

CANopen FD devices identification via New Layer Setting Services (LSS)

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Since the CAN in Automation (CiA) has published the CiA 1301 – CANopen FD in September 2017, one CiA technical group discusses how CANopen Layer Setting Services (LSS) should be adapted to CANopen FD.

LSS Fastscan service (CiA 305) used in the CANopen for identifying unconfigured LSS slaves is complex and requires up to 128 messages exchanged. Benefited from the larger payload of the CANopen FD, the full 128-bit LSS address can be sent in one request of the new service – LSS switch state selective FD service. This new service is totally different to Fastscan and will be specified in the CiA 1305 document, which is currently under development.

This article introduces the operating principles of the new service, the service and protocol specification, and the operation sequences, as how to identify LSS slaves if LSS addresses are known or unknown.

I. Introduction

CANopen devices require a node-ID in the value range from 1 to 127 for unique addressing for many CANopen services. The Layer Setting Services (LSS) defined in the CiA 305 document offer the possibility to assign the node-ID and bit rate dynamically over the CANopen network. The LSS is used for CANopen devices, which do not have a hardware interface (e.g. DIP-switches, RS-232) or for applications requiring a high level of plug-and-play support. Since the CAN in Automation (CiA) has published the CiA 1301 – CANopen FD application layer and communication profile in September 2017, the CiA technical group “SIG LSS FD” of the “IG CANopen FD” discusses how CANopen Layer Setting Services (LSS) should be adapted to CANopen FD.

When it comes to node-ID assignment, a basic requirement for participating devices is the availability of the 1018h Identity object with all 4 sub-indexes of 32 bit each: vendor-ID, product code, revision number and serial number. Together these make a unique 128-bit value that is called LSS address. CANopen (FD) devices can be identified by the LSS address.

LSS distinguishes between an LSS master (typically residing in the host controller) and the LSS slaves. In a CANopen network the LSS Fastscan service is used for identifying the unconfigured LSS slaves. LSS Fastscan service is complex and requires up to 128 messages exchanged. By means of the new service for CANopen FD – LSS switch state selective FD service the complete LSS address can be identified automatically with exchange of only maximum 33 messages. This new service replaces the LSS switch state selective service in CiA 305 and will be specified in the CiA 1305 document. Benefited from the larger payload of the CANopen FD the full 128-bit LSS address can be sent in one request.

II. How to adapt the LSS fastscan service for CANopen FD

A. If the LSS master knows the entire LSS address

If the LSS master knows the entire LSS address, the node-ID assignment is simple. In general, the LSS master asks: “Is there anybody here with this 128-bit LSS address?” On CANopen, this question is fragmented into four CAN frames; in CANopen FD the request goes into a single

frame. The LSS slave with a matching LSS address replies that it is available. Then this LSS slave is selected and is the only one accepting LSS master configuration commands; all others ignore the commands, as they have not been selected.

B. If the LSS master does not know the LSS address

Over the last years, there have been several solutions to this question: how to proceed as the LSS master, if the LSS addresses of the connected devices are not known.

Past approaches to this challenge were variations of a binary or bit-by-bit search. The LSS master would ask questions like “Is there anybody here whose 128-bit LSS address is in the range from X to Y?” or “Is this particular bit of your LSS address set or not?” All LSS slaves that want to answer “yes” to such a question reply with a single “ping” message. It is CAN frame with a fixed CAN-ID and length zero. If multiple devices transmit the frame at the same time, then there are no errors on the bus, as these frames can literally be transmitted in parallel by multiple devices at the exact same time.

On the bottom line, such a method requires the LSS master to typically send 128 requests narrowing the requests down to finally have an exact 128-bit LSS address selected. Even with a challenging timeout for each request of 30 ms this takes about 4 s per device to execute.

C. New LSS method now used for CANopen FD

As CAN FD is not backward compatible to CAN, LSS for CANopen FD would also not need to be backward compatible. This allows us to completely re-think if other better solutions would make sense.

A new method now used divides the 128-bit LSS address into 32 nibbles of each 4 bit, which are numbered from 0 to 31. The numbering is from the most significant bit (nibble number 0) to the lowest significant bit (nibble number 31). With each LSS master request, devices verify if their own

LSS address matches the request and if it does, they respond with one of the 16 response messages with the information containing the value of the requested nibble. The complete LSS address can be identified with exchange of only maximum 32 messages. This service is called “LSS switch state selective FD service” and will be specified in the CiA 1305 document: CANopen FD Layer setting service (LSS) and protocols.

III. The new service “LSS Switch State Selective FD”

A. General

The LSS switch state selective FD service allows the LSS master to select LSS slaves based on their LSS address or portions thereof, and to switch LSS slaves into LSS configuration state. Selected LSS slaves respond with the switch state selective FD response containing information about the part of their own LSS address.

All unconfigured nodes will handle switch state selective FD requests from the LSS master. All other LSS slaves will ignore the switch state selective FD requests.

B. Parameters of the LSS switch state selective FD service

- LSS master timeout (tim)
This value indicates the time in ms, in which the LSS slave transmits the response
- Nibble number (nibno)
Actual nibble number to be checked, sent in the request by the LSS master
- Portion LSS address (portion)
Portion or all of the LSS address that is already determined
- Value of the nibble
Value of the requested nibble of the selected LSS slave
- Complete
Confirmation that the complete LSS address is selected

The parameter portion LSS address may contain one portion of or all the 128-bit LSS address and is sent by the LSS master.

The relationship of nibble numbers and the portion LSS address is shown in Figure 1. The LSS address is divided into an array (0 to 31) of 4-bit values. The parameter nibble number indicates the actual nibble to be checked and is sent in the request by the LSS master. It checks that whether all previous nibbles (from nibble 0 to the nibble before the actual nibble) of one LSS slave's LSS address match the portion LSS address sent by the LSS master.

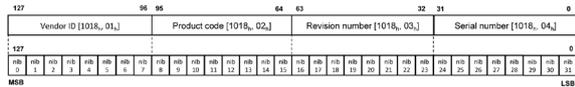


Figure 1: Relationship of nibble numbers and portion LSS address

C. Example for an LSS master request with nibble number 3

In the example of Figure 2 the LSS master sends a request to check the value of nibble number 3; the portion LSS address is the value from nibble 0 to nibble 2. In the request by the LSS master the parameter nibno = 3_h and portion = 006_h as shown in Fig. 3. The LSS master uses the CAN data frame format FBFF (FD Base Frame Format, 11-bit identifier, maximum 64 byte data) with the fixed CAN-ID 7E5_h.

If the value of nibble 0 to nibble 2 of the LSS slave matches the value of the portion LSS address of the LSS master, then the LSS slave transmits an LSS identify response containing the value of its nibble 3. The CAN-ID of the response is calculated as the rules as follows. If the nibno is in the range of 00_h to 1F_h (00_d to 31_d), the CAN-ID of the LSS slave's response is calculated as the formula:

$$\text{CAN-ID} = 7D0_h + \text{value of the nibble} \quad (1)$$

In the example the requested nibble is nibble 3, so the value of nibble 3 is D_h. From this the CAN-ID of the LSS slave's response is 7D0_h + D_h = 7DD_h.

The LSS master processes the response and packs the value of the nibble into the next request. In Fig. 3 the LSS master sends the second request with nibno = 4_h and portion = 006D_h. The LSS slave handles the request as above described.

Portion LSS address from the LSS master request "switch state selective FD service":

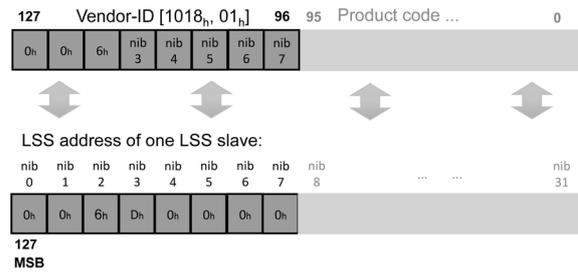


Figure 2: Example of an LSS master request with nibble number 3

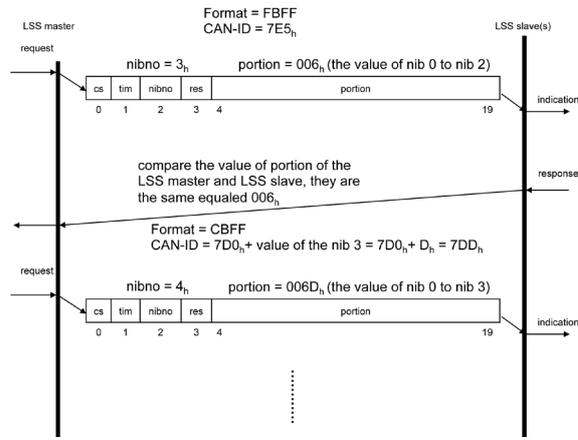


Figure 3: Messages for an LSS master request with nibble number 3

D. LSS slave handling

Figure 4 illustrates the LSS slave's view of the LSS switch state selective FD service handling. After receiving any request of the LSS switch state selective FD service, LSS slave checks at first, if they can answer it within the LSS master timeout. LSS slaves that do not know how fast they are, use a timeout value of 100 ms. The default value of the LSS master timeout is manufacturer-specific.

An LSS slave determines whether the own LSS address matches the portion LSS address requested from the LSS master, which is already described in the example for an LSS master request with nibble number 3. Because the data type of the value of the nibble is UNSIGNED4, the value range is 00_h to 0F_h. According to Eq. (1), the 16 CAN-IDs from 7D0_h to 7DF_h are used to provide the value of the requested nibble.

When the nibble number in the LSS master request reaches the value of 32_d , which is the final request. Actually there is no nibble with the number 32_d , this value indicates only that the entire own LSS address matches the LSS address given in the LSS master request. The LSS slave sends now the final response with the fixed CAN-ID $7E4_h$, and switches itself to the LSS configuration state.

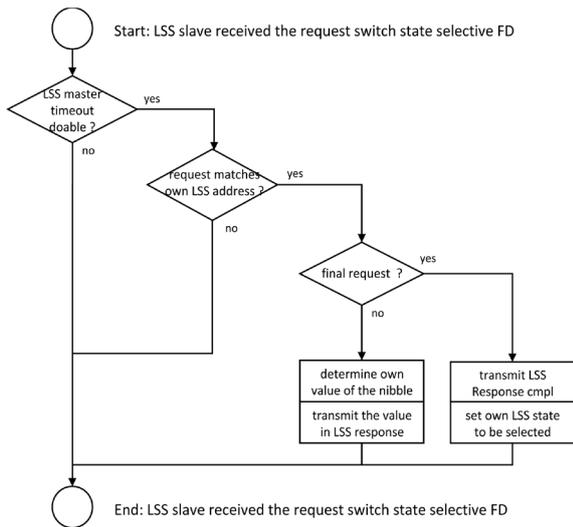


Figure 4: LSS slave's view of a scan cycle

E. LSS master handling

If the LSS master knows the complete LSS address of an LSS slave on the network, a single request is sufficient to select one LSS slave. For the request it is to set that the nibble number equals 32_d , the LSS master timeout equals the timeout supported by the LSS slave, and the portion LSS address equals the known LSS address of the LSS slave. The selected LSS slave replies with the CAN-ID $7E4_h$.

If there are LSS slaves on the network whose LSS addresses are completely unknown, the LSS master initiates an LSS scan cycle by initializing the service switch state selective FD. To scan the LSS slaves whose LSS addresses are completely unknown, the first LSS master request is transmitted with nibble number 0. All unconfigured LSS slaves send a response. The LSS master continuously executes the scan process as illustrated in Figure 5. While waiting for the timeout for the last transmitted request to expire, the LSS master collects all responses of LSS slaves. When timeout is expired, the LSS master

verifies whether any response is available. If one or multiple responses are available, the LSS master processes the feedback value and transmit the next LSS master request. Once the nibble number reaches 32_d and the final response is received, the scan cycle is completed and a single LSS slave is selected.

Figure 6 illustrates the sub-process “process received LSS responses” used in Figure 5. This sub-process executes until the LSS master timeout is reached. The first response received is buffered in the LSS master for later processing. All further responses received are ignored. With the reception of any LSS response, the LSS master checks that whether the LSS master timeout is smaller than 5 ms. If yes, it will be extended to 5 ms.

This ensures that the LSS master timeout is extended if many LSS responses are produced.

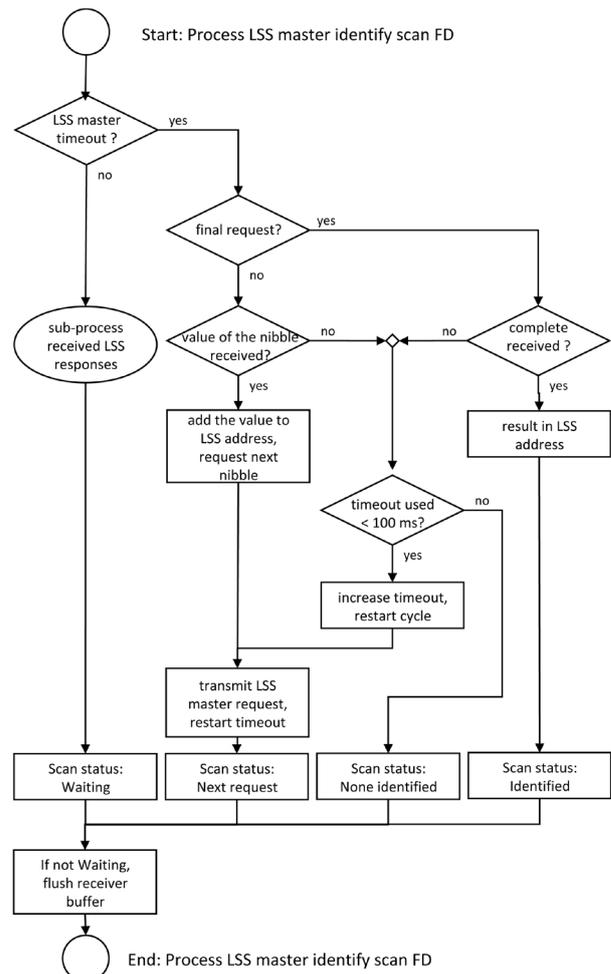


Figure 5: LSS master's view of a scan cycle

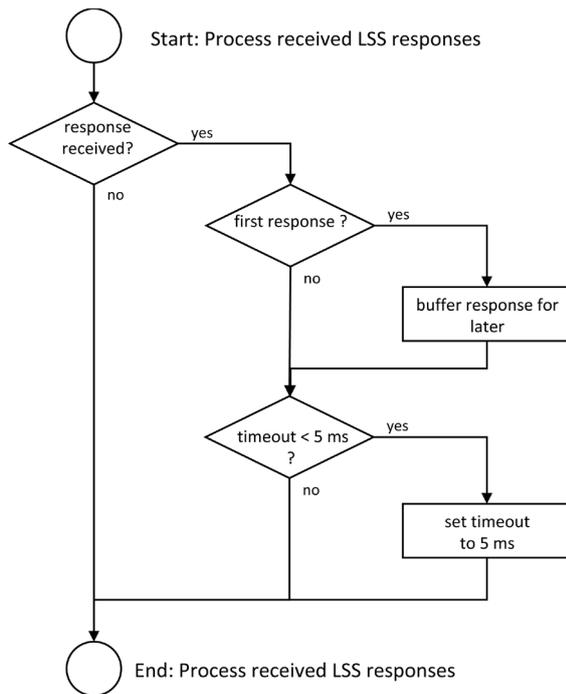


Figure 6: LSS master's view of a scan cycle

IV. Operation sequences

A. identify an LSS slave if the LSS address is known

In case there are several LSS slaves operated in the same CANopen FD network, the LSS master is enabled to address one specific LSS slave by means of the LSS switch state selective FD service. The LSS switch state selective FD service triggers the addressed LSS slave to transit into LSS configuration state so that the LSS master is able to assign the CANopen FD network-ID and node-ID.

- The LSS master requests the LSS switch state selective FD service. The transmitted LSS address shall be equal to the identity object (object 1018_h) of the related LSS slave. Wait for confirmation from LSS slave.
- The LSS slave switches itself into LSS configuration state
- The LSS master requests the configure network-ID and node-ID protocol. Wait for confirmation from LSS slave.

B. Identify an LSS slave if the LSS address is not entirely known or is unknown

In order to scan for unconfigured LSS slaves, whose LSS addresses are not

entirely known or completely unknown, the same operation sequences of “identify an LSS slave if the LSS address is known” are used with the changing of the first step:

- If LSS address is not entirely known (e.g. vendor-ID is known), the LSS master requests the LSS switch state selective FD service. The transmitted LSS address is set to the vendor-ID of the identity object (object 1018_h sub-index 01_h) of the related LSS slave. The nibble number is set to 8_d. The service runs automatically until a single LSS slave sends the final response.
- If LSS address is completely unknown, the LSS master initiates the LSS switch state selective FD service. The transmitted LSS address and the nibble number is set to zero. The service runs automatically until a single LSS slave sends the final response.

In general, the new service LSS switch state selective FD makes the operation sequences of identifying LSS slave simpler and more flexible.

V. Summary and outlook

Since LSS services may be ignored or not served, the response of a confirmed LSS service may never arrive. To resolve this situation, after a certain amount of time, a LSS master generates locally a timeout indication. A timeout is not a confirmation of the LSS service. A timeout indicates that the service has not completed yet. Timeout values are considered to be implementation-specific. However, it is recommended that a LSS master implementation provides facilities to adjust these timeout values.

First test implementations have shown, that if both LSS slave and LSS master are capable of a real-time behavior below 10 ms (the LSS slave replies to the LSS master requests in less than 10 ms) the detection of an unconfigured device and assigning it a node-ID can be completed within less than 350 ms. This is a significant improvement in comparison to the previous Fastcan mechanism that took about 1.4 s to complete using a 10 ms timeout.

The LSS switch state selective FD service will be specified in the CiA 1305 document CANopen FD Layer setting service (LSS) and protocols, which is currently under development.

The CiA 1305 document is not backward compatible to the CiA 305 document, while CAN FD is not backward compatible to CAN.

The LSS switch state selective FD mechanism can also be used on other CAN FD based systems using other higher layer protocols.

References

- [1] CiA 301 version 4.2.0, CANopen application layer and communication profile
- [2] CiA 1301 version 1.0.0, CANopen FD application layer and communication profile
- [3] CiA 305 version 3.0.0, CANopen layer setting services (LSS) and protocols

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