive in terms of bandwidth. The global form of Identify Event is similar to the combination of an Identify Producers and an Identify Consumers message.

2.5 States

After the IC message is sent, but before any Producer/Consumer Event Report messages are sent, each node must identify all events produced or consumed via zero or more Identify Consumers, Identify Consumed Range, Identify Producers and Identify Consumed Range messages. These are not required to be in any particular order.

2.6 Interactions

Nothing prevents extra Producer/Consumer Identified messages. Nothing prevents combining replies to multiple requests. This allows simplified implementations, for example setting a bit to indicate that a reply can be sent when time/priority is available.

Nodes can send identify/identified messages for automatically-routed Event IDs. Nodes aren't required to reply to Identify Producer/Consumer messages for automatically-advertised Event IDs to simplify node programming, but it is useful if they do.

Identify Producer/Consumer messages for well-known Event IDs require response; there's no exemption for those.

The state of the system can sometimes be constructed from the received Producer/Consumer Identified messages and their “valid”, “invalid”, “unknown” subforms. It is possible that these will result in conflicting and/or ambiguous state.

Note that the Advertised/Not-Advertised state machine is reset by the Initialization Complete message, and not by any lower level link (CAN or other) state machine.

Delay in sending the Producer Identified/Producer Range Identified and Consumer Identified/Consumer Identified Range messages after Initialization Complete is allowed, but there's no delivery guarantee for this node's events until those have been sent and the state has transitioned to Advertised.

When a node changes the events it manages, it still needs to emit the PI/PRI and/or CI/CRI messages. For example, reconfiguration could cause this. It can be handled by sending individual messages, or by resetting and sending them all as part of that process.

There is no way to indicate that a node is no longer interested in a particular Event ID. (Sending IC again says that all events are not interesting, though). This could be added, but it is much harder for gateways to decide that an Event ID is not interesting than that it is interesting, because they have to keep a list of all the node IDs that are interested,and back that off. Better to just let the set of interesting Event IDs grow until the layout or gateway is reset.

To ensure that event messages are properly routed, nodes must announce when they start to produce or consume messages. Specifically, they must do this at two times:

- When the node is first initialized, after the "Initialization Complete" message has been sent.
- When a configuration change has added another Event ID that can be produced or consumed.

To announce new Event IDs, the node must transmit a Producer Identified message for each P/C Event ID it can newly produce, and a Consumer Identified message for each P/C Event ID that it can newly consume.

2.6.1 Event Transfer

The last sentence is the key to gateway traffic reduction. See §3.1 below.

2.6.2 Event Enquiry

Two forms of identify events; recommendation on uses for global form. This can be a huge load, and should only be used when needed.

The two forms of this message are sent to request that the specified nodes report all the events they produce or consume. These reports can be ether Identified messages specifying individual Event IDs or ranges of events. One form is an unaddressed message sent globally to all nodes, and the other is an addressed message to a specific node.

It is useful to be able to rapidly determine which, if any, P/C Event IDs that a particular node is listening for and that it can emit.

This can be used as a configuration diagnostic.

To determine which P/C Event IDs can be send by a particular node, the inquiring node sends an Identify Events message addressed to the target node.

The node must reply with a Producer Identified message for each P/C Event ID it can produce, and a Consumer Identified message for each P/C Event ID for which it is listening.

2.6.3 Producer Enquiry

It is useful to be able to determine which, if any, nodes are configured to possibly transmit a specific PCER message and the current state of those producers. This can be used as a configuration diagnostic, and as a way of building filtering and routing tables.

To determine which nodes can send a particular P/C Event ID, a node sends an Identify Producers message carrying the desired P/C Event ID. This is an unaddressed message addressed to all nodes.

All nodes that are listening for that P/C Event ID reply with a Producer Identified broadcast message.

The “valid” bit indicates that the node's internal condition is consistent with sending this P/C Event ID. For example, assume a node sends P/C Event ID 2 when the input goes active and P/C Event ID 4 when the input goes inactive. Then if the input was active and the node was asked about P/C Event ID 2, it would reply “valid”; if asked about P/C Event ID 4, it would reply “not valid”. Depending on the node's structure, it might not always be possible to set the “valid” bit with certainty, in which case the “unknown” bit must be set.

You can query a state when you come up with the request-id message. Conflicting states can happen, and have to be addressed. You might also want to enquire of the consumers if you don't get a definitive answer from the producers.

In regard to valid/invalid/unknown, it is always possible to send only unknown, or to ignore the three sub-forms, but a lot of capability is then lost.

2.6.4 Consumer Enquiry

It is useful to be able to determine which, if any, nodes are listening for a specific P/C Event ID message.

This can be used as a configuration diagnostic, and as a way of building routing tables.

To determine which nodes are listening for a particular P/C Event ID, a node sends an Identify Consumers message carrying the desired P/C Event ID. This is an unaddressed message processed by all nodes.

All nodes that are listening for that P/C Event ID reply with a Consumer Identified broadcast message.

The “valid” bit indicates that the node is currently in the state it would be if this message had been received last. For example, assume a node sets its output active for P/C Event ID 2, and inactive for a P/C Event ID 4. Then if the output was active and the node was asked about P/C Event ID 2, it would reply "valid"; if asked about P/C Event ID 4, it would reply "not valid". Depending on the node's structure, it might not always be possible to set the “valid” bit with certainty, in which case the “unknown” bit must be set.

3 Background information

This section is general information of interest to the reader, implementers, etc.

An OpenLCB Event represents the sum of all the causes and actions associated with particular concept , such as “Night is falling”, and implements a many-to-many relationship. It has been referred to as the Producer-Consumer Model, in opposition to the Master-Slave Model.[5] Each Event is abstracted into a single unique event-number. An Event-message contains only this event-number. An advantage of this model is that new triggers or new causes which cause the production of the event-number, or new actions resulting from the consumption the event-number, can be implemented by a node without reference to other producers or consumers, which makes this model very flexible and extensible.

Events are most often used to advertise changes in system state, for example a occupancy detector's state. The model maintains the distributed-state model of a layout because Events-messages are broadcast[6] to all nodes, and this allows individual producers and consumers to use them to change their knowledge of the distributed state.

Other important, and perhaps not obvious, uses include: publishing a capability using an event from a list of well-known Event IDs; transmitting well-known ranges of data, such as fast-clock time; and embedding an other system's message into the bytes of the Event ID, for example a DCC accessory message. Notice that these latter uses allows any node to respond to these messages using its usual event-handling. For example, a node can activate an output in response to a specific fast-clock time.

3.1 Gateways

Gateways can route PCERs only to segments with nodes expressing interest by processing the other event messages.

The automatically-routed event range always has to be routed. This can be done by making a permanent entry in routing tables, or any other implementation method.

3.2 Examples

Consider a OpenLCB installation with two CAN segments A and B connected via gateways and a TCP/IP link. In addition, a program is attached via a TCP/IP link and additional gateway to CAN segment B.

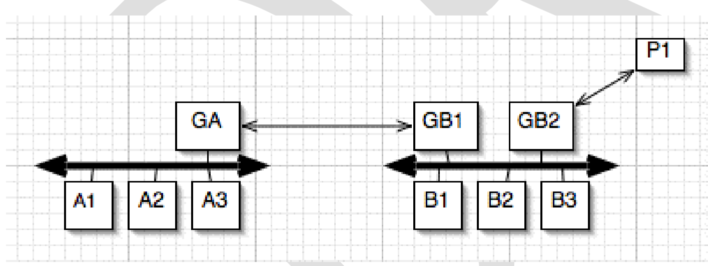


Figure 1 – Example OpenLCB Network

The program has to be able to fully communicate with all OpenLCB nodes on both segments A and B. These examples shows how the gateways can make that happen. For simplicity, the labels on the figure will be used as if they were the full NID of the node, e.g. "GB1" for the left gateway on segment B. Frames and messages are represented by [“source address”, “content”, “optional destination address”]

[5] For a general discussion, see: http://openlcb.org/trunk/documents/notes/ProducerConsumerModel.html and http://openlcb.org/trunk/scratchpads/JohnSL/Tech_Note_Introduction_to_the_PC_Model_2007-10-10.pdf

[6] OpenLCB uses interest-based routing, which means that Event messages are actually broadcast only to those bus segments on which a node has expressed interest. Event-ranges are used to express interest in a classes of events.

triplets. Not all messages are shown. Note that there are many ways that gateways can manage traffic, and this is just one approach.

Before the cases below, both segments come up, assign the numbers 1,2,3 as aliases to their local nodes, 10 to gateway 1 and 20 to gateway 2 on segment B. For simplicity, A1 produces event X, which A2 and B2 want to consume. A1 also produces Y, which no other node wants to consume.

3.2.1 Case 1: All nodes initialized before link established, event X is sent

The A-B gateways initialize their internal tables.

A1 sends X. GA receives it. Because GA hasn't seen X before, X is forwarded across the link to GB, followed by an “Identify Consumers of X” message.

GB puts the X message on the CAN segment, and B2 consumes it.

GB puts the “Identify Consumers of X” message on the CAN segment.

B2 responds with “Consumer of X Identified”

GB receives “Consumer of X Identified”, forwards to GA, which marks its tables to continue forwarding these. GA forwards that message on the CAN segment in case there are other listeners for it.

3.2.2 Case 2: Node B2 comes up, after event X has been sent in the example above

The gateways are up, but don't know about B2. GA has seen X sent by A1, but has marked it as “do not forward” because there was no consumer for it on B.

B2 comes up, gets a NID alias assigned, sends “AMD” and “Initialization Complete”.

B2 sends “Consumer of X Identified”. GB forwards that to GA.

GA remembers that event X must be forwarded across this link if seen.

A1 sends X, GA receives it, forwards it across link.

3.2.3 Case 3: Node A1 comes up, then event X is sent

The gateways are up, but don't know about A1 or X.

A1 comes up, gets a NID alias assigned, sends “AMD” and “Initialization Complete”.

A1 sends “Producer of X Identified”. GA forwards that to GB.

GA notes that event X currently must be forwarded across this link if/when seen.

A1 sends X. GA receives it. Because GA hasn't seen X before, X is forwarded across the link to GB, followed by an “Identify Consumers of X” message.

The rest of this proceeds like case 1.

3.2.4 Case 4: Node A1 comes up, then event Y is sent

The gateways are up, but don't know about A1 or Y.

A1 comes up, gets a NID alias assigned, sends “AMD” and “Initialization Complete”.

A1 sends “Producer of Y Identified”. GA forwards that to GB.

GA notes that event Y currently must be forwarded across this link if seen.

A1 sends X. GA receives it. Because GA hasn't seen Y before, Y is forwarded across the link to GB, followed by an “Identify Consumers of Y” message.

No “Consumer of Y Identified” message is received back, so after a short timeout GA marks it's tables to not forward Y. (If a not later comes up that consumes Y, a sequence similar to Case 2 occurs.)

3.3 Node Implementation hints

Buffering issues, particularly on CAN, have to be carefully considered. All nodes have to be able to keep up with PCER messages that can arrive about every millisecond (125000 bps / 120 bits per message)

- Don't do long linear searches to match an incoming Event ID to internal structures.
- Instead, consider just decoding the Event ID and setting a “process as available” bit, and then doing further work outside the CAN receive loop.

There is no requirement that events be processed in any particular order. Multiple PCER messages with the same Event ID may result in multiple actions inside a consumer, or may not, depending on the details of the consumer. There's a whole range of ways that events could be handled. A consumer might always handle them in the order received, and with the inter-event time intervals as received, down to the microsecond. Or it might do them in-order on a time-available basis, and generally be able to do them in 50 milliseconds. Or it might do them in the order that lets it get done fastest. Or whatever. Similar discussion goes for repeated events: Does the hardware have to do something twice? That depends. In some cases, it's not even clear what it means. Specifying this is the node manufacturers job, because they have uses in mind, and they make nodes to meet those uses. OpenLCB just arranges to deliver events for them their processing. Node manufacturers should certainly specify the performance of their nodes. More knowledge is good, but the standard doesn't compel anything because it's hard to write a testable requirement. The range of possible behaviors is so wide. Similar discussion goes for repeated events: Does the hardware have to do something twice? That depends. In some cases, it's not even clear what it means. Specifying this is the node manufacturers job, because they have uses in mind, and they make nodes to meet those uses. OpenLCB just arranges to deliver events for them their processing.

The Standard doesn't make any statements about delivery performance because it's specific to the link-types, arrangement of OpenLCB nodes & links, etc that make up a specific OpenLCB network. In general, OpenLCB is going to provide sub-millisecond, millisecond, or perhaps even 10's of millisecond timing quality, for example. Nor can it guarantee absolute order of events. If Node A and Node B emit events at the same time on different segments, there's no guarantee of when node C will receive them, nor in what order, nor that Node D will receive it at the same time & in the same order as Node C.

3.4 Well known events

There are a small number of cases where a globally-allocated and reserved Event ID will simplify operation. These “well-known Event ID numbers” can be used to e.g. advertise that a node can provide a specific capability, or to tell locomotive control hardware to stop all trains instantly, etc.

For these to be useful, they not only have to be unique (so there are no collisions that accidentally trigger reactions to them), but they must also be well-known. All of these are assigned with the 01.00.00.00.00.00 or 01.01.00.00.00.00 reserved IDs in their upper six bytes to ensure uniqueness and simplify recognition. The OpenLCB group maintains a central list of the individual assigned Event IDs.[7]

The Event IDs that start 01.00.00.00.00.00 are the automatically-routed events, a subset of the well-known events.

Except for the automatically-routed events, nodes producing or consuming well-known events must mention them when identifying the event IDs they produce and consume. Gateways may filter on these, but are not required to. (For ease of implementation, a gateway may just pass all events with the common values of the top 6 bytes).

3.5 History section

For monitoring purposes, it was proposed that a PCER message carry a sequence number which increments each time the associated P/C Event ID is sent. It is not at all clear how to do this across nodes, or even across Producers within a single node, as there may be more than one thing that can cause the same P/C Event ID to be sent by a single board;. We decided this would cause more problems than it solved, and omitted it.

There is not room in a CAN frame for both a destination NID and a EID. This protocol has therefore been constructed so that any message carrying an EID is globally addressed.

[7] See http://www.openlcb.org/trunk/specs/EventIdAllocations.pdf for specific definitions

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