



## Specification

### Z-Wave Long Range Network Layer Test Specification

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## 1 ABBREVIATIONS

Abbreviation	Explanation
AL	Always Listening
FL	Frequently Listening
NL	Non-Listening
API	Application Programming Interface
GUI	Graphical User Interface
DSK	Device Specific Key
NWI HomeID	Network Wide Inclusion HomeID – This HomeID based on the devices S2 DSK and is constructed in the same approach for Z-Wave and Z-Wave Long Range

## 2 INTRODUCTION

### 2.1 Purpose

The purpose of this document is to provide a set of tests that verifying compliance with the Network layer of the Z-Wave Long Range protocol.

### 2.2 Audience and prerequisites

Developers and testers of the Z-Wave Long Range protocol.

## 3 NETWORK-LAYER TEST CASE DESCRIPTIONS

### 3.1 General Assumptions

This test specification assumes that the PHY and MAC layers are functional and comply to the Z-Wave Long Range PHY/MAC specification [1] and has been verified with the test cases found in the Z-Wave Long Range PHY and MAC test specifications. [2] [3].

All components are defined by the Z-Wave and Z-Wave Long Range Network Layer Specification [4] and that document is the sole reference for this test specification.

### 3.2 Command Frames – Z-Wave Long Range Protocol Command Class – No Operation Command

All frames commanding the Z-Wave Long Range network function and maintenance functionalities are constructed in a standard way.

The No Operation (NOP) Command is used to test the availability of a node in a network.

#### 3.2.1 Prerequisites

- 1 x Z-Wave Long Range Capable Sniffer.
- 1 x Z-Wave LR Capable Controller.
- 1 x Z-Wave LR End Node.
- 1 x Z-Wave LR FL End Node.
- 1 x Z-Wave LR AL End Node.

#### 3.2.2 Test Setup

1. The DSK of the End Node is entered into the Controllers Provisioning List.
2. The End Node is in direct range of the Controller and is powered up.
3. Include the End Node to the Controller's network using SmartStart.
4. Send a singlecast to the End Node from the Controller with Payload = 0x0400 (NOP).
5. The Controller is set into Learn Mode Exclude.
6. The End Node enters Learn mode and is excluded from the Controllers Network.
7. Redo the Whole Test for the FL and AL End Node to go through all Pass Criteria.

#### 3.2.3 Test Result

3. The End Node is Successfully included to the Controllers Network using SmartStart.
4. A No Operation Frame is sent from the Controller to the End Node.
  - a. Observe that the End node answers with a Mac Layer acknowledgement frame, notifying the Controller that the End Node is functional.
6. The End Node is Excluded from the Controllers Network.

- a. The Controller Sends a NOP frame to the End Node to verify that the device has been excluded from the network.
  - b. The End Node is excluded from the Network and does therefore not send an Acknowledgement.
7. The FL and AL End Node will create the same overall test results as the End Node.

#### 3.2.4 Pass Criteria

1. The singlecast command is constructed as described by figure 6.3 (LR-NWK:000F.1).
2. The singlecast command has no additional encryption and has no additional payload from upper layers (LR-NWK:000B.1).
3. All Command classes from 0x00 – 0x1F are NWK command classes, so it's ID is within that interval (LR-NWK:000C.1).
4. This command **shall** be sent using singlecast addressing and **shall not** be sent using broadcast addressing – This can be verified using the Z-Wave Long Range Sniffer (LR-NWK:0010.1).
5. This Command **may** be used to verifying if an excluded node is still part of the network. This Command may also be used on application level e.g. checking if a node is still operational (LR-NWK:000F.1).
6. The NOP frame is answered by the End Node regardless of the type of End Node. It has no payload (LR-NWK:0011.1).
7. The End Node shall not do anything other than sending a MAC Layer acknowledgement notifying the Controller that the End Node is functional (LR-NWK:0012.1).
8. It is used as a probing tool and it can be seen both in the inclusion process and in the exclusion process (LR-NWK:0011.1).

#### 3.2.5 Fail Criteria

1. Any of the passing criteria is not met.
2. Variation outside of the allowed parameters in the NOP frame causes successful results when they should not be.

### 3.3 Command Frames – Z-Wave Long Range Protocol Command Class – Node Information Frame Command

All frames commanding the Z-Wave Long Range network function and maintenance functionalities are constructed in a standard way. This will not be mentioned for further test cases and it is expected to be true for all test cases part of this document.

This Command Class is used for Setup and Maintenance of Networks. The Node Information Frame command is used to advertise the capabilities of the sending node.

### 3.3.1 Prerequisites

- 1 x Z-Wave Long Range Capable Sniffer.
- 1 x Z-Wave LR capable Controller.
- 1 x Z-Wave LR End Node.
- 1 x Z-Wave LR FL End Node.
- 1 x Z-Wave LR AL End Node
- 1 x Z-Wave LR NL End Node

*Here it is assumed that the Controller has an API making it capable of sending a NIF or using a Frame Generator to send a Request Node Info Command to the Controller.*

### 3.3.2 Test Setup

1. The DSK of the End Node is entered into the Controllers Provisioning List.
2. The End Node is in direct range of the Controller and is powered up.
3. Include the End Node to the Controller's network using SmartStart.
4. Send Request Node Info from the Controller to the End Node.
5. The End Node sends a Node Information Frame to the Controller.
6. Make the Controller send out its own Node Information Frame using API or GUI.
7. Redo the Whole Test for the FL, AL and NL End Nodes to go through all Pass Criteria.

### 3.3.3 Test Result

3. End Node is included successfully to the network using SmartStart.
4. A Send a Request Node Info is sent from the Controller to the End Node.
5. The End Node's NIF is broadcasted.
6. The Controller's NIF is broadcasted.
7. The FL, AL and NL End Nodes will create the same overall test results as the End Node. Here it should be noted that for the NL End Node shall be woken up for it to be able to answer the Request Node Info frame.

### 3.3.4 Pass Criteria

1. The singlecast commands are constructed as described by figure 6.2 (LR-NWK:000A.1).
2. The singlecast commands have no additional encryption and have no additional payload from upper layers (LR-NWK:000B.1).
3. All Command classes from 0x00 – 0x1F are NWK command classes, so it's ID is within that interval (LR-NWK:000C.1).
4. Z-Wave Long Range Protocol Command Class shall be supported by all nodes (LR-NWK:000D.1).
5. The Node Information Frame Command is formatted as per Figure 6.4 (LR-NWK:0013.1):
  - a. Supported Speed (Max Baud Rate) field consists of 3 bits and should hold at least one of the values from Table 6.3 – Here it is expected that all reserved fields are set to zero (LR-NWK 0088.1).
  - b. Listening Bit advertises if the node Listens or Not. AL nodes shall set this field to 1 (NWK:006C.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).
  - c. Listening bit is set to 0 by NL and FL nodes (NWK:006D.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).

- d. The Controller bit determines if the emitting node is a Controller by setting it to 1, or if it's not by setting it to 0. This test has used only End Nodes so they should be set to 0 (NWK:0070.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).
  - e. The Sensor 1000ms bit should be set to 0, if the End Node is not a Z-Wave Long Range FLiRS device and 1 if the Device is a Z-Wave Long Range FLiRS device. (NWK:0077.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).
  - f. Command Class Bytes list the Supported Command Classes. It shall not be longer than 35 bytes. The Command Classes are in the range 0x21... 0xFFFF. Command Classes in the Range 0x00 ... 0x20 are not advertised (LR-NWK:0016.1, LR-NWK:0017.1, LR-NWK:0018.1).
6. For the End Node, when it sends its NIF: Its format matches the one described in the Criteria 5.a – 5.f. And the Data of the NIF shall be forwarded to the upper protocol layer of the nodes within range (LR-NWK:0019.1).
  7. When the Controller sends its NIF, its format is mostly the same as 5.a – 5.f but for the following differences:
    - l. The Controller bit is set to 1 and the Node Information Frame includes a Basic Device Type field (NWK:0070.1, NWK:0071.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).

### 3.3.5 Fail Criteria

1. The singlecast commands are NOT constructed as described by figure 6.2 (LR-NWK:000A.1).
2. The singlecast commands have additional encryption or have additional payload from upper layers (LR-NWK:000B.1).
3. The command's class ID of inclusion frames are higher than 0x1F (LR-NWK:000C.1).
4. The device does not support Z-Wave Long Range Protocol Command Class (LR-NWK:000D.1).
5. The Node Information Frame is not formatted as per Figure 6.4 (LR-NWK:0013.1):
  - a. Supported Speed (Max Baud Rate) field is either more or less than of 3 bits or does not hold any value from Table 6.3 (LR-NWK 0088.1), which is not reserved – The reserved fields are not set to zero.
  - b. The End Node sets its Listening Bit to 0 if it's an AL node (NWK:006C.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).
  - m. The End Node sets its Listening Bit to 1 if it's either an FL or NL node (NWK:006D.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).
  - c. The Controller bit is set to 0 for the Controller or 1 for End Nodes (NWK:0070.1, NWK:0072.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).
  - d. The Sensor 1000ms bit is set to 0, for a Z-Wave Long Range FLiRS device or if the bit is set to 0 for a non-Z-Wave Long Range FLiRS device. (NWK:0077.1) – See (LR-NWK:0014.1) for reference (Same field as for Z-Wave).
  - e. Command class bytes are more than 35 bytes. Or Their values are outside the range 0x21... 0xFFFF. Or it advertises Command Classes in the Range 0x00 ... 0x20 (LR-NWK:0016.1, LR-NWK:0017.1, LR-NWK:0018.1).
6. When the Controller sends its NIF, its format met any of the failing conditions 5.a – 5.e.
7. Any of the passing criteria is not met.
8. Variation outside of the allowed parameters causes successful results when they should not be.

### 3.4 Command Frames – Z-Wave Long Range Protocol Command Class – Request Node Information Frame Command

This command is used to request a node to return a Node information Frame Command.

*For future Test Cases it might be specified that a node is included using SmartStart, it is assumed that the DSK of the node being included is already included into the Controller Provisioning List and the node is in direct range of the Controller.*

#### 3.4.1 Prerequisites

1 x Z-Wave Long Range Capable Sniffer.

1 x Z-Wave LR Capable Controller.

1 x Z-Wave LR End Node.

*Here it is assumed that the End Node has an API making it capable of sending a Request Node Info Frame or using a Frame Generator to send a Request Node Info Command to the Controller.*

#### 3.4.2 Test Setup

1. The DSK of the End Node is entered into the Controllers Provisioning List.
2. The End Node is in direct range of the Controller and is powered up.
3. Include the End Node to the Controller's network using SmartStart.
4. Send Request Node Information Frame to End Node.
5. Send Request Node Information Frame to End Node as multicast.
6. Send Request Node Information Frame to the Controller as a singlecast from the End Node.
7. Send Request Node Information Frame to the Controller as a multicast from the End Node.

#### 3.4.3 Test Result

3. End Node is included successfully to the network using SmartStart.
4. The End Node answers with a Node Information Frame as a singlecast.
5. The End Node does not answer the request that was sent as a multicast.
6. The Controller answers the request that was sent as a singlecast.
7. The Controller does not answer the request that was sent as a multicast.

#### 3.4.4 Pass Criteria

1. The singlecast command is constructed as described by figure 6.2 (LR-NWK:000A.1).
2. The singlecast command has no additional encryption and has no additional payload from upper layers (LR-NWK:000B.1).
3. All Command classes from 0x00 – 0x1F are NWK command classes, so it's ID is within that interval (LR-NWK:000C.1).
4. The Request Node Information Frame Command is formatted as per Figure 6.5 (LR-NWK:001A.1).
5. This command is only sent as a singlecast for both receiving nodes (LR-NWK:001B.1)

6. The receiving node returns a Node Information Frame Command in response to the singlecast command and ignores it when it's sent as a multicast for both receiving nodes (LR-NWK:001D.1, LR-NWK:001E.1).
7. The End Node answers the singlecast Request Node Information with a Node Information Frame that follows the same format as described in Pass Criteria 5 of the previous Test Case.
8. The Controller answers the singlecast Request Node Information with a Node Information Frame that follows the same format as described in Pass Criteria 7 in the previous Test Case.

### 3.4.5 Fail Criteria

1. The singlecast command is NOT constructed as described by figure 6.2 (LR-NWK:000A.1).
2. The singlecast command has additional encryption or has additional payload from upper layers (LR-NWK:000B.1).
3. The command's class ID is higher than 0x1F (LR-NWK:000C.1).
9. The request Node Information Frame Command does not follow the format of Figure 6.5 (LR-NWK:001A.1).
4. The command is sent as multicast by default for either receiving node (LR-NWK:001B.1)
5. Either of the receiving nodes answers to the Request Node Information Command with a Node Information Frame regardless if it was sent as singlecast or multicast (LR-NWK:001D.1 , LR-NWK:001E.1).
6. The End Node answers with a Node Information Frame that meets any of the fail conditions from the Fail Criteria 4 in the previous Test Case.
7. The Controller answers with a Node Information Frame that meets any of the fail conditions from the Fail Criteria 5 in the previous Test Case.
8. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.5 Command Frames – Z-Wave Long Range Protocol Command Class – Assign IDs Command

This command is used to assign NodeID and HomeID to the receiving node.

### 3.5.1 Prerequisites

- 1 x Z-Wave Long Range Capable Sniffer.
- 1 x Z-Wave LR Capable Controller.
- 1 x Z-Wave LR End Node.

*Here it is assumed it is possible to send the Assign ID commands when not including a node, and that the command can be send as a singlecast and a multicast. This could be done using a frame generator or a Controller with these functionalities.*

*Furthermore, when specifying removing a node or including a node using SmartStart it is expected to follow the format as described in the Functional Description in the end of this document.*

*This test case goes through several scenarios and therefore is the End Node excluded several times to accommodate this.*

### 3.5.2 Test Setup

1. Include the End Node to the Controller's network using SmartStart.

2. Send Assign ID command to End Node as a singlecast after inclusion.
3. Send Assign ID command to End Node as a multicast after inclusion.
4. Remove the End Node from the Controller's network.
5. Set Assign ID to be sent as multicast during SmartStart inclusion.
6. Remove the End Node from the Controller's network.
7. Set Assign ID to be sent as single during SmartStart inclusion.
8. Remove the End Node from the Controller's network.
9. Include the End Node to the Controller's network using SmartStart.
10. Set Assign ID to be sent as singlecast during inclusion and set the NodeID value to be greater than 0xFA0.
11. Remove the End Node from the Controller's network.
12. Include the End Node to the Controller's network using SmartStart.
13. Set Assign ID to hold a value in its NodeID field to not be 0x00.
14. Set Assign ID to hold a value in its HomeID field to not be 0x00.

### 3.5.3 Test Result

1. End Node is included successfully to the Controller's Network.
2. End Node answers the singlecast Assign ID command with an Ack frame only after the Inclusion.
3. End Node ignores the multicast Assign ID.
4. End Node is removed from the network, to make sure it's reset and ready for a new inclusion.
5. The End Node ignores the "Assign ID" command sent as Multicast during inclusion and inclusion fails.
6. End Node is removed from the network, to make sure it's reset and ready for a new inclusion.
7. The End Node is successfully included.
8. End Node is removed from the network, to make sure it's reset and ready for a new inclusion.
10. The End Node ignores the "Assign ID" command sent with NodeID set higher than 0xFA0 and inclusion fails.
11. End Node is removed from the network, to make sure it's reset and ready for a new inclusion.
12. The End Node is included Successfully to the Network.
13. The End Node does not accept the change in its NodeID and remains in the Network with the same NodeID.
14. The End Node does not accept the change in its HomeID and remains in the Network with the same NodeID and HomeID.

### 3.5.4 Pass Criteria

1. During SmartStart inclusion of the End Node and the Controller, the "Assign ID" command is sent as a singlecast and follows the format as per Figure 6.6 (LR-NWK:001F.1, LR-NWK:0023.1).
2. The NodeID field of the command is not 0x00 and between 0x100..0xFA0 . (LR-NWK:0026.1, LR-NWK:0021.1).
3. The HomeID values are not displayed in the Sniffer but are found in the frame. They match the HomeID of the Network of the Controller in both cases (LR-NWK:0022.1).
4. The End Node accept both HomeID and NodeID as they have been put in SmartStart Learn Mode and its inclusion is successful (LR-NWK:0024.1).

5. The End Node ignore the command once they have been included to the network and they are no longer in SmartStart learning mode (LR-NWK:0024.1).
6. When the nodes are removed, the NodeID is set to 0x00 and the HomeID to the NWI HomeID (LR-NWK:0072.1).
7. The End Node the ignores the command when it's issued as a multicast (NWK:0089.1).
8. The End Node ignore the Assign ID command when the NodeID field is set between 0x100 to 0xFA0 (LR-NWK:0021.1).
9. During exclusion the End Node ignore the command when the NodeID field is not set to 0x00 (LR-NWK:0026.1).
10. A receiving node shall ignore the command if it is received via broadcast addressing (LR-NWK:0025.1).
11. During exclusion the End Node ignore the command when the HomeID field is not set to 0x00 (LR-NWK:0022.1).

### 3.5.5 Fail Criteria

1. The "Assign ID" command does not comply with the specified formant nor it's sent as a singlecast by default (LR-NWK:001F.1, LR-NWK:0023.1)
2. The NodeID field is set to 0x00 during inclusion or it's not in-between 0x100 and 0xFA0 (LR-NWK:0021.1).
3. The HomeID values don't match the HomeID of the Controller's network (LR-NWK:0022.1).
4. The End Node don't accept the command regardless of being set in SmartStart learning mode (LR-NWK:0022.11).
5. The End Node change their Node ID or Home ID when receiving the "Assign ID" command after being SmartStart included even if they are not in learning mode (LR-NWK:0024.1).
6. The NodeID and HomeID are not set by default to 0x00 when removing the nodes (LR-NWK:0072.1).
7. The nodes accept the "Assign ID" command when it's issued as multicast (LR-NWK:0025.1).
8. The nodes accept values outside the interval 0x100 to 0xFA0 for NodeID when being included using SmartStart (LR-NWK:0021.1).
9. The nodes accept changing their NodeID to something other than 0x00 and remain in the same Network (NWK:0087.1).
10. The nodes accept changing their HomeID to something other than the HomeID of the Controller's Network while being excluded and retain their same NodeID (NWK:0088.1).
11. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.6 Command Frames – Z-Wave Long Range Protocol Command Class – Exclude Request Command

This command is used by a node looking to be excluded from its current network.

### 3.6.1 Prerequisites

- 1 x Z-Wave Long Range Capable Sniffer.
- 1 x Z-Wave LR Capable Controller.
- 1 x Z-Wave LR End Node.

### 3.6.2 Test Setup

1. Include the End Node to the Controller using SmartStart.
2. The Controller is put into Exclude Mode.
3. The End Node is put into Learn Mode Exclude.
4. The Exclude Request is sent to the broadcast destination (Node ID 0xFFFF) from the End Node.
5. Include the End Node to the Controller using SmartStart.
6. The End Node is put into Learn Mode Exclude.
7. The Exclude Request is sent to the broadcast destination (Node ID 0xFFFF) from the End Node.

### 3.6.3 Test Result

1. The End Node is included in direct range to the Controller using SmartStart.
2. The Controller is put into Exclude Mode.
3. The Exclude request is send from the End Node to the broadcast destination (Node ID 0xFFFF) and is received by the Controller.
4. The Controller Answers with a Exclude Request Confirmation Command sent to the End Node.
  - a. The End Node is Excluded successfully from the Controllers Network.
5. The End Node is included in direct range to the Controller using SmartStart.
7. The Exclude request is send from the End Node to the broadcast destination (Node ID 0xFFFF) and is received by the Controller.
  - a. The Controller Ignores the Exclude Request, because it's not trying to exclude, and the End Node is not excluded from the Network.

### 3.6.4 Pass Criteria

1. The format of the command follows the Figure 6.7 (LR-NWK:0027.1).
2. This command extends its fields from the Node Information Frame (LR-NWK:0029.1).
3. This command is sent as a broadcast frame and is broadcasted to direction 0xFFFF (LR-NWK:0028.1).
4. This command proceeds to exclude a node only if currently in exclusion mode, it ignores the command, otherwise (LR-NWK:002B.1, LR-NWK:002C.1).

### 3.6.5 Fail Criteria

1. Any of the passing criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

### 3.7 Command Frames – Z-Wave Long Range Protocol Command Class – SmartStart Included Node Information Command

This command is used by nodes to notify a controller that it was just powered up and is already part of a network.

#### 3.7.1 Prerequisites

- 1 x Z-Wave Long Range Capable Sniffer.
- 2 x Z-Wave LR Capable Controller.
- 1 x Z-Wave LR End Node.

#### 3.7.2 Test Setup

1. Add the DSK number of the End Node to Controller-1's Provisioning List.
2. Make sure the End Node is in direct range of the Controller and power it up.
3. Let SmartStart inclusion of the End Node finish.
4. Remove power from the End Node.
5. Add the DSK number of the End Node to Controller-2.
6. Return power to the End Node.

#### 3.7.3 Test Result

3. The End Node is included to Controller-1's network using SmartStart.
4. The End Node is powered down.
5. The Controller-2 holds the DSK of the End Node in its Provisioning List.
6. The End Node is powered up and emits a broadcast frame with the Included Node Info Command.
  - a. The Controller-2 does not attempt including the End Node.

#### 3.7.4 Pass Criteria

1. The SmartStart Included Node Information command follows the format from Figure 6.8 (LR-NWK:002D.1).
2. The "NWI HomeID" field identifies that the Node has been included to the network with that HomeID (Follows the same format as Z-Wave: NWK:0163.1).
3. The format of the bytes forming the "NWI HomeID" field is structured to match bytes 9 ... 12 of the S2 DSK. Bits 7 & 6 of the "NWI HomeID 1" field are set to 1. Bit 0 of the "NWI HomeID 4" field is set to 0 – Illustrated by Figure 4.55 (Follows the same format as Z-Wave: NWK:0164.1, NWK:0165.1, NWK:0166.1).
4. This SmartStart Include Node Information Frame is transmitted in a broadcast Frame and it's broadcasted to NodeID 0xFFFF (LR-NWK:002E.1).

#### 3.7.5 Fail Criteria

1. Any of the passing criteria is not met.

2. Variation outside of the allowed parameters causes successful results when they should not be.

### **3.8 Command Frames – Z-Wave Long Range Protocol Command Class – SmartStart Prime Command**

This command is used to notify SmartStart including controllers that a node is about to make an inclusion request.

#### **3.8.1 Prerequisites**

- 1 x Z-Wave LR Capable Sniffer.
- 1 x Z-Wave LR Capable Controller.
- 1 x Z-Wave LR AL End Node.
- 1 x Z-Wave LR FL End Node.
- 1 x Z-Wave LR NL End Node.

*All Z-Wave Long Range Network Layer constant used in this test case can be found in table 6.4 (LR-NWK:0048.1).*

#### **3.8.2 Test Setup**

1. Introduce the DSK value of the End Nodes into the Controller's Provisioning List.
2. Power up the End Nodes.

#### **3.8.3 Test Result**

1. The DSK of the End Nodes is in the Controller's Provisioning List.
2. The End Nodes each issue a SmartStart Prime Command.
  - a. AL & FL nodes wait until their wakeup period is completed and then they send SmartStart Prime Command after `nwkSmartStartInclusionRequestDuration` has passed.

#### **3.8.4 Pass Criteria**

1. The format of the SmartStart Prime Command follows the format from figure 6.9 and it extends from the Node Information Frame (LR-NWK:0030.1, LR-NWK:0031.1).
2. This command is sent in a broadcast frame, it must be addressed as a broadcast to node 0xFF. Must hold the NWIHomeID as HomeID. It is sent after `nwkSmartStartInclusionRequestDuration` has passed. Non-AL nodes may return to sleep between sending SmartStart Prime Command and SmartStart Inclusion Request Command (LR-NWK:0032.1, LR-NWK:0033.1, LR-NWK:0034.1, LR-NWK:0035.1).
3. When it's received, the Controller compares the NWIHomeID to the one obtained in the DSK keys in its Provisioning List. When finding a match, the Controller enters SmartStart Inclusion when the node issues a SmartStart Inclusion Request. IF there are more DSK matches for the received NWIHomeID, the Controller shall enter SmartStart Inclusion alternating between the DSK candidates (LR-NWK:0036.1, LR-NWK:0037.1, LR-NWK:0038.1).

### 3.8.5 Fail Criteria

1. Any of the passing criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.9 Command Frames – Z-Wave Long Range Protocol Command Class – SmartStart Inclusion Request Command

This command is used to request to initiate a SmartStart inclusion.

### 3.9.1 Prerequisites

- 1 x Z-Wave LR Capable Sniffer.
- 1 x Z-Wave LR Capable Controller.
- 1 x Z-Wave LR AL End Node.
- 1 x Z-Wave LR FL End Node.
- 1 x Z-Wave LR NL End Node.

*All Z-Wave Long Range Network Layer constant used in this test case can be found in table 6.4 and table 6.5 (LR-NWK:0048.1, LR-NWK:0049.1).*

### 3.9.2 Test Setup

1. Introduce the DSK value of the End Nodes into the Controller's Provisioning List.
2. Power up the End Nodes.

### 3.9.3 Test Result

1. The DSK of the End Nodes is in the Controller's Provisioning List.
2. The End Node each issue a SmartStart Prime Command.
  - a. AL & FL nodes wait until their wakeup period is completed and then they send SmartStart Prime Command after `nwkSmartStartInclusionRequestDuration` has passed.
  - b. After the End Nodes have issued SmartStart Prime, they issue SmartStart Inclusion Request.
  - c. When the Controller receives SmartStart Inclusion Request, it will initiate SmartStart inclusion by issuing the Assign ID Command.

### 3.9.4 Pass Criteria

1. The format of the SmartStart Inclusion Request Command follows the format from figure 6.10 and it extends from the Node Information Frame (LR-NWK:0039.1, LR-NWK:003A.1).
2. This command is sent in an inclusion broadcast frame, it must be addressed as a broadcast to node 0xFF. Must hold the NWIHomeID as HomeID. The Sending node shall listen and accept Assign IDs Command after the HomeID has been authenticated (LR-NWK:003B.1, LR-NWK:003C.1, LR-NWK:003D.1).
3. When it's received, the Controller compares the NWIHomeID to the one obtained in the DSK keys in its Provisioning List. When finding a match the Controller begins SmartStart Inclusion by

issuing AssignID and it should authenticate the HomeID by constructing the 4 bytes of NWIHomeID matching bytes 13 ... 16 of the DSK, in its bits 7 & 6 of the Auth HomeID byte 1 are set to 1 and bit 0 of Auth HomeID byte 4 is set to 0 as per Figure 3.58 (LR-NWK:003E.1).

### 3.9.5 Fail Criteria

1. Any of the passing criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.10 Command Frames – Z-Wave Long Range Protocol Command Class – Exclude Request Confirmation Command

*The Exclude Request Confirmation Command is used by a controller node to confirm to a node that it can leave the current network.*

### 3.10.1 Prerequisites

- 1 x Z-Wave LR Capable Sniffer.
- 1 x Z-Wave LR Capable Controller.
- 1 x Z-Wave LR End Node.

### 3.10.2 Test Setup

1. Introduce the DSK value of the End Node into the Controller's Provisioning List.
2. Power up the End Node.
3. The End Node is included into the Controller Network using SmartStart.
4. The Controller sends a Exclude Request Confirmation command to the End Node.
5. Exclude the End Node from the network by setting the Controller in Learn Mode Exclude followed by setting the End Node in Learn Mode and it expected network exclusion.

### 3.10.3 Test Result

1. The DSK of the End Nodes is in the Controller's Provisioning List.
3. The End Node is included into the network using SmartStart.
4. The End Node receives a Exclude Request Confirmation from the Controller and ignores the command, because it's not in Learn Mode Exclude.
5. The Controller is put into Learn Mode Exclude.
5. The End Node sends out a Exclude Request Command.
  - a. The Controller then sends a Exclude Request Confirmation Command to the End Node. The Exclude Request Confirmation with the NodeID of the End Node sending the Exclude Request Command and HomeID of the node sending the Exclude Request Command.
  - b. The Exclude Request Confirmation Command is then Acknowledged by the End Node.
  - c. The Controller sends out a No Operation Command Frame, if this is not acknowledged by the End Node. The End Node have successfully been excluded.

### 3.10.4 Pass Criteria

1. The format of the Exclude Request Confirmation Command follows the format from figure 6.11 (LR-NWK:003F.1).
2. The Exclude Request Confirmation Command is ignored, when the End Node is not in Learn Mode Exclude. (LR-NWK:0043.1)
3. The Exclude Request Confirmation Command is sent to the End Node, which have issued a Exclude Request. (LR-NWK:0040.1)
4. The controller has been instructed to exclude a node from a Z-Wave Long Range Network. (LR-NWK:0041.1)
5. After the End Node have received the Exclude Request Confirmation it shall leave its current network. (LR-NWK:0042.1)

### 3.10.5 Fail Criteria

1. Any of the passing criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.11 Command Frames – Z-Wave Long Range Protocol Command Class – Non-Secure Inclusion Step Complete Command

The Non-Secure Inclusion Step Complete Command is used by a controller node to indicate to a joining node that the non-secure part of the network inclusion is completed.

### 3.11.1 Prerequisites

1 x Z-Wave LR Capable Sniffer.

1 x Z-Wave LR Capable Controller.

1 x Z-Wave LR End Node.

*All Z-Wave Long Range Network Layer constant used in this test case can be found in table 6.4 and table 6.5 (LR-NWK:0048.1, LR-NWK:0049.1).*

### 3.11.2 Test Setup

1. Introduce the DSK value of the End Nodes into the Controller's Provisioning List.
2. Power up the End Nodes.
3. The End Node is included securely using SmartStart.

### 3.11.3 Test Result

1. The DSK of the End Nodes is in the Controller's Provisioning List.
3. The End Node is included into the network using SmartStart.
  - a. During the SmartStart Inclusion a Non-Secure Inclusion Step Complete command is sent from the Controller to the End Node to signal that the Non-Secure part of the inclusion is over. This will initiate the S2 Security Bootstrapping.

### 3.11.4 Pass Criteria

1. The format of Non-Secure Inclusion Step Complete Command follows the format from figure 6.12 (LR-NWK:0044.1).
2. The Controller shall after issuing this command initiate the S2 Bootstrapping. (LR-NWK:0045.1)
3. The End Node shall start its S2 TB1 timer upon reception of this command and its instructed that the non-secure inclusion is completed and that the S2 bootstrapping shall now take place. (LR-NWK:0046.1, LR-NWK:0047.1)

### 3.11.5 Fail Criteria

1. Any of the passing criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.12 Compliance with Z-Wave Long Range NWK Layer Constants and Attributes

Tables 6.4 and 6.5 define the Constants and Attributes the Network Layer can use for different procedures.

### 3.12.1 Prerequisites

1 x Z-Wave LR capable Sniffer.

2 x Z-Wave LR capable Controller.

1 x Z-Wave LR End Node.

*All Z-Wave Long Range Network Layer constant used in this test case can be found in table 6.4 and table 6.5 (LR-NWK:0048.1, LR-NWK:0049.1).*

### 3.12.2 Test Setup

1. The End Node is powered up.
2. After a while the DSK of the End Node is added in Controller-1's Provisioning List.
3. The End Node is included into Controller-1's network using SmartStart.
4. The End Node is then put into Learn Mode Exclude.
5. After a While Controller-1 is then also put into Learn Mode Excluded.
6. The End Node is then put into Learn Mode Exclude again and is excluded from Controller-1 network.
7. The End Node is included into Controller-2s network.
8. Controller-1 is set to Learn Mode Exclude.
9. The End Node is set into Learn Mode Exclude and excluded from the network of Controller-2 using Controller-1.

### 3.12.3 Test Result

3. During the First Inclusion using SmartStart the following durations should be checked:
  - a. The duration between the SmartStart prime Command and the SmartStart Inclusion Request Command. (Constant: nwkSmartStartInclusionRequestDuration)

- b. The duration between the SmartStart inclusion requests – this is the reason for the late insertion of the DSK. (Constant: `nwkSmartStartInclusionBackoffDuration`)
    - c. The maximum time interval between the SmartStart Inclusion Requests. (Attribute: `aNwkSmartStartMaxInclusionRequestInterval`)
    - d. After sending Assign ID Command count the number of No Operation Command. (Constant: `nwkAssignIDConfirmationRetries`)
    - e. Verify that the time between each command of the non-secure part of the network inclusion for joining nodes. (Constant: `nwkNonSecureInclusionCommandTimeout`)
  6. During the first Exclusion of the End Node the following durations should be checked.
    - a. Minimum duration in which a node shall stay in Learn Mode during Network Exclusion. (Constant: `nwkLearnModeMinDuration`)
  9. During the second Exclusion of the End Node from Controller-1, the following durations should be check:
    - a. Minimum back-off for a controller after an Exclude Request command to issue a Exclude Request Confirmation command on a foreign Network. (Constant: `nwkLRExcludeRequestForeignNetBackOff`)

#### 3.12.4 Pass Criteria

1. All values correspond to table 6.4 and 6.5 (LR-NWK:0048.1, LR-NWK:0049.1).

#### 3.12.5 Fail Criteria

1. Neither value corresponds to either table 6.4 or 6.5 (LR-NWK:0048.1, LR-NWK:0049.1).
2. Variation outside of the allowed parameters causes successful results when they should not be.

### 3.13 Functional Description – Communication between Z-Wave Long Range nodes.

Functional description of communication between Z-Wave Long Range nodes.

#### 3.13.1 Prerequisites

1 x Z-Wave LR Capable Sniffer.

1 x Z-Wave LR Capable Controller.

1 x Z-Wave LR End Node.

*All Z-Wave Long Range Network Layer constant used in this test case can be found in table 6.4 and table 6.5 (LR-NWK:0048.1, LR-NWK:0049.1).*

#### 3.13.2 Test Setup

1. The End Node is included into the Controllers Z-Wave Long Range Network using SmartStart.
2. The End Node is then powered off.
3. The Controller continuously sends a Request Node Information Frame Command for a minimum of `nwkMinTransmitAttempts`.

### 3.13.3 Test Result

1. The End Node is included into the Z-Wave Long Range Controllers Network using SmartStart.
  - a. The End Node and Controller are communicating only using direct range and operating on a Z-Wave Long Range PHY/MAC.
2. The End Node is powered off.
3. The End Node is powered off and can't reply any messages from the Controller continuously sending a Request Node Information Frame Command. After `nwkMinTransmitAttempts` the End Node is marked as a failing node on the Controller.

### 3.13.4 Pass Criteria

1. All communication between the End Node and Controller use direct range with operation on a Z-Wave Long Range PHY/MAC. (LR-NWK:004A.1)
2. The Controller node shall issue a minimum of `nwkMinTransmitAttempts` direct range frames to the End Node before concluding that the destination is failing. (LR-NWK:004B.1)

### 3.13.5 Fail Criteria

1. Any of the passing criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.14 Functional Description – Z-Wave Long Range Network Formation & Learn Mode.

Functional description of Z-Wave Long Range Network Formation and Learn Mode.

### 3.14.1 Prerequisites

1 x Z-Wave LR Capable Sniffer.

1 x Z-Wave LR Capable Controller.

1 x Z-Wave LR End Node.

*All Z-Wave Long Range Network Layer constant used in this test case can be found in table 6.4 and table 6.5 (LR-NWK:0048.1, LR-NWK:0049.1).*

### 3.14.2 Test Setup

1. Power on the Controller
2. Include the DSK of the End Node into the Controllers Provisioning List.
3. Power on the End Node.
4. The End Node is included into Controllers Network using SmartStart.
5. The Controller is put into Learn Mode Exclude.
6. The End Node is also set into Learn Mode Exclude
7. The End Node is removed from the Controllers Network.

### 3.14.3 Test Result

1. The Controller is not belonging to a Network and shall therefore start a new Z-Wave Long Range Network by assigning itself with a HomeID and the NodeID 0x01. The HomeID (aNwkRandomHomeID) shall be generated using a random number generator.
2. The End Nodes DSK is inserted into the Controllers Provisioning List.
3. The End Node is powered up and is not part of a network and shall therefore wait until it gets included into a network by a controller node. And until the End Node gets included into a network it shall assign their NWI HomeID to itself.
4. The End Node is Included to the Controller network using SmartStart.
5. The Controller enters Learn Mode Exclude for a minimum period of nwkLearnModeMinDuration.
6. The End Node also enters Learn Mode Exclude.
7. The End Node is Excluded from the Controller Network

### 3.14.4 Pass Criteria

1. The Controller starts Z-Wave Long Range Network and Assigns itself a HomeID and NodeID 0x01. The HomeID shall be generated using a random number generator. (LR-NWK:0053.1, LR-NWK:0054.1)
2. The End Node shall not start a new network and shall wait until it gets included in a network by a controller and shall assign itself with its NWI HomeID until it is included. This Controller is now the Primary Controller. (LR-NWK:0051.1, LR-NWK:0052.1)
3. The Controller enters Learn Mode Exclude only when necessary. (LR-NWK:004E.1)
4. The End Nodes enters Learn Mode Exclude for a minimum duration of nwkLearnModeMinDuration. (LR-NWK:004F.1)
5. The End Node is excluded from the Network.

### 3.14.5 Fail Criteria

1. Any of the passing criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.15 Functional Description – Z-Wave Long Range SmartStart

SmartStart allows for an automatic inclusion if the user holds the DSK number of the device.

### 3.15.1 Prerequisites

- 1 x Z-Wave LR Capable Sniffer.
- 2 x Z-Wave LR Capable Controller. (Controller-1 and Controller-2)
- 2 x Z-Wave LR End Node. (End Node-1 and End Node-2)
- 1 x End Node supporting both Z-Wave and Z-Wave Long Range. (End Node-3)

### 3.15.2 Test Setup

1. Take the DSK from End Node-1 and add it to the Provisioning List of the Controller-1.
2. Place the End Nodes in direct range of both the Controllers.
3. Power on both the End Nodes.
4. The End Node-1 is included using SmartStart into the Controller-1s' network.
5. Take the DSK from End Node-3, which support both Z-Wave and Z-Wave Long Rang and add it to the Provisioning List of the Controller-1.
6. Power up End Node-3.
7. End Node-3 is included into the Controller-1s' network using SmartStart and is Included as a Z-Wave Long Range Device.

### 3.15.3 Test Result

1. The DSK of the End Node-1 is included in Controller-1's Provisioning List.
2. The End Nodes are in direct Range of both the Controllers, where only Controller-1 have its DSK in its Provisioning List.
3. The End Node-2 is powered up and continuously send SmartStart Prime Commands and SmartStart Inclusion Requests.
3. The End Node-1 is Powered up and sends a SmartStart Prime Command, which is then Acknowledged by the Controller.
4. The End Node-1 then sends a SmartStart Inclusion Request Command and the SmartStart inclusion is initiated.
  - a. The End Node-1 is Successfully included by Controller-1 and all the messages are ignored by Controller-2.
5. The DSK of the End Node-3 is included in Controller-1's Provisioning List.
6. The End Node-3 is powered up.
  - a. After Wakeup the End Node-3 issue SmartStart Prime and SmartStart Inclusion Request both on the Z-Wave and Z-Wave Long Range channels.
7. End Node-3 is included into the Controller-1s' network using SmartStart and is Included as a Z-Wave Long Range Device.

### 3.15.4 Pass Criteria

1. SmartStart supporting nodes go into SmartStart Learn Mode right as they are powered up (LR-NWK:0055.1).
2. After powering up, node shall initiate SmartStart inclusion depending on their state (LR-NWK:0056.1)
3. A node Capable of operating both in Z-Wave and Z-Wave Long Range shall issue SmartStart Prime and SmartStart Inclusion Request both on the Z-Wave and Z-Wave Long Range channels. (LR-NWK:0056.1)
4. When a node is not part of a network, it shall issue SmartStart Prime and SmartStart Inclusion Request in intervals (LR-NWK:0058.1, LR-NWK:0059.1).
5. SmartStart Inclusion request follows Figure 6.13 (LR-NWK:005A.1).
6. Nodes requesting SmartStart Inclusion do so as per Table 4.29 (NWK:01B3.1).

7. A node already included in a network sends a single SmartStart Included node Information upon power up as per Figure 6.14 (LR-NWK:005D.1).
8. A Controller shall be Primary Controller to include nodes via SmartStart. (LR-NWK:005E.1)
9. A Controller needs the DSK of a node to include it via SmartStart (LR-NWK:005F.1).
10. A Controller including via SmartStart shall perform S2 bootstrapping (LR-NWK:0060.1).
11. Direct Smart Start inclusion follows Figure 6.15 (LR-NWK:0061.1).
12. When S2 bootstrapping fails, SmartStart Inclusion is considered failed (LR-NWK:0062.1, LR-NWK:0063.1).
13. A node that fails being included leaves the network and considers itself not included to any network and shall return to SmartStart Learn Mode (LR-NWK:0069.1, LR-NWK:006A.1).
14. A Controller that fails including a node, should consider the joining node removed from the network. It may verify by issuing NOP commands (LR-NWK:006B.1, LR-NWK:006C.1).

### 3.15.5 Fail Criteria

1. Any of the passing Criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

## 3.16 Functional Description – Z-Wave Long Range Network Exclusion

Nodes exit a Z-Wave Long Range network using direct range Network Exclusion.

### 3.16.1 Prerequisites

- 1 x Z-Wave LR Capable Sniffer.
- 1 x Z-Wave LR Capable Controller.
- 1 x Z-Wave LR End Node.

### 3.16.2 Test Setup

1. Take the DSK from the End Nodes and add it to the Provisioning List of the Controller.
2. Place the End Node in direct range of the Controller.
3. The End Node is included using SmartStart into the Controllers' network.
4. The Controller is set into Z-Wave Long Range Network Exclusion
5. The End Node is inserted into Learn Mode and Expects network Exclusion.
6. The End Node is excluded from the network.

### 3.16.3 Test Result

1. The DSK of the End Node is included in the Controller's Provisioning List.
2. The End Node is in direct Range of the controllers.
3. The End Node is Successfully included into the Controllers network using SmartStart.
4. The Control the enters Z-Wave Long Range Network Exclusion.

5. The End Node then enable Learn Mode and expects network exclusion.
6. The End Node is Exclude from the Controllers Network and assumes it NWI HomeID and NodeID 0x00.

#### 3.16.4 Pass Criteria

1. The Network Exclusion process will exclude the node from a network.
2. The Network Exclusion procedure shall be according to Figure 6.17 (LR-NWK:0070.1).
3. When starting Learn Mode Exclusion, a node shall issue an Exclude Request Command to the broadcast destination NodeID (LR-NWK:0071.1).
4. End Nodes excluded from a network shall assume the NodeID 0x00 after the exclusion and shall assume their NWI HomeID as HomeID (LR-NWK:0072.1).
5. Controller nodes excluded from a network shall start a new network (LR-NWK:0073.1).

#### 3.16.5 Fail Criteria

1. Any of the passing Criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

### 3.17 Functional Description – Z-Wave Long Range Network Exclusion from a foreign Network

Controllers instructed to remove a node shall also remove nodes from foreign networks.

#### 3.17.1 Prerequisites

1 x Z-Wave LR Capable Sniffer.  
2 x Z-Wave LR Capable Controller.  
1 x Z-Wave LR End Node.

#### 3.17.2 Test Setup

1. Take the DSK from the End Nodes and add it to the Provisioning List of Controller-1.
2. Place the End Node in direct range of both of the two Controllers.
3. The End Node is included using SmartStart into Controllers-1' network.
4. Controller-2 is set into Z-Wave Long Range Network Exclusion.
5. The End Node is inserted into Learn Mode and Expects network Exclusion.
6. The End Node is excluded from the network using a foreign network.

#### 3.17.3 Test Result

1. The DSK of the End Node is included in Controller-1's Provisioning List.
2. The End Node is in direct Range of the two Controllers.
3. The End Node is Successfully included into Controller-1s network.
4. Controller-2 then enters Z-Wave Long Range Network Exclusion.
5. The End Node then enable Learn Mode and expects network exclusion.

6. The End Node is Exclude from Controller-1s Network using a foreign network and assumes it NWI HomeID and NodeID 0x00.

#### 3.17.4 Pass Criteria

1. The Network Exclusion process will exclude the node from a foreign network and shall follow the procedure as illustrated in figure 6.18.
2. A Controller that has started a node removal shall return an Exclude Request Confirmation Command if an Exclude Request Command has been issued in another HomeID. The Exclude Request Confirmation Command if issued by the excluding controller shall be on its own HomeID (LR-NWK:0075.1, LR-NWK:0076.1).
3. A controller shall issue the Exclude Request Confirmation Command on its own HomeID. When returning an Exclude Request Confirmation Command to a node in a foreign network, an MDPU Ack shall not be requested (LR-NWK:0077.1).
4. A randomized delay in the range 0..1 second should be added by controller nodes to the nwkLRExcludeRequestForeignNetBackOff time (LR-NWK:0078.1).
5. A node in Learn Mode (exclusion) shall accept Exclude Request Confirmation Command if issued in another HomeID. (LR-NWK:0079.1)

#### 3.17.5 Fail Criteria

1. Any of the passing Criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be.

### 3.18 Functional Description – Z-Wave Long Range Dual Z-Wave and Z-Wave Long Range Networks

Controllers may create both a Z-Wave and Z-Wave Long Range network that they operate on simultaneously. In this case, they shall use the same HomeID.

#### 3.18.1 Prerequisites

- 1 x Z-Wave LR and Z-Wave Capable Sniffer.
- 1 x Z-Wave LR and Z-Wave Capable Controller.
- 2 x End Node Supporting Z-Wave and Z-Wave LR.

#### 3.18.2 Test Setup

1. Take the DSK from End Node-1 and add it to the Provisioning List of the Controller.
2. Make sure the End Nodes is in direct range of the Controller.
3. Power up both End Nodes.
4. End Node-1 is included using SmartStart to the Controller Network.
5. End Node-2 is included using Classic Inclusion to the Controller Network.

#### 3.18.3 Test Result

1. The DSK of End Node-1 is included in the Controller's Provisioning List.

2. The two End Nodes is placed in direct range of the Controller.
3. The two End Nodes are power up.
4. End Node-1 is included as a Z-Wave Long Range device using SmartStart and can communicate with the Controller.
5. End Node-2 is included using Classic Inclusion and is included as a Z-Wave device and communicate with the Controller.

#### **3.18.4 Pass Criteria**

1. The End Nodes supporting both Z-Wave and Z-Wave Long Range shall issue a SmartStart Prime and SmartStart Inclusion Request on both PHY/MAC. (LR-NWK:0086.1)
2. When the End Nodes are successfully included in a network, they shall only use the PHY/MAC they got included with. (LR-NWK:0087.1)
3. The Controller may create both a Z-Wave And Z-Wave long Range Network that they operate on simultaneously. In this case, they shall use the same HomeID. (LR-NWK:0082.1, LR-NWK:0083.1)

#### **3.18.5 Fail Criteria**

1. Any of the passing Criteria is not met.
2. Variation outside of the allowed parameters causes successful results when they should not be

## REFERENCES

- [1] Z-Wave Alliance, ZWA\_Z-Wave Long Range PHY and MAC Layer Specification\_SPE\_1x
- [2] Z-Wave Alliance, ZWA\_Z-Wave Long Range PHY Layer Test Specification\_SPE\_1x
- [3] Z-Wave Alliance, ZWA\_Z-Wave Long Range MAC Layer Test Specification\_SPE\_1x
- [4] Z-Wave Alliance, ZWA\_Z-Wave and Z-Wave Long Range Network Layer Specification\_SPE\_1x