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Clarification and Implementation Guideline for Isochronous Connection Management of IEC 61883-1

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Abstract:
This document includes clarifications of IEC 61883-1 connection management procedures (CMP) and guidelines for setting several fields defined in CMP.

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CMP (connection management procedures).
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Editor, 1394 Trade Association
Regency Plaza Suite 350
2350 Mission College Blvd.
Santa Clara, Calif. 95054, USA

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# Table of contents

1. Overview .................................................................................................................... 7  
   1.1 Purpose.................................................................................................................... 7  
   1.2 Scope...................................................................................................................... 7  

2. References .................................................................................................................. 8  

3. Definitions ................................................................................................................. 9  
   3.1 Conformance levels ......................................................................................................... 9  
   3.2 Glossary of terms .......................................................................................................... 9  
   3.3 Acronyms and abbreviations ................................................................................................. 10  

4. Clarification of Isochronous data flow management ........................................................... 11  
   4.1 Plug states ................................................................................................................ ......................... 11  
      4.1.1 Setting On-line bit ...................................................................................................... ............11  
   4.2 OUTPUT_MASTER_PLUG register .......................................................................................11  
      4.2.1 Broadcast channel for establishing or overlaying broadcast connection ..................11  
      4.2.2 Overlaying broadcast connection ...........................................................................................11  
   4.3 OUTPUT_PLUG_CONTROL register definition ..............................................................12  
      4.3.1 Changing payload field and bandwidth value under connected state .....................12  
      4.3.2 Payload field after power-on initialization .................................................................12  
      4.3.3 Guideline for overhead_ID field setting .................................................................................12  
   4.4 Plug control register modification rules ........................................................................... ........15  
   4.5 Command reset .............................................................................................................. ...................16  

5. Connection management procedures ............................................................................. 17  
   5.1 Managing connections after a bus reset ........................................................................ 17  
      5.1.1 Owner of a connection .................................................................................................17  
      5.1.2 Restoring connections after a bus reset .............................................................................17  
      5.1.3 Restoring connections after consecutive bus resets ......................................................17
List of figures

Figure 4.1 – isochronous Time slices required to send an isochronous packet..............................................13
Figure 5.1 – Time chart of PCR activities (restoration succeeded) .................................................................18
Figure 5.2 – Time chart of PCR activities (restoration failed)............................................................................18
Figure 5.3 – Time chart of PCR activities (in the case of following bus reset).................................................19
Figure 5.4 – Time chart of recommended PCR activities (in the case of following bus reset).......................19
List of tables

Table 4.1 – Guideline to pseudo-optimal encoding of overhead_ID field and bandwidth for Cycle_Start_Packet_Time (CSPT) ...........................................................................................................................................15
The following table shows the change history for this specification.

**Version 1.0 (date)**

Original version.
1. Overview

1.1 Purpose

This document provides an informative guideline for implementation of isochronous connection management defined in IEC 61883-1 [R2]. It also provides clarifications of some points in isochronous connection management of IEC 61883-1. Therefore, the purpose of this document is to provide an efficient connectability and interoperability between digital audio/video devices which support IEC 61883-1 specification.

1.2 Scope

This document describes implementation guideline for isochronous connection management of IEC 61883-1, which is setting payload and overhead_ID fields in oPCR. Also this document describes clarifications for ambiguous points in isochronous connection management of IEC 61883-1, which are restoring connection after a bus reset and definitions of PCR.
2. References

The following standards contain provisions, which through reference in this document, constitute provisions of this standard. All the standards listed are normative references. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.


[R5] AV/C Connection and Compatibility Management Specification 1.0, TA document number 1999031
3. Definitions

3.1 Conformance levels

3.1.1 expected: A key word used to describe the behavior of the hardware or software in the design models assumed by this Specification. Other hardware and software design models may also be implemented.

3.1.2 may: A key word that indicates flexibility of choice with no implied preference.

3.1.3 shall: A key word indicating a mandatory requirement. Designers are required to implement all such mandatory requirements.

3.1.4 should: A key word indicating flexibility of choice with a strongly preferred alternative. Equivalent to the phrase is recommended.

3.1.5 reserved fields: A set of bits within a data structure that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall zero these fields. Future revisions of this specification, however, may define their usage.

3.1.6 reserved values: A set of values for a field that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall not generate these values for the field. Future revisions of this specification, however, may define their usage.

NOTE — The IEEE is investigating whether the “may, shall, should” and possibly “expected” terms will be formally defined by IEEE. If and when this occurs, draft editors should obtain their conformance definitions from the latest IEEE style document.

3.2 Glossary of terms

3.2.1 byte: Eight bits of data, used as a synonym for octet.

3.2.2 isochronous: A term that indicates the essential characteristic of a time-scale or signal, such that the time intervals between consecutive instances either have the same duration or durations that are integral multiples of the shortest duration. In the context of serial bus, "isochronous" is taken to mean a bounded worst-case latency for the transmission of data; physical and logical constraints that introduce jitter preclude the exact definition of "isochronous."

3.2.3 point-to-point connection: Defined by IEC 61883-1, a point-to-point connection is a type of agreement between two devices such that the transmission of an isochronous stream from one device to the other shall be terminated only by the initiating device.

3.2.4 broadcast connection: Defined by IEC 61883-1, a broadcast connection is where one device transmits on an isochronous channel and where other devices "listen" to that channel.

3.2.5 PCR: Plug Control Register, as defined by IEC 61883, Digital Interface for Consumer Electronic Audio/Video Equipment.

3.2.6 iPCR: Input plug PCR, as defined by IEC 61883.

3.2.7 oPCR: Output plug PCR, as defined by IEC 61883.
3.3 Acronyms and abbreviations

AV/C  Audio Video control
IEEE  The Institute of Electrical and Electronics Engineers, Inc.
CMP   Connection management procedures
IRM   Isochronous resource manager
4. Clarification of Isochronous data flow management

This chapter provides a clarification and guideline for isochronous data flow management described in chapter 7 of IEC 61883-1 [R2]. The device that conforms to IEC 61883-1 specification should refer to the contents described in this chapter.

4.1 Plug states

4.1.1 Setting On-line bit

According to IEC 61883-1, section 7.4, only a plug that is on-line is capable of transmitting or receiving an isochronous data flow. Therefore, when a device can not input or output data through a plug, the on-line bit of the plug shall be set to zero. For example, in case that a device is in power standby mode or a FIFO for link layer hardware is occupied for receiving data, then isochronous transmission function in link layer can not output data and its oPCR becomes off-line. Even so, a device can maintain its oPCR as always on-line except for power standby mode and transmit at least empty packets, because sending empty packets may not need FIFO. Refer to IEC 61883-1, section 7.7 and 7.8 also.

4.2 OUTPUT_MASTER_PLUG register

4.2.1 Broadcast channel for establishing or overlaying broadcast connection

In IEC 61883-1, section 7.5, there is a formula that describes the relationship between the broadcast channel base field in the oMPR and output channel numbers to be set on oPCRs when establishing broadcast-out connection. However, there is a case, that a source device establishes a broadcast-out connection to a channel other than the one chosen by the formula.

If there is a point-to-point connection on an oPCR and a channel other than the one assigned in the broadcast channel base, a broadcast-out connection can be overlaid on the same channel. It is device dependent that whether the device actually overlays the broadcast-out connection or not. If there is no point-to-point connection on the channel, the broadcast-out connection can only be established on the channel chosen by the formula.

4.2.2 Overlaying broadcast connection

A broadcast-out or a broadcast-in connection can be overlaid on a PCR where a point-to-point connection already exists. In this case, the isochronous channel which is connected to the PCR shall stay. Overlaying a broadcast-out or broadcast-in connection is only permitted to an application on the device where the PCR is located (see IEC 61883-1 Figure 15).

However, it is also possible that a remote device make the device perform overlaying a broadcast-out or broadcast-in connection by using higher layer command.
4.3 OUTPUT_PLUG_CONTROL register definition

4.3.1 Changing payload field and bandwidth value under connected state

The bit rate of an isochronous data stream may be changed while the output plug is under connected state. For example, while watching a broadcast content with STB, the bit rate may be changed if the user switches channels (e.g. from channel 33-1 to 33-2 in US DTV). Also, while watching a recorded content with DVC, the bit rate may be changed when the recorded content changes (e.g. from HD content to SD one).

In these examples, one solution for setting payload field in the oPCR is to set the maximum value expected during connected state, and to leave it fixed. However, there may be some devices that want to reflect the change of bit rate into payload field encoding and bandwidth allocation. This strategy is more desirable from the viewpoint of the efficiency of network bandwidth management. When there is a need for changing the payload field, the source device shall take the responsibility of updating the payload field and allocating / deallocating the variation of bandwidth accordingly.

IEC 61883-1 specification does not require that the controller that establishes the point-to-point connection should manage the payload field. So a notification of the change to the controller is not.

When a source device wants to update the payload field under connected state, it does not need to break the current connection and to establish a new one with new bandwidth. It issues a lock request to the BANDWIDTH_AVAILABLE register of the IRM to allocate/deallocate the variation of bandwidth, and after successful completion, it updates the payload field.

There has been some consensus on this issue as follows:

1) When a connection is established, the bandwidth to be allocated shall be computed based on the value of the oPCR at that time.

2) When there is a need for changing the payload field, the source device shall take the responsibility of updating the field and allocating / deallocating the variation of bandwidth accordingly.

3) When a connection is broken and the related output plug becomes unconnected state, the bandwidth to be deallocated shall be computed based on the value of the oPCR just before the oPCR becomes unconnected state. The node that removes the last connection is responsible for deallocating the resources. The node that needs to deallocate the resources may be different from the node that has allocated the resources. Therefore the deallocating node must look into the oPCR (payload, overhead_ID) to calculate how much bandwidth has to be deallocated.

4.3.2 Payload field after power-on initialization

According to IEC 61883-1 specification, initial value of payload field should be set to zero. Then, it should be set appropriately after initialization as soon as possible. Therefore, there may be a controller that wants to establish connection before the payload field is not properly set. In order to alleviate this case, it is recommended that a controller does not establish a connection while the oPCR is off-line state.

4.3.3 Guideline for overhead_ID field setting

The overhead_ID field in an oPCR specifies the bandwidth to be allocated in addition to that for payload, and serves to cope with delays caused by IEEE 1394 bus parameters [R1]. This field is critical to efficient bandwidth management of the network.
The isochronous packet flowing in the IEEE 1394 line can be modeled as follows:

Figure 4.1 – isochronous Time slices required to send an isochronous packet

In Figure 4-1, the total time to send an isochronous packet is divided by several components, and each component time can be obtained as follows.

1. **phy_delay (= one_hop_delay) ≈ 144 [ns]**  
   (IEEE 1394-1995[R1], Annex E.1)

2. **cable_delay (= one_line_delay) ≤ 5.05 [nsec/m] * 4.5 [m]**
   = 22.725 [nsec]  
   (IEEE 1394-1995, Table 4-29)

3. **Dtx (= one_way_propagation_delay) = N * cable_delay + (N-1) * phy_delay**
   = N * 22.725 + (N-1) * 144 [nsec]
   = N * 166.725 - 144 [nsec]

4. **iso_gap = 50 [nsec]**
   (IEEE 1394-1995, Table 4-33)

5. **arbitration decision time ≡ phy_delay**
   (difference is negligible compared with the total overhead_time)

6. **data_prefix ≤ 1630 [nsec]**
   (MAX_BUS_HOLD in IEEE 1394-1995, Table 4-32)

7. **data_end ≤ 260 [nsec]**
   (DATA_END_TIME in IEEE 1394-1995, Table 4-32)

8. **speed ≤ 120 [nsec]**
   (SPEED_SIGNAL_LENGTH in IEEE 1394-1995, Table 4-32)

9. **Overhead_Time = iso_gap + Dtx + arbitration decision time + Dtx + max (data_prefix, speed) + data_end +Dtx**

Finally, we can get the following inequality.

1 The speed signaling is performed within the date prefix. For worst case, speed_signal_length is not used because data_prefix_time is longer than speed_signal_length.
Overhead_Time $\leq 1652 + N \times 500.175$ [nsec]

From the inequality above, it is concluded that Overhead_Time is upper-bounded by the value of the Max_hops of the network. Therefore, a device that wants to use optimal Overhead_Time should compute the Max_hops and the Overhead_Time if it has sufficient computing power. If the device cannot compute Max_hops but can know the value of gap_count, then it should check the value of gap_count and get the value of Max_hops from Table C-2 of IEEE Std 1394a-2000[R4]. If this value is set as the maximum value, then it is assumed that there is no such a device that can calculate the Max_hops in local bus. In this case, the Max_hops can be roughly estimated as the Root_ID value, which is the upper bound of the Max_hops. In table 4-1, the relations among Max_hops, gap_count and overhead_ID values are shown. If simpler implementation is required, then a device always set Max_hops value as 16, the worst-case value, for safety.

Note that the above rule may not be applied to IEEE Std 1394a-2000 compliant bus. It is required to modify the above rule considering the new arbitration scheme of IEEE Std 1394a-2000 in near future. If all the devices in a bus are 1394a compliant, then some nodes may send ping-packet to measure the real maximum round-trip delay and set the overhead_ID field correspondingly. Refer to IEEE Std 1394a-2000 specification for more detail information.

In Figure 4.1, a transmission of a cycle start packet, denoted as CSP, is illustrated for convenience. Although the time required for this transmission is reserved out of the initial value for the bw_remaining in the BANDWIDTH_AVAILABLE register, the following informatively describes the calculation of the time.

$$\text{arb\_delay} = \text{gap\_count} \times 4 / \text{BASE\_RATE} \quad \text{(IEEE1394-1995, Annex E.1.1)}$$

$$\text{Cycle\_Start\_Packet} = 160 \text{[bit]} / \text{PHY\_SPEED} \text{[bit/sec]}$$

$$\text{Cycle\_Start\_Packet\_Time} = \text{arb\_delay} + \max (\text{data\_prefix}, \text{speed}) + \text{Cycle\_Start\_Packet} + \text{data\_end} + \text{Dtx}$$

$$\leq \text{gap\_count} \times 4 / \text{BASE\_RATE} + 1630 + 1630 + 260 + \text{Dtx}$$

$$= \text{gap\_count} \times 40 + 1630 + 1630 + 260 + \text{Dtx}$$

$$= \text{gap\_count} \times 40 + 3520 + (N \times 166.725 - 144) \text{[nsec]}$$

Finally, we can obtain the following inequality.

$$\text{Cycle\_Start\_Packet\_Time} \leq \text{gap\_count} \times 40 + N \times 166.725 + 3376 \text{[nsec]}$$

Required bandwidth for Cycle\_Start\_Packet\_Time calculated by this inequality is shown in table 4-1.
Table 4.1 – Guideline to pseudo-optimal encoding of overhead_ID field and bandwidth for Cycle_Start_Packet_Time (CSPT)

<table>
<thead>
<tr>
<th>Max_hops</th>
<th>Gap_count</th>
<th>Overhead_ID</th>
<th>Bandwidth for CSPT (BWU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0100₂</td>
<td>184</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>0101₂</td>
<td>197</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>0101₂</td>
<td>207</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>0110₂</td>
<td>219</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>0111₂</td>
<td>233</td>
</tr>
<tr>
<td>6</td>
<td>16</td>
<td>1000₂</td>
<td>247</td>
</tr>
<tr>
<td>7</td>
<td>18</td>
<td>1000₂</td>
<td>259</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>1001₂</td>
<td>273</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>1010₂</td>
<td>299</td>
</tr>
<tr>
<td>10</td>
<td>26</td>
<td>1011₂</td>
<td>314</td>
</tr>
<tr>
<td>11</td>
<td>29</td>
<td>1011₂</td>
<td>328</td>
</tr>
<tr>
<td>12</td>
<td>32</td>
<td>1100₂</td>
<td>342</td>
</tr>
<tr>
<td>13</td>
<td>35</td>
<td>1101₂</td>
<td>354</td>
</tr>
<tr>
<td>14</td>
<td>37</td>
<td>1110₂</td>
<td>354</td>
</tr>
<tr>
<td>15</td>
<td>40</td>
<td>1111₂</td>
<td>368</td>
</tr>
<tr>
<td>16</td>
<td>43</td>
<td>1111₂</td>
<td>382</td>
</tr>
<tr>
<td>17</td>
<td>46</td>
<td>0000₂</td>
<td>396</td>
</tr>
<tr>
<td>18</td>
<td>48</td>
<td>0000₂</td>
<td>408</td>
</tr>
<tr>
<td>19</td>
<td>51</td>
<td>0000₂</td>
<td>422</td>
</tr>
<tr>
<td>20</td>
<td>54</td>
<td>0000₂</td>
<td>436</td>
</tr>
<tr>
<td>21</td>
<td>57</td>
<td>0000₂</td>
<td>451</td>
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<tr>
<td>22</td>
<td>59</td>
<td>0000₂</td>
<td>463</td>
</tr>
<tr>
<td>23</td>
<td>62</td>
<td>0000₂</td>
<td>477</td>
</tr>
</tbody>
</table>

4.4 Plug control register modification rules

The lock transaction to a PCR shall follow the PCR modification rule of IEC 61883-1. An erroneous modification of a PCR may yield unexpected results. Therefore, the device that requests to modify a PCR should always check whether the lock transaction obeys the PCR modification rule, and has a responsibility for the results.
4.5 Command reset

In IEEE Std 1394a-2000, IEEE Standard for a High Performance Serial Bus--Amendment 1[R4], section 10.19 Command reset effects, the rule for command reset is described as follows.

"A write to the RESET_START register (command reset) shall have no effects upon any of the Serial Bus-dependent registers defined either in this document or in clause 8.3.2.3 of IEEE Std 1394-1995."

The sentence above means that Serial Bus-dependent registers shall not be changed in the case of command reset.

In IEEE Std 1394a-2000[R4], section 10.23 Unit registers, Table 10-11 "Serial Bus-dependent registers in initial units space" indicates that Serial Bus-dependent registers includes oMPR, oPCR, iMPR and iPCR.

However, according to Figure 10, 11,12, and 13 of IEC 61883-1[R2] these registers shall be changed in the case of command reset. For example, in the Figure 12 - oPCR format of IEC 61883-1, the figure of the "Bus reset and command reset values "indicates that broadcast connection counter, p-to-p connection counter and overhead ID fields in an oPCR are reset to zero at command reset.

As a result, a controller should not expect IEC 61883-1 compliant devices to keep the value in their oPCR unchanged at a command reset. In addition to that, IEC 61883-1 compliant devices may reset the value in its BANDWIDTH_AVAILABLE register or CHANNELS_AVAILABLE register at command reset. Therefore, controllers are encouraged not to use command reset to IEC 61883-1 compliant devices.
5. Connection management procedures

This chapter provides clarification for CMP in chapter 8 of IEC 61883-1. A device conforming to IEC 61883-1 specification is also expected to comply with the contents described in this chapter.

5.1 Managing connections after a bus reset

5.1.1 Owner of a connection

IEC 61883-1 specification does not explicitly define an owner of a connection. Usually, an owner is interpreted as the application that sets up the connection. Among the owners of connections that are set up at a plug, the owner that firstly establishes a connection to the plug allocates the isochronous resources as defined in the IEEE 1394-1995 and the owner that lastly breaks the connection to the plug deallocates the isochronous resources. In this sense, the isochronous resources allocated on a plug are shared among the owners of connections.

5.1.2 Restoring connections after a bus reset

According to IEC 61883-1 specification, when a bus reset occurs all procedures to restore the previous connections shall be executed within isoch_resource_delay (1.0 second for a single bus reset). However, there can be a situation that a controller disappears after a bus reset. For example, suppose that a destination device (ex. DVCR2) has been recording an output of a source device (ex. STB) using a connection established by a controller that is neither a source device nor a destination device. If the controller disappears with a bus reset, it may cause suspension of recording. Therefore, it may be better that either the source or the destination device establishes a connection.

One possible solution to achieve this is that the INPUT SELECT command defined in the AV/C Connection and Compatibility Management (CCM) Specification 1.0 [R5] is employed. By using this command, a connection can always be established by a destination device.

Consider more complex situations to understand the process for a restoration of connection more clearly. Suppose that node A establishes a connection as a destination to an oPCR of node B as a source and that node C and node D overlays connections on it as destinations. After that, node A breaks the first connection and a bus reset occurs. In this case, when the bus reset occurs, the point-to-point connection counter in the oPCR of node B becomes zero according to section 8.5.1 and Figure 12 of IEC 61883-1 specification. And node C and node D try to restore the connections according to the procedure in Figure 26 of IEC 61883-1 specification. Therefore, one node will succeed in allocating the channel that was used before the bus reset and try to allocate bandwidth. Meanwhile, the other node will fail to allocate the channel and should wait until the connection counter in the oPCR becomes nonzero or isoch_resource_delay expires. Node A does not try to reallocate the isochronous resources in this case. As a conclusion, an owner that has broken a connection shall not try to restore bus resources after a bus reset even if it has allocated them. Although it is beyond the scope of IEEE 1394-1995 that another node deallocates the isochronous resources on behalf of the node which allocated the isochronous resources, IEC 61883-1 defines how another node deallocates the isochronous resources or reallocates them after a bus reset.

5.1.3 Restoring connections after consecutive bus resets

The rules for transmitting isochronous data after a bus reset are described in the section 7.10 of IEC 61883-1 as follows.
a) All AV devices that had connected input and output plugs prior to the bus reset shall continue to respectively receive and transmit the isochronous data flow immediately after the bus reset according to the values in the plug control registers immediately before the bus reset.

b) AV devices that had connected input and output plugs prior to the bus reset shall behave according to the values in the corresponding plug control registers after isoch_resource_delay (equal to 1.0 s) following the bus reset.

The rule for restoring connections after a bus reset is described in section 8.5 of IEC 61883-1 as follows.

All procedures to restore the connections that existed in a plug immediately before the bus reset shall be executed before isoch_resource_delay following the bus reset to prevent that the isochronous data flows being stopped (see 7.10). In these procedures, the channel and data_rate used before the bus reset for the connection shall be used.

The purpose of these rules is to help the isochronous data stream to keep on flowing after a bus reset.

![Diagram](image)

**Figure 5.1 – Time chart of PCR activities (restoration succeeded)**

*If a bus reset occurs again before the connections have restored, the isochronous data flows are stopped because the status of the PCRs immediately before the following bus reset is unconnected according to the rule a). The following bus reset means that it occurs within 1 second since the previous bus reset in this*
situation. Some of the current device stops the isochronous data flows after the following bus reset by obeying the rule a) strictly.

In addition to that, according to the rule in 8.5 of 61883-1, the connection before the first bus reset is not restored because the status of the PCRs immediately before the following bus reset is unconnected.

![Figure 5.3 – Time chart of PCR activities (in the case of following bus reset)](image1)

However, in this case above, considering original purpose, the isochronous data flows is recommended to be kept after the following bus reset according to the values in the corresponding PCRs before the first bus reset.

![Figure 5.4 – Time chart of recommended PCR activities (in the case of following bus reset)](image2)

Conclusion:

As a note of the rule a) in section 7.10 of IEC 61883-1,

In the case that a bus reset occurs again before the isoch_resource_delay expires, the devices are recommended to continue to receive and transmit the isochronous data flow immediately after the following bus reset according to the values in the PCRs immediately before the first bus reset.

As a note of section 8.5 of IEC 61883-1,

In the case that a bus reset occurs again before the isoch_resource_delay expires, all procedures to restore the connections that existed in a plug immediately before the first bus reset are recommended to be executed. Then, the channel and data_rate that have been used before the first bus reset for the connection have to be used.