



Z-Wave MAC Layer Test Specification

Release 5.0.0

Z-Wave Alliance

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1 Preamble

1.1 Description

Test case descriptions for the Z-Wave MAC-Layer

Reviewed by the Z-Wave Alliance Core Stack Working Group (CSWG) and approved by the Technical Committee.

1.2 Disclaimer

THIS SPECIFICATION IS BEING OFFERED WITHOUT ANY WARRANTY WHATSOEVER, AND IN PARTICULAR, ANY WARRANTY OF NON-INFRINGEMENT IS EXPRESSLY DISCLAIMED. ANY USE OF THIS SPECIFICATION SHALL BE MADE ENTIRELY AT THE IMPLEMENTER'S OWN RISK, AND NEITHER THE ALLIANCE, NOR ANY OF ITS MEMBERS OR SUBMITTERS, SHALL HAVE ANY LIABILITY WHATSOEVER TO ANY IMPLEMENTER OR THIRD PARTY FOR ANY DAMAGES OF ANY NATURE WHATSOEVER, DIRECTLY OR INDIRECTLY, ARISING FROM THE USE OF THIS SPECIFICATION.

1.3 Revision Record

Table 1.1: Revision History

Doc. Rev	Date	By	Pages Affected	Brief Description of Changes
0.7	2020/09/11	CSWG	ALL	Full MAC test plan written and reviewed
0.8	2021/03/01	CSWG	None	Revision updated to 0.8 for TC review
0.9	2021/03/30	CSWG	Frontpage	Cleanup for IPR review Added abbreviations
1.0	2021/10/29	CSWG	ALL	Inclusion of negative testing.
1.5	2021/11/16	Silicon Labs	ALL	Editorial on PHY-Layer test Cases that benefit from being part of the MAC-layer test spec
1.7	2021/12/06	CSWG	3.5	Added review comment #102, description of Rx-Tx turnaround time
1.9	2021/12/15	CSWG	Revision	Approved without comments by TC on meeting December 15, 2021. Updating to version 1.9
2.0	2022/04/21	Board		Approved for Publication
2.5	2022/10/26	CSWG	Multiple	Various typos corrections & clarifications: Test Cases: 3.2, 3.10, 3.11, 3.19, 3.27, 3.34, 3.45, 3.46, 3.47, 3.48, 3.49, 3.51, 3.52, 3.53, 3.59, 3.60
2.9	2022/11/11	CSWG	Revision	Approved without comments by CSWG and TC
3.0	2022/12/15	ZWA Board		Approved for Publication
3.5	2023/08/03	CSWG	Multiple	Various typos corrections & clarifications: Test Cases 3.18, 3.19, 3.20, 3.21, 3.26, 3.30, 3.35, 3.39, 3.41
4.5.0	2024/10/16	CSWG	all	Migrated from Word to Github
4.5.1	2025/01/02	CSWG	3.4	Start of Frame can be tested for only one region
			3.2, 3.3	Preamble must be tested for all combinations of data rate and type of frame in one region. It does not need to be tested for both controller and end device
			3.5	Turnaround time must be checked for each data rate (2ch region: for each channel configuration, 3ch region: for one channel configuration)
4.5.2	2025/02/24	CSWG	3.4	Improve SoF test to cover each frame type and each data rate.
4.5.3	2025/03/19	MK Logic	3.2, 3.3	Fixed preamble test clarifying that testing one RF region requires several RF profiles for 2-channel configurations but only one RF profile for 3-channel configurations. Fixed that payload is a NOP in all cases. Removed unnecessary associations. Typos fixed.
4.7.0	2025/03/21	CSWG	n/a	Ready for the TC review.
4.9.0	2025/05/30	TC	n/a	Approved for IPR review.
5.0	2025/08/29	ZWA Board	n/a	Approved for publication.

1.4 Abbreviations

Table 1.2: Abbreviations

Abbreviation	Explanation
ACK	Acknowledgement
AL	Always Listening
CRC	Cyclic Redundancy Check
DUT	Device Under Test
FCS	Frame Check Sequence
FL	Frequently Listening
ID	Identification
ISM	Industrial, Scientific and Medical
LBT	Listen Before Talk
LLC	Logical Link Control
LSB	Least Significant Bit
MAC	Medium Access Control
MSDU	MAC Data
MFR	MAC Footer
MHR	MAC Header
MIB	Management Information Base
MLME	MAC Layer Management Entity
MLME-SAP	MAC Layer Management Entity – Service Access Point
MPDU	MAC Protocol Data Unit
MSB	Most Significant Bit
MSDU	MAC Service Data Unit
NIF	Node Information Frame
NPDU	Network layer Protocol Data Unit
PHY	Physical layer
RF	Radio Frequency
RSSI	Receive Signal Strength Indication
RX	Receive/Receiver
TX	Transmit/Transmitter

2 INTRODUCTION

2.1 Purpose

To provide a set of tests that help verify compliance with the MAC layer of the Z-Wave technology implemented outside of the Z-Wave development R&D group and Silicon Labs.

2.2 Audience and Prerequisites

An RF sniffer hardware and analyzer software that can be tuned in on the valid frequencies for Z-Wave or a Z-Wave Zniffer module and PC Application. Z-Wave PC controller or equivalent to execute communication between the different nodes.

3 MAC-LAYER TEST CASE DESCRIPTIONS

3.1 General assumptions

The PHY layer is functional and follows the specification in ITU-T G.9959 (01/2015) and is verified by the set of tests described in the “ZWA_Z-Wave PHY Layer Test Specification_SPE” document from the Z-Wave alliance.

All components are defined in [1] and that document is the sole reference for the present Test Plan.

All **times** and **time-out periods** must be compliant with the values described in tables 8-18 & 8-19 from [1].

Inclusion in Z-Wave refers to Bootstrapping in [1] – 8.1.1.2, each device has the same HomeID and different NodeID. The controller needs to have each End node registered in its Node List with a unique NodeID.

Test Cases towards the end of the spec are the Negative Testing complement to Test Cases described earlier, they show the number and title of the Test Case they relate to for identification. These Negative Testing Test Cases, at the current time of issuing of this spec, are not mandatory.

3.2 Preamble field, 2-channel frequencies

Data frames transmitted by a Z-Wave device must be formatted as described in ITU section 7.1.3.1: With a preamble field, a Start of Frame delimiter, payload and an End of Frame delimiter. The requirements for the number of preamble bytes to transmit are stated in ITU table 7-10.

The preambles are coded according to ITU tables 7-2, 7-4, 7-5 and 7-6.

The number of preamble bytes transmitted must be tested for each combination of data rate and type of Z-Wave frame according to ITU table 7-10 for at least one 2-channel RF region from ITU table 7-1, e.g. EU or US.

3.2.1 Prerequisites

1. All Z-Wave devices are capable of transmitting Z-Wave packages correctly formatted according to ITU section 7.
2. The Z-Wave devices must be able to transmit each of the various types of Z-Wave frames described in ITU table 7-10.
3. The Z-Wave devices must be mounted on a PCB enabling a cabled RF connection between a RF measurement device and a 50 Ohms matched output of the Z-Wave device.
4. A spectrum analyzer with better or identical specifications to a Keysight CXA N9000A, 7.5GHz
5. An analog demodulator option installed on the spectrum analyzer with the capabilities of at least Keysight option “N9063A Analog Demod Measurement”.

The spectrum analyzer should be initialized to:

Table 3.1: Preamble Spectrum Analyzer settings

Spectrum analyzer parameter	Setting
f_{center}	$f_{\text{center_frequency}}$ according to ITU table 7-1
Span	200kHz
Resolution Bandwidth	1kHz
Video Bandwidth	Auto
Amplitude reference level	10dBm
Detector type	Average
Analog demodulation type	FSK
Demodulation time (time across screen)	$t_{\text{demod_time}}$
IF filter	700 kHz
Trigger option	RF burst

$$t_{\text{demod_time}} = 1/\text{BitRate} \times \#\text{Preamble Bytes} \times 8 + 1/\text{BitRate} \times 2 \times 8$$

example: $t_{\text{demod_time}}$ for Single Cast frame at data rate **R1**:

According to ITU table 7-2 **R1** = 9600 bit/s

According to ITU table 7-10, Single Cast frame at **R1** = minimum 10 preamble bytes

$$t_{\text{demod_time}} = 1/9600 \times 10 \times 8 + 1/9600 \times 2 \times 8 = 10\text{ms}$$

The sweep time of the spectrum analyzer has now been set to capture the minimum number of preambles to expect + 2 more bytes:

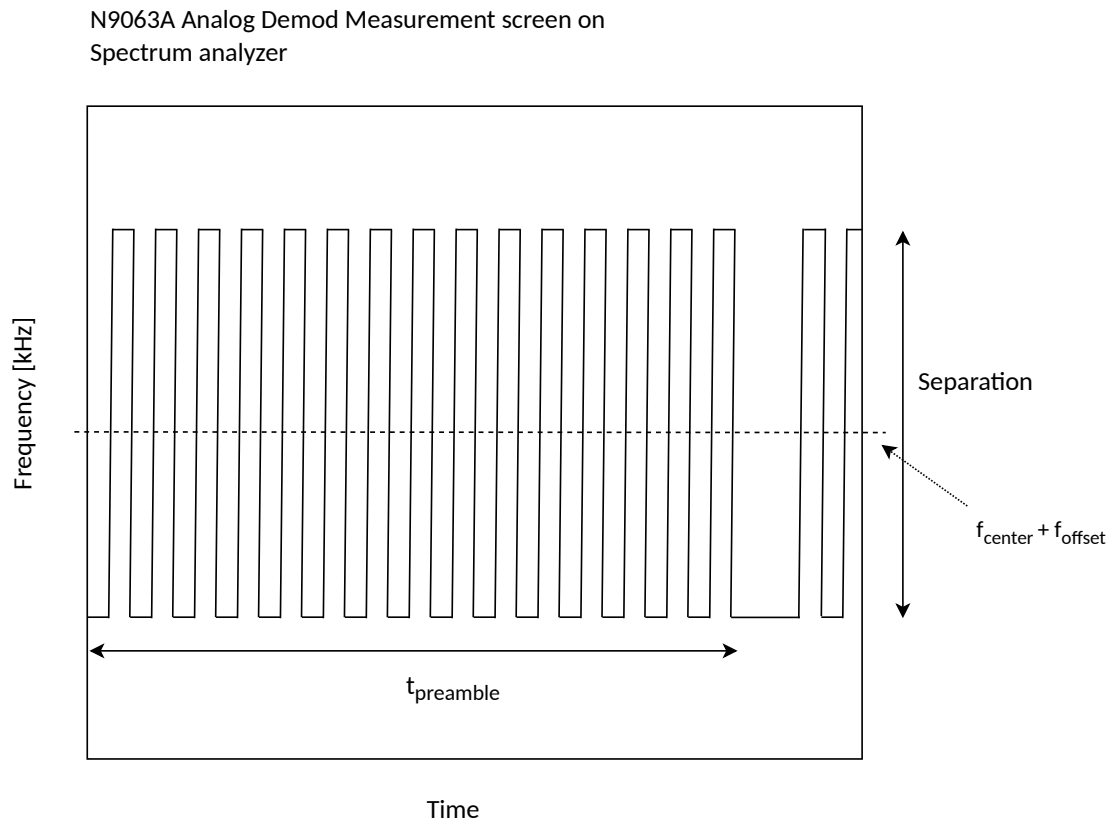


Figure 3.1: Preamble field length measurement

Within the minimum time duration of the preamble bytes to be expected to be transmitted according to ITU table 7-10 :

$$t_{\text{preamble}} = 1/\text{BitRate} \times \#\text{Preamble Bytes} \times 8$$

Nothing but alternating bits with a symbol duration of $1/\text{BitRate}$ may be observed.

6. Devices all flashed to work in 2-ch frequencies with rates as per ITU table 7-10:

- 1 x Serial API Controller
- 2 x Always Listening End Node (AL) with the ability to activate associations
- 1 x Frequently Listening End Node (FL)

3.2.2 Test Setup

1. Include Non-securely all End Nodes to the Controller's Network
2. Connect the Controller's Antenna to the Spectrum Analyzer with a coaxial cable and turn off the AL & FL End nodes.
3. From the PC Controller application, try sending frames to the End Nodes with Data Payload (MSDU) = 0x00 (NOP), as follows:
 - a. Sending a Broadcast frame.
 - b. Sending a Singlecast frame to one AL End Node.
 - c. Sending a Multicast frame to the two AL End Nodes. (Multicast in R1 is not possible.)
 - d. Sending a Singlecast frame to the FL End Node.

3.2.3 Test Result

1. All End Nodes are included to the Controller's Network.
2. The antenna of the Controller device is connected to the Spectrum Analyzer and the AL & FL End Nodes are turned off.
3. Each frame type is captured correctly in the Spectrum Analyzer:
 - a. The Broadcast frame.
 - b. The Singlecast to an AL End Node.
 - c. The Explorer Frames when PC Controller cannot reach it.
 - d. The frames attempting routing when the PC Controller cannot reach the End Node.
 - e. The Multicast Frame (multicast in R1 is not expected).
 - f. The Singlecast frame to the FL End Node
 - g. The Wake-Up Beam frames when the Controller cannot reach the FL End Node.

The measurement result is an analysis of the preamble pattern for each type of Z-Wave frame type transmitted at each data rate as stated in ITU table 7-10. If any irregularities are found within the time period t_{preamble} , the Z-Wave device has failed the test.

3.2.4 Pass Criteria

The Z-Wave device shall pass the test if:

1. The right pattern is observed (ITU Figures 7-5 & 7-6) for the preamble is transmitted (7.1.3.2).
2. The minimum amount of required preamble bits (8 alternating '0' & '1') is transmitted (7.1.3.2).

3.2.5 Fail Criteria

The Z-Wave device shall fail the test if:

1. The right pattern (ITU Figures 7-5 & 7-6) for the preamble is not transmitted.
2. The minimum amount of required preamble bits is not transmitted.

3.2.6 Exception

The number of preamble bytes can be higher than stated in ITU table 7-10.

3.3 Preamble field, 3-channel frequencies

Data frames transmitted by a Z-Wave device must be formatted as described in ITU section 7.1.3.1: With a preamble field, a Start of Frame delimiter, payload and an End of Frame delimiter. The requirements for the number of preamble bytes to transmit are stated in ITU table 7-10.

The preambles are coded according to ITU tables 7-2, 7-4, 7-5 and 7-6.

The number of preamble bytes transmitted must be tested for each type of Z-Wave frame according to ITU table 7-10 for at least 3-channel RF region from ITU table 7-1, e.g. JP or KR. Since there is only one data rate (R3), testing one RF profile is sufficient.

3.3.1 Prerequisites

1. All Z-Wave devices are capable of transmitting Z-Wave packages correctly formatted according to ITU section 7
2. The Z-Wave devices must be able to transmit each of the various types of Z-Wave frames described in ITU table 7-10.
3. The Z-Wave devices must be mounted on a PCB enabling a cabled RF connection between a RF measurement device and a 50 Ohms matched output of the Z-Wave device.
4. A spectrum analyzer with better or identical specifications to a Keysight CXA N9000A, 7.5GHz
5. An analog demodulator option installed on the spectrum analyzer with the capabilities of at least Keysight option “N9063A Analog Demod Measurement”.

The spectrum analyzer should be initialized to (same values as the previous Test Case):

Table 3.2: Preamble Spectrum Analyzer settings

Spectrum analyzer parameter	Setting
f_{center}	$f_{\text{center_frequency}}$ according to ITU table 7-1
Span	200kHz
Resolution Bandwidth	1kHz
Video Bandwidth	Auto
Amplitude reference level	10dBm
Detector type	Average
Analog demodulation type	FSK
Demodulation time (time across screen)	$t_{\text{demod_time}}$
IF filter	700 kHz
Trigger option	RF burst

$$t_{\text{demod_time}} = 1/\text{BitRate} \times \#\text{Preamble Bytes} \times 8 + 1/\text{BitRate} \times 2 \times 8$$

example: $t_{\text{demod_time}}$ for Single Cast frame at data rate **R3**:

According to ITU table 7-2 **R3** = 100,000 bit/s

According to ITU table 7-10, Single Cast frame at **R3** = minimum 10 preamble bytes

$$t_{\text{demod_time}} = 1/10000 \times 24 \times 8 + 1/10000 \times 2 \times 8 = 2.08\text{ms}$$

The sweep time of the spectrum analyzer has now been set to capture the minimum number of preambles to expect + 2 more bytes:

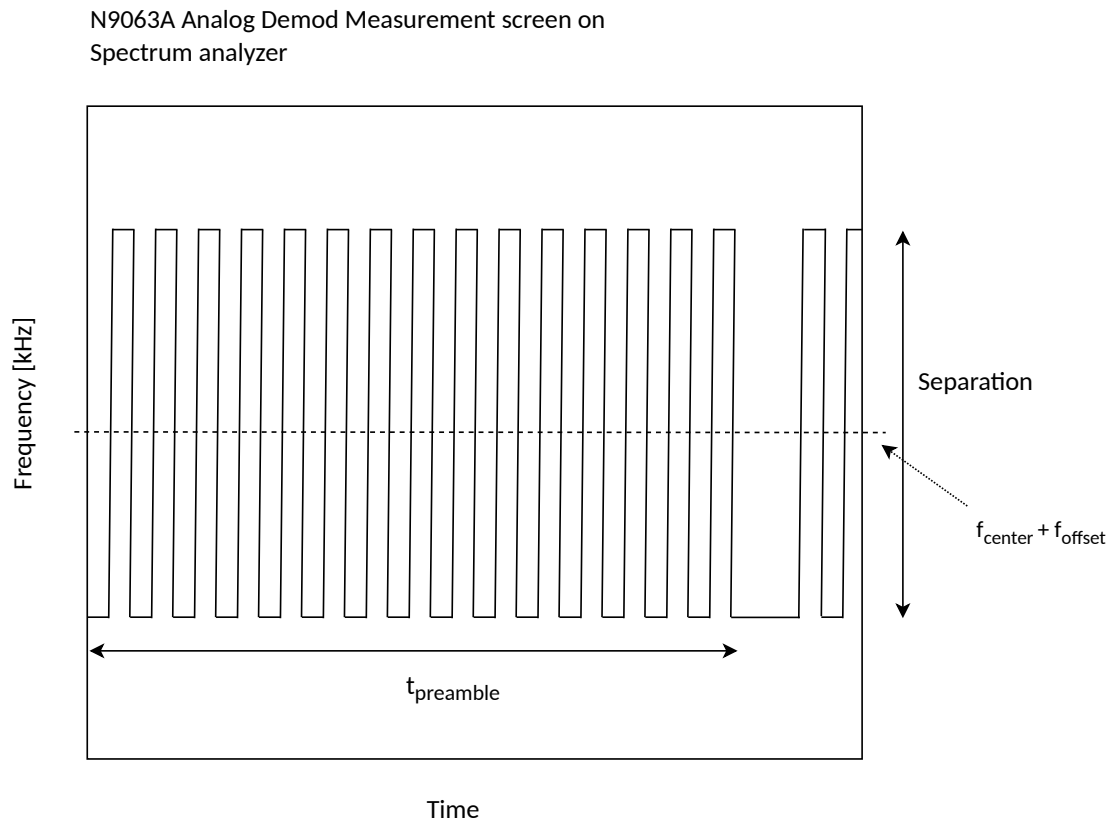


Figure 3.2: Preamble field length measurement

Within the minimum time duration of the preamble bytes to be expected to be transmitted according to ITU table 7-10 :

$$t_{\text{preamble}} = 1/\text{BitRate} \times \#\text{Preamble Bytes} \times 8$$

Nothing but alternating bits with a symbol duration of $1/\text{BitRate}$ may be observed.

6. Devices all flashed to work in 3-ch frequencies with rates as per ITU table 7-10:

- 1 x Serial API Controller
- 2 x Always Listening End Node with the ability to activate associations
- 1 x Frequently Listening End Node

3.3.2 Test Setup

1. Include all End Nodes to the Controller's Network
2. Connect the Controller's Antenna to the Spectrum Analyzer with a coaxial cable and turn off the AL & FL End nodes.
3. From the PC Controller application, try sending frames to the End Nodes with Data Payload (MSDU) = 0x00 (NOP), as follows:
 - a. Sending a Broadcast frame.
 - b. Sending a Singlecast frame to one AL End Node.
 - c. Sending a Multicast frame to the two AL End Nodes. (Multicast in R1 is not possible.)
 - d. Sending a Singlecast frame to the FL End Node.

3.3.3 Test Result

1. All End Nodes are included to the Controller's Network.
2. The antenna of the Controller device is connected to the Spectrum Analyzer and the AL & FL End Nodes are turned off.
3. Each frame type is captured correctly in the Spectrum Analyzer:
 - a. The Broadcast frame.
 - b. The Singlecast to an AL End Node.
 - c. The Explorer Frames when PC Controller cannot reach it.
 - d. The frames attempting routing when the PC Controller cannot reach the End Node.
 - e. The Multicast Frame.
 - f. The Singlecast frame to the FL End Node
 - g. The Wake Up Beam frames when the Controller cannot reach the FL End Node.

The measurement result is an analysis of the preamble pattern for each type of Z-Wave frame type transmitted at each data rate as stated in ITU table 7-10. If any irregularities are found within the time period t_{preamble} , the Z-Wave device has failed the test.

3.3.4 Pass Criteria

The Z-Wave device shall pass the test if:

1. The right pattern is observed (ITU Figure 7-6) for the preamble is transmitted (7.1.3.2).
2. The minimum amount of required preamble bits (8 alternating '0' & '1') is transmitted (7.1.3.2).

3.3.5 Fail Criteria

The Z-Wave device shall fail the test if:

1. The right pattern (ITU Figure 7-6) for the preamble is not transmitted (7.1.3.2).
2. The minimum amount of required preamble bits is not transmitted (7.1.3.2).

3.3.6 Exception

The number of preamble bytes can be higher than stated in ITU table 7-10.

3.4 Start of Frame Field

The transceiver of a Z-Wave must be able to correctly transmit and correctly receive Z-Wave start of frame information as described in ITU section 7.1.3.3. The data content of the Start of Frame field is described in ITU table 7-11. The handling of Start of Frame field in Z-Wave frames must be tested for at least one region from ITU table 7-1 using the channel configuration 2. Each frame type and each data rate from ITU table 7-10 must be tested.

3.4.1 Prerequisites

1. The following devices are flashed with the same regional frequency according to ITU table 7-1 (to cover all the available profiles):
 - 1 x Serial API Controller
 - 1 x Always Listening End Nodes (AL)
 - 1 x Frequently Listening Node (FL)
 - a. All Z-Wave devices can transmit and receive, decode, and error handle Z-Wave frames formatted according to ITU section 7.1.3. The Z-Wave devices must be able to decode and data process at transmissions rates stated in ITU table 7-2. The Z-Wave devices must be able to indicate when a frame is not correctly received, and all incoming Z-Wave frames must be answered with an acknowledgement frame.
2. A spectrum analyzer with better or identical specifications to a Keysight CXA N9000A, 7.5GHz
 - a. An analog demodulator option installed on the spectrum analyzer with the capabilities of at least Keysight option “N9063A Analog Demod Measurement”.

The spectrum analyzer should be initialized to:

Table 3.3: Preamble Spectrum Analyzer settings

Spectrum analyzer parameter	Setting
f_{center}	$f_{\text{center_frequency}}$ according to ITU table 7-1
Span	200kHz
Resolution Bandwidth	1kHz
Video Bandwidth	Auto
Amplitude reference level	10dBm
Detector type	Average
Analog demodulation type	FSK
Demodulation time (time across screen)	$t_{\text{demod_time}}$
IF filter	700 kHz
Trigger option	RF burst

Performing Measurements:

During Step 2 of the Test setup: The Z-Wave devices must be mounted on a PCB enabling a cabled RF connection between a RF measurement device and a 50 Ohms matched output of the End Node Z-Wave device as per [Figure 3.3](#). A *Power Splitter* should be used for this setup (which is sitting where the three wires meet).

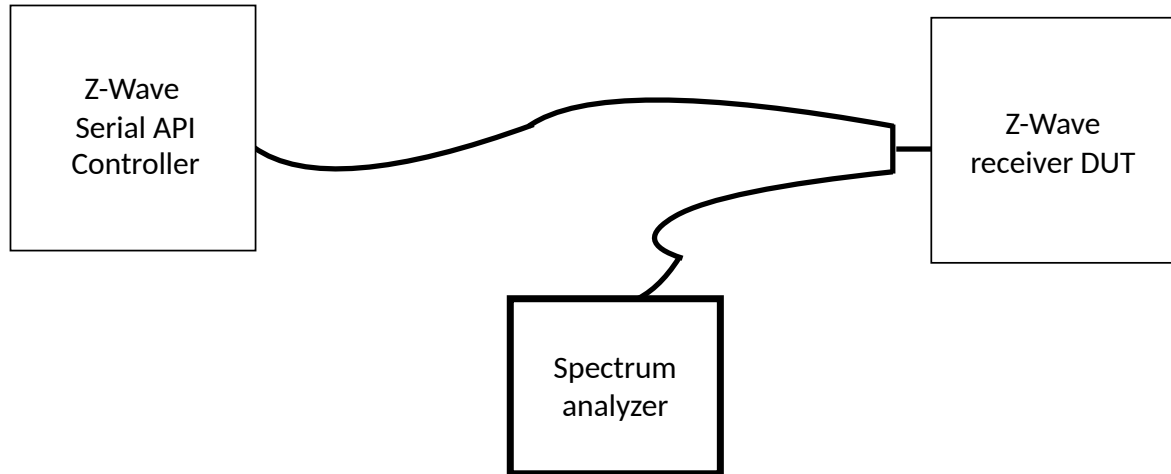


Figure 3.3: Start of frame measurement setup

The received power at the power splitter P_{DUT} , must be set to -50 dBm.

The End Node is taking the place of the DUT in the diagram.

Use the **Analogue Demodulator** option on the Spectrum Analyzer to be able to observe the SOF byte right after the Preamble field (as in the previous Test Case).

3.4.2 Test Setup

1. Include all End Nodes to the Network of the Controller.
2. Connect the AL End Node to the Controller module with a coaxial cable and the Spectrum Analyzer's probe at the End Node using a Power Splitter as in [Figure 3.3](#).
3. From the PC Controller application, send a frame with Data Payload (MSDU) = 0x00 (NOP) as Broadcast.
4. From the PC Controller application, send a frame to the AL End Node with Data Payload (MSDU) = 0x00 (NOP) as Default, and "force multicast" Enabled.
5. Disconnect the AL End Node from the Power Splitter (attached to the Controller) and connect the FL End Node instead.
6. From the PC Controller application, send a frame to the FL End Node with Data Payload (MSDU) = 0x00 (NOP) as Default (and "force multicast" Disabled).

3.4.3 Test Result

1. All End Nodes are included to the Network of the Controller.
2. The Controller is connected to the End Node with the Coax cable and the probe is measuring on the End node as in [Figure 3.3](#). The FL End Node is turned Off.
3. The Broadcast frame is captured correctly by the Spectrum Analyzer and uses the data rate R1 (9.6 kbit/s).
 - a. It shows the Start of Frame after the Preamble following the defined format as per table 7-11 on ITU-T G.9959 for the singlecast. (The broadcast frame is considered a singlecast frame with a specific destination NodeID.)
4. The first frame is captured correctly. It must be a multicast frame using data rate R3 (100 kbit/s). Follow up frames are not relevant for the test. (PC Controller app is sending singlecast frames after the multicast frame.)
 - a. The Spectrum Analyzer shows the Start of Frame after the Preamble following the defined format as per ITU table 7-11 for the multicast.
5. The Diagram of [Figure 3.3](#) now connects the Controller to the FL End Node. The AL End Node is turned Off.
6. Beam Frames are captured correctly by the Spectrum Analyzer and use the data rate R2 (40 kbit/s).
 - a. The Spectrum Analyzer shows the Start of Frame after the Preamble following the defined format as per ITU table 7-11 for the Beam frames.

3.4.4 Pass Criteria

The Z-Wave device shall pass the test if:

1. The Start of Frame field matches the description in Table 7-11 on ITU-T G.9959 (7.1.3.3).

3.4.5 Fail Criteria

The Z-Wave device shall fail the test if:

1. It does not hold a Start Of Frame field matching Table 7-11 on ITU-T G.9959 (7.1.3.3).

3.5 RX-to-TX Turnaround time

The response time of the transceiver of a Z-Wave device should not be too fast, for giving the transmitting device the chance to switch back from TX to RX, the so-called RX-to-TX turnaround time. The RX-to-TX turnaround time must be measured under the test conditions given in ITU section 7.1.2.5.9. and it should be more than $aPhyTurnaroundTimerRXTX$ (See ITU table 7-27). This must be Tested at least in EU or US (for each channel) and JP or KR (for one channel) regional frequencies.

3.5.1 Prerequisites

1. The following devices are flashed with the same regional frequency according to Table 7-1 (EU or US and JP or KR):
 - 1 x Serial API Controller
 - 1 x Always Listening End Nodes (AL)
 - a. All Z-Wave devices can transmit and receive, decode, and error handle Z-Wave frames formatted according to ITU section 7.1.3. The Z-Wave devices must be able to decode and data process at transmissions rates stated in ITU table 7-2. The Z-Wave devices must be able to indicate when a frame is not correctly received, and all incoming Z-Wave frames must be answered with an acknowledgement frame.
2. A spectrum analyzer with better or identical specifications to a Keysight CXA N9000A, 7.5GHz
 - a. An analog demodulator option installed on the spectrum analyzer with the capabilities of at least Keysight option “N9063A Analog Demod Measurement”.

The spectrum analyzer should be initialized to:

Table 3.4: Preamble Spectrum Analyzer settings

Spectrum analyzer parameter	Setting
f_{center}	$f_{\text{center_frequency}}$ according to ITU table 7-1
Span	200kHz
Resolution Bandwidth	1kHz
Video Bandwidth	Auto
Amplitude reference level	10dBm
Detector type	Average
Analog demodulation type	FSK
Demodulation time (time across screen)	$t_{\text{demod_time}}$
IF filter	700 kHz
Trigger option	RF burst

Performing Measurements:

During Step 2 of the Test setup: The Z-Wave devices must be mounted on a PCB enabling a cabled RF connection between a RF measurement device and a 50 Ohms matched output of the End Node Z-Wave device as per [Figure 3.3](#). A *Power Splitter* should be used for this setup (which is sitting where the three wires meet).

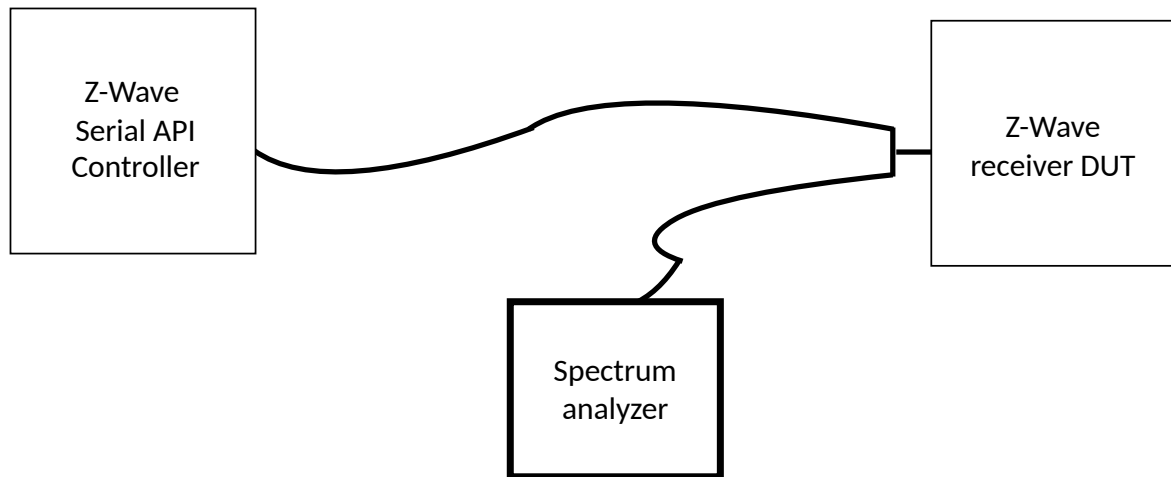


Figure 3.4: Rx-to-Tx turnaround measurement setup

The received power at the power splitter P_{DUT} , must be set to -50 dBm.

The End Node is taking the place of the DUT in the diagram.

Use the **Zero Span** mode on the Spectrum Analyzer to be able to observe the transmission from both the Controller and the End Node.

3.5.2 Test Setup

1. Include the End Node to the Network of the Controller.
2. Connect the AL End Node to the Controller module with a Coaxial cable and the Spectrum Analyzer's probe at the End Node using a Power Splitter as in [Figure 3.4](#).
3. Send a singlecast with Data Payload (MSDU) = 0x00 (NOP) from the Controller.
4. Measure the RX-to-TX turnaround time.

3.5.3 Test Result

1. The End Node is included to the Network of the Controller.
2. The Controller is connected to the End Node with the Coax cable and the probe is measuring on the End node as in [Figure 3.4](#).
3. The singlecast frame is answered with an Acknowledgement frame by the End Node.
 - a. The Spectrum Analyzer shows the type of plot as seen on [Figure 3.5](#).
4. The RX-to-TX turnaround time is measured.

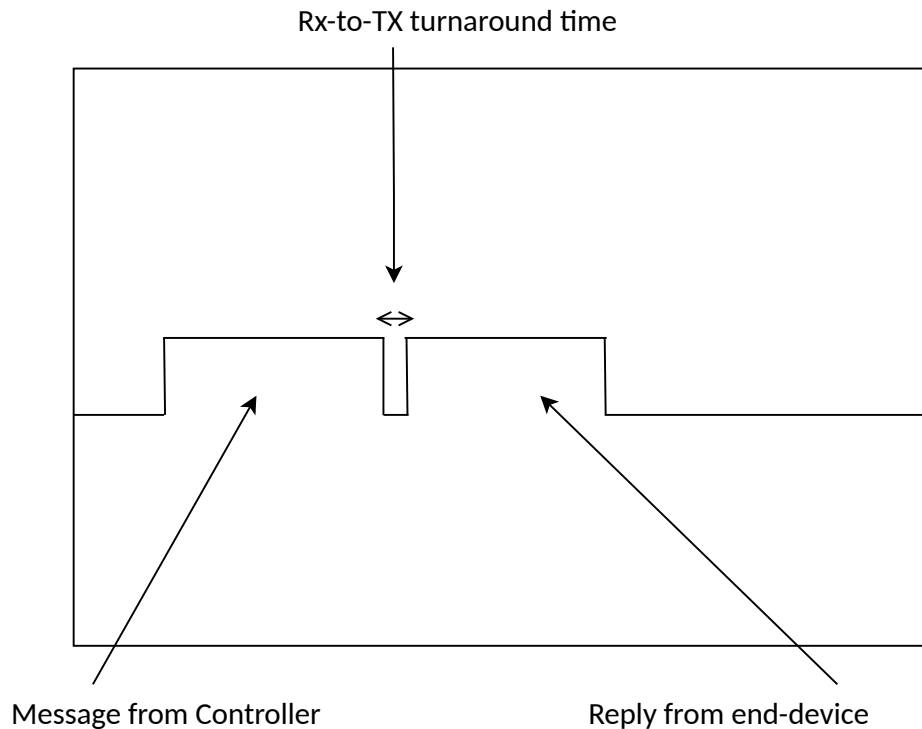


Figure 3.5: RX-to-TX turnaround time measurement

3.5.4 Pass Criteria

The Z-Wave device shall pass the test if:

1. For each Regional Frequency the RX-to-TX time complies with the minimum of 1ms aPhy-TurnaroundTimerRXTX (ITU table 7-27) (7.1.2.5.9).

3.5.5 Fail Criteria

The Z-Wave device shall fail the test if:

1. The RX-to-TX time does not comply with the minimum of 1ms *aPhyTurnaroundTimerRXTX* (ITU table 7-27) (7.1.2.5.9).

3.5.6 Exception

The RX-to-TX turnaround time can be higher than *aPhyTurnaroundTimerRXTX* (ITU table 7-27).

3.6 Format of MPDU, Singlecast 2-channel frequencies

A device must be able to produce the 3 types of frames: Single Cast, Acknowledge and Multicast in 2-channel frequencies.

3.6.1 Prerequisites

- 1 x Z-Wave Zniffer.
- 1 x Z-Wave PC controller.
- 1 x End node.

3.6.2 Test Setup

1. Include End node to PC Controller network.
2. PC Controller sends Singlecast frame to End node with Data Payload (MSDU) = 0x00 (NOP).

3.6.3 Test Result

2. Verify on sniffer that End node responds with an Acknowledgement frame to the Controller (Header type: 0x03).

3.6.4 Pass Criteria

If the frames are displayed in the Z-Wave Zniffer, that means the PHY-layer header and EOF Delimiter are structured correctly (8.1.1.4.1.1).

1. The singlecast frame sent to the End node has the format from ITU figure 8.2 (8.1.1.4.1.1).
2. The singlecast frame sent to the End node has the frame type set to: 0x01 (8.1.2.1.3.1 – Table 8-4).
3. The singlecast frame sent to the End node has the ACK bit set to 0x01 (8.1.3.3)
4. The End node responds with an Acknowledgement frame (8.1.1.4.2.2).
5. This Acknowledgement frame matches the description (8.1.1.4.1.2).
6. This Acknowledgement singlecast responded has the frame type set to: 0x03 (8.1.2.1.3.1 – Table 8-4).
7. The ACK bit (byte 5, bit 6) in the Acknowledgement frame is set to 0 (8.1.3.3.2 – Figure 8.11).
8. This singlecast acknowledgement responded has the same HomeID as the sent singlecast (8.1.1.2).
9. This singlecast acknowledgement responded has the destination ID set to the node ID of the Controller (8.1.1.2).

3.6.5 Fail Criteria

1. The single cast does Not have the format described by figure 8.2 (8.1.1.4.1.1).
2. The singlecast frame sent to the End node doesn't have the frame type set to: 0x01 (8.1.2.1.3.1 – Table 8-4).
3. The singlecast frame sent to the End node doesn't have the ACK bit set to 0x01 (8.1.3.3).
4. The End node did not respond using an Acknowledgement frame (8.1.1.4.2.2).
5. The Acknowledgement singlecast frame does not match the description (8.1.1.4.1.2).
6. This Acknowledgement singlecast responded does not have the frame type set to: 0x03 (8.1.2.1.3.1– Table 8-4).
7. The ACK bit (byte 5, bit 6) in the Acknowledgement frame is NOT set to 0 (8.1.3.3.2 – Figure 8.11).
8. This singlecast acknowledgement responded has a Different HomeID than the singlecast (8.1.1.2).
9. This singlecast acknowledgement responded has a different destination ID than the node ID of the Controller (8.1.1.2).

3.7 Format of MPDU, Singlecast 3-channel frequencies

A device must be able to produce the 3 types of frames: Single Cast, Acknowledge and Multicast in 3-channel frequencies.

3.7.1 Prerequisites

- 1 x Z-Wave Zniffer.
- 1 x Z-Wave PC controller.
- 1 x End node.

3.7.2 Test Setup

1. Include End node to PC Controller network.
2. PC Controller sends Singlecast frame to End node with Data Payload (MSDU) = 0x00 (NOP).

3.7.3 Test Result

2. Verify on sniffer that End node responds with an Acknowledgement frame to the Controller (Header type: 0x03).

3.7.4 Pass Criteria

If the frames are displayed in the Z-Wave Zniffer, that means the PHY-layer header and EOF Delimiter are structured correctly (8.1.1.4.1.1).

1. The singlecast frame sent to the End node has the format from ITU figure 8.2 (8.1.1.4.1.1).
2. The singlecast frame sent to the End node has the frame type set to: 0x01 (8.1.2.1.3.1 – Table 8-4).
3. The singlecast frame sent to the End node has the ACK bit set to 0x01 (8.1.3.3)
4. The End node responds with an Acknowledgement frame (8.1.1.4.2.2).
5. This Acknowledgement frame matches the description (8.1.1.4.1.2).
6. This Acknowledgement singlecast responded has the frame type set to: 0x03 (8.1.2.1.3.1– Table 8-4).
7. The ACK bit (byte 5, bit 7) in the Acknowledgement frame is set to 0 (8.1.3.3.2– Figure 8.12).
8. This singlecast acknowledgement responded has the same HomeID as the sent singlecast (8.1.1.2).
9. This singlecast responded has the destination ID set to the node ID of the Controller (8.1.1.2).

3.7.5 Fail Criteria

1. The single cast does Not have the format described by figure 8.2 (8.1.1.4.1.1).
2. The singlecast frame sent to the End node doesn't have the frame type set to: 0x01 (8.1.2.1.3.1 – Table 8-4).
3. The singlecast frame sent to the End node doesn't have the ACK bit set (8.1.3.3).
4. The End node did not respond using an Acknowledgement frame (8.1.1.4.2.2).
5. The singlecast Acknowledgement frame does not match the description (8.1.1.4.1.2).
6. This singlecast Acknowledgement responded does not have the frame type set to: 0x03 (8.1.2.1.3.1 – Table 8-4).
7. The Request ACK bit (byte 5, bit 7) in the Acknowledgement frame is NOT set to 0 (8.1.3.3.2 – Figure 8.12).
8. This singlecast acknowledgement responded has a Different HomeID than the singlecast (8.1.1.2).
9. This singlecast acknowledgement responded has a different destination ID than the node ID of the Controller (8.1.1.2).

3.8 Format of MPDU, Multicast 2-channel frequencies

A device must be able to produce the 3 types of frames: Single Cast, Acknowledge and Multicast in 2-channel frequencies.

3.8.1 Prerequisites

- 1 x Z-Wave Zniffer.
- 1 x Z-Wave PC controller.
- 2 x End nodes

3.8.2 Test Setup

1. Include End node 1 and End node 2 to PC Controller network.
2. PC Controller sends Multicast frame to End node 1 and 2 with Data Payload (MSDU) = 0x00 (NOP).

3.8.3 Test Result

2. Controller sends 1 Multicast frame to both End nodes, automatically followed by one Singlecast to each of them with the same payload.
 - a. End nodes respond with an Acknowledgement frame to the Singlecast frames (Header type: 0x03).

3.8.4 Pass Criteria

If the frames are displayed in the Z-Wave Zniffer, that means the PHY-layer header and EOF Delimiter are structured correctly (8.1.1.4.1.1).

1. The multicast frame has the format from ITU figure 8.2 (8.1.1.4.1.3).
2. The multicast frame sent to the End nodes has the frame type set to: 0x02 (8.1.2.1.3.1 – Table 8-4).
3. The multicast frame sent to the End nodes has the ACK bit set to 0x00 (8.1.3.6.1)
4. The multicast frame has 29 Mask Bytes and uses only the first one for the 2 End nodes (8.1.3.6.1)
5. End nodes do not respond to the Multicast frame with an Acknowledgement frame (8.1.3.6.1).
6. Each Single cast frame complies with the all the Pass Criteria from TC 3.6.4.

3.8.5 Fail Criteria

1. The multicast frame does Not have the format from ITU figure 8.2 (8.1.1.4.1.3).
2. The multicast frame sent to the End nodes doesn't have the frame type set to: 0x02 (8.1.2.1.3.1 – Table 8-4).
3. The multicast frame sent to the End nodes Doesn't have the ACK bit set to 0x00 (8.1.3.6.1)
4. The multicast frame does not reserve the 29 Mask Bytes or uses more than the first byte for the 2 End nodes nodes (8.1.3.6.1)
5. At least one of the End nodes answers the Multicast frame with an Acknowledgement frame (8.1.3.6.1).
6. Any of the Fail criteria from TC 3.6.5 is met.

3.9 Format of MPDU, Multicast 3-channel frequencies

A device must be able to produce the 3 types of frames: Single Cast, Acknowledge and Multicast in 3-channel frequencies.

3.9.1 Prerequisites

- 1 x Z-Wave Zniffer.
- 1 x Z-Wave PC controller.
- 2 x End nodes

3.9.2 Test Setup

1. Include End node 1 and End node 2 to PC Controller network.
2. PC Controller sends Multicast frame to End node 1 and 2 with Data Payload (MSDU) = 0x00 (NOP).

3.9.3 Test Result

2. Controller sends 1 Multicast frame to both End nodes, automatically followed by one Singlecast to each of them with the same payload.
 - a. End nodes respond with an Acknowledgement frame to the Controller (Header type: 0x03) to the Singlecast frames.

3.9.4 Pass Criteria

If the frames are displayed in the Z-Wave Zniffer, that means the PHY-layer header and EOF Delimiter are structured correctly (8.1.1.4.1.1).

1. The multicast frame has the format from ITU figure 8.2 (8.1.1.4.1.3).
2. The multicast frame sent to the End nodes has the frame type set to: 0x02 (8.1.2.1.3.1 – Table 8-4).
3. The multicast frame sent to the End nodes has the ACK bit set to 0x00 (8.1.3.6.1)
4. The multicast frame has 29 Mask Bytes and uses only the first one for the 2 End nodes nodes (8.1.3.6.1)
5. End nodes do not respond to the Multicast frame with an Acknowledgement frame (8.1.3.6.1).
6. Each Single cast frame complies with the all the Pass Criteria from TC 3.7.4.

3.9.5 Fail Criteria

1. The multicast frame does Not have the format from ITU figure 8.2 (8.1.1.4.1.3).
2. The multicast frame sent to the End nodes doesn't have the frame type set to: 0x02 (8.1.2.1.3.1 – Table 8-4).
3. The multicast frame sent to the End nodes Doesn't have the ACK bit set to 0x00 (8.1.3.6.1)
4. The multicast frame does not reserve the 29 Mask Bytes or uses more than the first byte for the 2 End nodes nodes (8.1.3.6.1)
5. At least one of the End nodes answers the Multicast frame with an Acknowledgement frame (8.1.3.6.1).
6. Any of the Fail criteria from TC 3.7.5 is met.

3.10 Network Robustness, Clear channel assessment: 2-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.10.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x RF combiner
- 2 x Noise Generator (can either be: RF noise generator at the Z-Wave frequencies or Z-Wave modules loaded with RailTest configured to constant carrier transmission at the Z-Wave frequencies)

3.10.2 Test Setup



Figure 3.6: Connection structure for 2-ch frequencies

1. Configure Noise Generator 1 to operate 40kbit. Configure Noise Generator 2 to operate on 100kbit (RF noise = Constant carrier signal at the channel frequency, 0dBm).
2. Include End node to PC Controller network.
3. On the Zniffer observe that communication between Controller and End node is possible and which channels are used.
4. Configure PC Controller to send One Broadcast frame (HEX [00 00] – as a broadcast we don't expect an answer). Do not send it yet.
5. Start the noise Generator 1 & 2 generating noise with 0dBm RF power.
6. Send the Broadcast. This is the reference start time for the next point.
7. After 1 second stop Noise Generator 1. Wait 3 additional seconds to verify the frame is sent.
8. After 3 seconds more start Noise Generator 1.
9. Send the Broadcast again. This is the reference start time for the next point.
10. After 1 second, stop Noise Generator 2. Wait 3 additional seconds to verify the frame is sent.
11. After 3 seconds start Noise Generator 2.

3.10.3 Test Result

2. End Node is included to Controller.
3. There is communication between Controller and End Node shown on the Zniffer.
4. The Broadcast frame is only configured.
5. Noise generator 1 & 2 are generating noise.
6. Observe on the Zniffer there is no traffic.
7. Observe on Zniffer the Broadcast frame at 40kbit.
8. Noise Generator 1 is active again.
9. The Zniffer shows no new communication.
10. Observe on Zniffer the Broadcast frame at 100kbit.
11. The Zniffer shows no new communication.

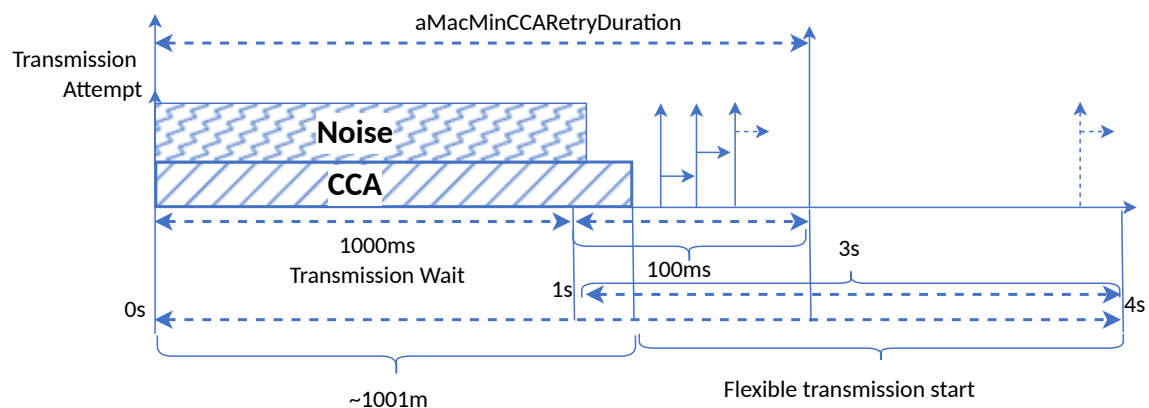


Figure 3.7: Clear Channel Assessment Time Chart

3.10.4 Pass criteria

1. The Broadcast frames are sent while the corresponding channel is available and after the 1000ms, use [Figure 3.7](#) for reference. (8.1.4.1 – Table 8-18)
2. The Broadcast uses the channel with noise generator Switched off in steps 7 & 10 (8.1.1.4.2.1)

3.10.5 Fail criteria

1. The Broadcast frames appear before the noise is removed. (8.1.4.1 – Table 8-18)
2. The Broadcast fails to be transmitted by trying to use a high traffic channel: There is no communication in steps 7 & 10 (8.1.1.4.2.1).

3.11 Network Robustness, Clear channel assessment: 3-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.11.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node
- 3 x Noise Generator
- 2 x RF combiner

3.11.2 Test Setup



Figure 3.8: Connection structure for 3-ch frequencies

1. Configure Noise Generator 1 to operate on 100kbit for Ch0, Noise Generator 2 on 100 kbit for ch1 & Noise Generator 3 on 100 kbit for Ch 2 (RF noise = Constant carrier signal at the channel frequency, 0dBm).
2. Include End node to PC Controller network.
3. On the Ziffer observe that communication between Controller and End node is possible and which channels are used.
4. Configure PC Controller to send One Broadcast frame (HEX [00 00] – as a broadcast we don't expect an answer). Do not send it yet.
5. Start the noise Generators 1, 2 & 3 to generate noise with 0dBm RF power.
6. Send the Broadcast. This is the reference start time for the next point.
7. After 1 second, stop Noise Generator 1. Wait 3 additional seconds to verify the frame is sent.
8. After 3 seconds, start Noise Generator 1.
9. Send the Broadcast again. This is the reference start time for the next point.
10. After 1 second, stop Noise Generator 2. Wait 3 additional seconds to verify the frame is sent.
11. After 3 seconds, start Noise Generator 2.
12. Send the Broadcast again. This is the reference start time for the next point.
13. After 1 second, stop Noise Generator 3. Wait 3 additional seconds to verify the frame is sent.
14. After 3 seconds, start Noise Generator 3.

3.11.3 Test Result

2. End node is included to Controller.
3. There is communication between Controller and End Node shown on the Zniffer.
4. The Broadcast frame is only configured.
5. Noise Generators 1, 2 & 3 are generating noise.
6. Observe on the Zniffer there is no traffic.
7. Observe on Zniffer the Broadcast frame at 100kBit channel 0.
8. Noise Generator 1 is active again.
9. The Zniffer shows no new communication.
10. Observe on Zniffer the Broadcast frame at 100kBit channel 1.
11. Noise Generator 2 is active again.
12. The Zniffer shows no new communication.
13. Observe on Zniffer the Broadcast frame at 100kBit channel 2.
14. The Zniffer shows no new communication.

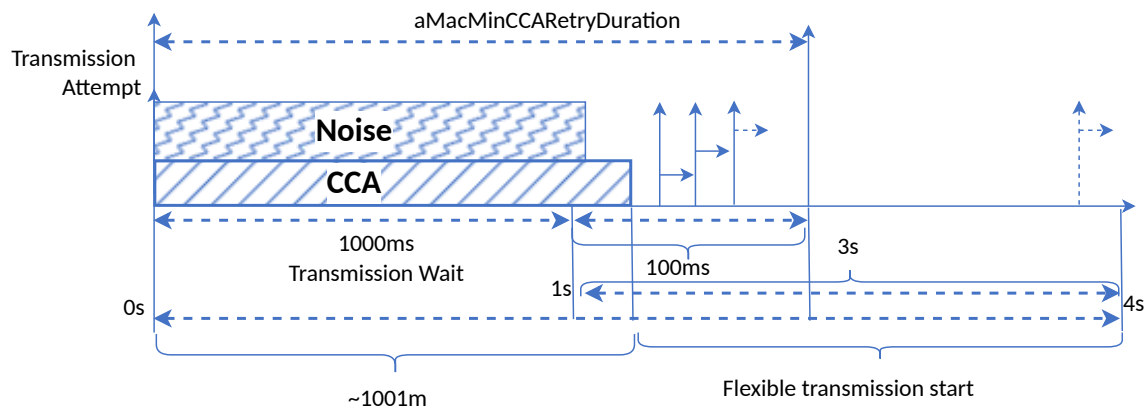


Figure 3.9: Clear Channel Assessment Time Chart

3.11.4 Pass criteria

1. The Broadcast frames are sent while the corresponding channel is available and after the 1000ms, use Figure 3.9 for reference. (8.1.4.1 – Table 8-18)
2. The Broadcast uses the channel with the noise generator switched off in steps 7, 10 & 13 (8.1.1.4.2.1)

3.11.5 Fail criteria

1. The Broadcast frames appear before the noise is removed. (8.1.4.1 – Table 8-18)
2. The Broadcast fails being transmitted by trying to use a high traffic channel channel: There is no Broadcast detection in the Zniffer in steps 7, 9 & 11 (8.1.1.4.2.1).

3.12 Network Robustness, Acknowledgement 2-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.12.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 1 x End node

3.12.2 Test Setup

1. Include End node to PC Controller network.
2. Include Secondary Controller to the primary one.
3. On the Zniffer observe that communication between both Controllers and End node is possible.
4. Perform an ERTT with 50 ms delay from one of the controllers to the End node and from the other Controller, send singlecast with MSDU = 0x00 (NOP) to the End node at the same time.

3.12.3 Test Result

4. Observe on the Zniffer how the End node replies to both controllers with one acknowledgement frame using the same sequence number as each singlecast. If the End node does not answer, the controller retransmits the frame with the same sequence number and the End node answer with the frame with it as described.

3.12.4 Pass criteria

1. The singlecast frames are answered with an acknowledgement frame (8.1.1.4.2.2).
2. This Acknowledgement frame matches the description (8.1.1.4.1.2).
3. This Acknowledgement singlecast responded has the frame type set to: 0x03 (8.1.2.1.3.1– Table 8-4).
4. The ACK bit (byte 5, bit 7) in the Acknowledgement frame is set to 0 (8.1.3.3.2– Figure 8.12).
5. This singlecast acknowledgement responded has the same HomeID as the sent singlecast (8.1.1.2).
6. This singlecast acknowledgement responded has the destination ID set to the node ID of the Controller that sent it (8.1.1.2).
7. When the Controllers send commands very close, the End node does not answer because both overlap for the End node to read correctly (8.1.1.4.2.2).
8. The controller retransmits the frames that weren't answered with an Acknowledgement (8.1.1.4.2.3)
9. When the Controller retransmit the frames, the End node answers with an acknowledgement using the same Sequence Number as the received frame (8.1.3.3.7).

3.12.5 Fail criteria

1. The End node did not respond using an Acknowledgement frame (8.1.1.4.2.2).
2. The Acknowledgement singlecast frame does not match the description (8.1.1.4.1.2).
3. This Acknowledgement singlecast responded does not have the frame type set to: 0x03 (8.1.2.1.3.1– Table 8-4).
4. The ACK bit (byte 5, bit 6) in the Acknowledgement frame is NOT set to 0 (8.1.3.3.2 – Figure 8.11).
5. This singlecast acknowledgement responded has a Different HomeID than the singlecast (8.1.1.2).
6. This singlecast acknowledgement responded has a different destination ID than the node ID of the Controller (8.1.1.2).
7. The End node answers the singlecasts with Acknowledgement frame even if it can't read them correctly (8.1.1.4.2.2).
8. The controller does not retransmit the frames that weren't answered with an Acknowledgement (8.1.1.4.2.3)
9. When the Controllers retransmit the frames, the End node does not answer or answers with an Acknowledgement using a different Sequence Number as the received frame (8.1.3.3.7).

3.13 Network Robustness, Acknowledgement 3-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.13.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 1 x End node

3.13.2 Test Setup

1. Include End node to PC Controller network.
2. Include Secondary Controller to the primary one.
3. On the Zniffer observe that communication between both Controllers and End node is possible.
4. Perform an ERTT with 50 ms delay from one of the controllers to the End node and from the other Controller, send singlecast with MSDU = 0x00 (NOP) to the End node at the same time.

3.13.3 Test Result

4. Observe on the Zniffer how the End node replies to both controllers with one acknowledgement frame using the same sequence number as each singlecast. If the End node does not answer, the controller retransmits the frame with the same sequence number and the End node answer with the frame with it as described.

3.13.4 Pass criteria

1. The singlecast frames are answered with an acknowledgement frame (8.1.1.4.2.2).
2. This Acknowledgement frame matches the description (8.1.1.4.1.2).
3. This Acknowledgement singlecast responded has the frame type set to: 0x03 (8.1.2.1.3.1– Table 8-4).
4. The ACK bit (byte 5, bit 7) in the Acknowledgement frame is set to 0 (8.1.3.3.2– Figure 8.12).
5. This singlecast acknowledgement responded has the same HomeID as the sent singlecast (8.1.1.2).
6. This singlecast acknowledgement responded has the destination ID set to the node ID of the Controller that sent it (8.1.1.2).
7. When the Controllers send commands very close, the End node does not answer because both overlap for the End node to read correctly (8.1.1.4.2.2).
8. The controller retransmits the frames that weren't answered with an Acknowledgement (8.1.1.4.2.3).
9. When the Controller retransmit the frames, the End node answers with an acknowledgement using the same Sequence Number as the received frame (8.1.3.5).

3.13.5 Fail criteria

1. The End node did not respond using an Acknowledgement frame (8.1.1.4.2.2).
2. The Acknowledgement singlecast frame does not match the description (8.1.1.4.1.2).
3. This Acknowledgement singlecast responded does not have the frame type set to: 0x03 (8.1.2.1.3.1– Table 8-4).
4. The ACK bit (byte 5, bit 7) in the Acknowledgement frame is NOT set to 0 (8.1.3.3.2 – Figure 8.11).
5. This singlecast acknowledgement responded has a Different HomeID than the singlecast (8.1.1.2).
6. This singlecast acknowledgement responded has a different destination ID than the node ID of the Controller (8.1.1.2).
7. The End node answers the singlecasts with Acknowledgement frame even if it can't read them correctly (8.1.1.4.2.2).
8. The controller doesn't retransmit the frames that weren't answered with an Acknowledgement (8.1.1.4.2.3).
9. When the Controllers retransmit the frames, the End node does not answer or answers with an Acknowledgement using a different Sequence Number as the received frame (8.1.3.5).

3.14 Network Robustness, Acknowledgement OFF 2-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.14.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node
- 1 x Frame Generator*

3.14.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections of the frame modified individually in order to test the behavior of the receiver.

1. Include End node to PC Controller network.
2. On the Zniffer observe that communication between both Controllers and End node is possible.
3. Generate a frame that sends to the End node a singlecast with MSDU = 0x00 (NOP) making sure ACK bit (byte 5, bit 6) is set to 0x00.
4. Send this frame as singlecast to the End node.

3.14.3 Test Result

4. Observe on the Zniffer how the End node ignores the singlecast.

3.14.4 Pass criteria

1. The ACK bit (byte 5, bit 6) in the singlecast frame is set to 0 (8.1.3.3.2– Figure 8.11).
2. The singlecast frames are not answered with an acknowledgement frame (8.1.1.4.2.2).

3.14.5 Fail criteria

1. The End node did respond using an Acknowledgement frame (8.1.1.4.2.2).

3.15 Network Robustness, Acknowledgement OFF 3-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.15.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node
- 1 x Frame Generator*

3.15.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include End node to PC Controller network.
2. On the Zniffer observe that communication between both Controllers and End node is possible.
3. Generate a frame that sends to the End node a singlecast with MSDU = 0x00 (NOP) making sure ACK bit (byte 5, bit 7) is set to 0x00.
4. Send this frame as singlecast to the End node.

3.15.3 Test Result

4. Observe on the Zniffer how the End node ignores the singlecast.

3.15.4 Pass criteria

1. The ACK bit (byte 5, bit 7) in the singlecast frame is set to 0 (8.1.3.3.2– Figure 8.12).
2. The singlecast frame is not answered with an acknowledgement frame (8.1.1.4.2.2).

3.15.5 Fail criteria

1. The End node did respond using an Acknowledgement frame (8.1.1.4.2.2).

3.16 Network Robustness, Multicast Acknowledgement ON 2-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.16.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End nodes
- 1 x Frame Generator*

3.16.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections of the frame modified individually in order to test the behavior of the receiver.

1. Include End nodes to PC Controller network.
2. On the Zniffer observe that communication between both Controller and End nodes is possible.
3. Generate a frame that sends to the End nodes a Multicast with MSDU = 0x00 (NOP) making sure ACK bit (byte 5, bit 6) is set to 0x01.
4. Send this frame as multicast to the End nodes.

3.16.3 Test Result

4. Observe on the Zniffer how the End nodes ignore the.

3.16.4 Pass criteria

1. The ACK bit (byte 5, bit 6) in the multicast frame is set to 1 (8.1.3.3.2– Figure 8.11).
2. The multicast frame sent to the End nodes has the frame type set to: 0x02 (8.1.2.1.3.1 – Table 8-4).
3. The Multicast frames are not answered with an acknowledgement frame (8.1.1.4.2.2).
4. The follow-up single cast frames are answered by the End nodes with an Acknowledgement frame (8.1.1.4.2.2).

3.16.5 Fail criteria

1. The End nodes did respond using an Acknowledgement frames to the Multicast frame (8.1.1.4.2.2).
2. The follow-up singlecast frames were not answered by the End nodes with an Acknowledgement frame (8.1.1.4.2.2).

3.17 Network Robustness, Multicast Acknowledgement ON 3-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.17.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End nodes
- 1 x Frame Generator*

3.17.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections of the frame modified individually in order to test the behavior of the receiver.

1. Include End nodes to PC Controller network.
2. On the Zniffer observe that communication between both Controller and End nodes is possible.
3. Generate a frame that sends to the End nodes a Multicast with MSDU = 0x00 (NOP) making sure ACK bit (byte 5, bit 6) is set to 0x01.
4. Send this frame as multicast to the End nodes.

3.17.3 Test Result

4. Observe on the Zniffer how the End nodes ignore the multicast.

3.17.4 Pass criteria

1. The ACK bit (byte 5, bit 7) in the multicast frame is set to 1 (8.1.3.3.2– Figure 8.12).
2. The multicast frame sent to the End nodes has the frame type set to: 0x02 (8.1.2.1.3.1 – Table 8-4).
3. The Multicast frames are not answered with an acknowledgement frame (8.1.1.4.2.2).
4. The follow-up single cast frames are answered by the End nodes with an Acknowledgement frame (8.1.1.4.2.2).

3.17.5 Fail criteria

1. The End nodes did respond using an Acknowledgement frames to the Multicast frame (8.1.1.4.2.2).
2. The follow-up singlecast frames were not answered by the End nodes with an Acknowledgement frame (8.1.1.4.2.2).

3.18 Network Robustness, Retransmission

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.18.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.18.2 Test Setup

1. Include End node to PC Controller network.
2. Disable the End node device by removing power or removing the antenna from it.
3. Send a singlecast from the controller to the End node. With MSDU = 0x00 (NOP).
4. On the Zniffer observe that communication between both Devices is not possible and the Controller sending the frame re-tries sending it.

3.18.3 Test Result

4. Observe on the Zniffer the transmission is attempted up to 2 times more (the maximum number of frame transmission retries “aMacMaxFrameRetries”) before increasing the Sequence Number and each re-transmission waits a random period to prevent collisions with other frames that may be being sent at the same time.

3.18.4 Pass criteria

1. The Controller sends only 2 retransmissions (“aMacMaxFrameRetries”) with the same Sequence Number waiting a random period of time after each attempt (8.1.1.4.2.3).
2. The Controller issues a new frame with the same contents but with its Sequence Number value changes and sent also only up to the value of “aMacMaxFrameRetries” waiting a random period of time after each attempt (8.1.1.4.2.3).

3.18.5 Fail criteria

1. When the Controllers retransmit the frames, the sequence number changes each time and does it a different amount of times than the one defined by “aMacMaxFrameRetries” (8.1.1.4.2.3).
2. The Controller does not issue any new frame, or it issues them with a Sequence Number entirely unrelated to the previously used one (8.1.1.4.2.3).

3.19 Network Robustness, Multi-hop routing 2-channel Frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission. The procedure is the same in 2 & 3 channel frequencies, but it must be tested independently.

3.19.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 1 x End node

3.19.2 Test Setup

1. Include End node and secondary Controller to PC Controller network.
2. Disable the End node device by removing power or removing the antenna from it.
3. Send a singlecast from the controller to the End node. With MSDU = 0x00 (NOP).

3.19.3 Test Result

3. On the Zniffer observe that communication between both Devices is not possible and the Controller sending the frame re-tries sending it.
 - a. Observe on the Zniffer the transmission is attempted up to 2 times more (the maximum number of frame transmission retries “aMacMaxFrameRetries”)
 - b. Then it increases the Sequence Number and tries again.
 - c. Re-transmissions wait a random period to prevent collisions with other frames that may be being sent at the same time.
 - d. On the Zniffer observe that after the second retransmission is attempted, the Controller sends routed frames through the secondary Controller up to the “aMacMaxFrameRetries”.
 - i. The Controller sends a routed frame through the secondary Controller in order to reach the End node.
 - ii. The secondary Controller attempts to reach the End node up to “aMacMaxFrameRetries”.
 - iii. Note: Additional possible subsequent retransmissions are not part of the “Multi-Hop Routing” mechanism.

3.19.4 Pass criteria

1. The Controller sends only 2 retransmissions (“aMacMaxFrameRetries”) with the same Sequence Number waiting a random period of time after each attempt (8.1.1.4.2.3).
2. The Controller issues a new frame with the same contents but with its Sequence Number value changes and sent also only up to the value of “aMacMaxFrameRetries” waiting a random period of time after each attempt (8.1.1.4.2.3).
3. The singlecast from the Controller to the secondary Controller has Header **Type: 0x01 for 2-channel frequencies.**
4. The singlecast from the Controller to the secondary Controller has Repeaters: 1.
5. The singlecast from the Controller to the secondary Controller has ACK bit set to 0x00.
6. The secondary Controller sends a singlecast to the End node with the same MSDU.
7. The singlecast the secondary Controller sends has Header **Type: Type: 0x01 for 2-channel frequencies.**
8. The singlecast the secondary Controller sends has Repeaters: 1.
9. The singlecast the secondary Controller sends has Hops: 0x01.
10. The singlecast the secondary Controller sends has ACK bit set to 0x00.
11. The secondary Controller retransmits the singlecast to the End node up to the value of “aMacMaxFrameRetries” waiting a random period of time after each attempt (8.1.1.4.2.3).

3.19.5 Fail criteria

1. When the Controllers retransmit the frames, the sequence number changes each time and does it a different amount of times than the one defined by “aMacMaxFrameRetries” (8.1.1.4.2.3).
2. The Controller does not issue any new frame, or it issues them with a Sequence Number entirely unrelated to the previously used one (8.1.1.4.2.3).
3. The singlecast from the Controller to the secondary Controller has a different Header **Type than: 0x01 for 2-channel frequencies.**
4. The singlecat from the Controller to the secondary Controller has a different number of repeaters than: 1.
5. The singlecast from the Controller to the secondary Controller as the ACK bit set to 0x01.
6. The secondary Controller sends a singlecast to the End node with a different MSDU.
7. The singlecast the secondary Controller sends has Header Type different than: **Type: 0x01 for 2-channel frequencies.**
8. The singlecast the secondary Controller sends has Repeaters other than: 1.
9. The singlecast the secondary Controller sends has set Hops other than: 0x01.
10. The singlecast the secondary Controller sends has ACK bit set to 0x01.
11. The secondary Controller does not retransmit the singlecast to the End node up to the same value of “aMacMaxFrameRetries” and waits a consistent period of time after each attempt or does not retransmit at all (8.1.1.4.2.3).

3.20 Network Robustness, Multi-hop routing 3-channel Frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission. The procedure is the same in 2 & 3 channel frequencies, but it must be tested independently.

3.20.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 1 x End node

3.20.2 Test Setup

1. Include End node and secondary Controller to PC Controller network.
2. Disable the End node device by removing power or removing the antenna from it.
3. Send a singlecast from the controller to the End node. With MSDU = 0x00 (NOP).

3.20.3 Test Result

3. On the Zniffer observe that communication between both Devices is not possible and the Controller sending the frame re-tries sending it.
 - a. Observe on the Zniffer the transmission is attempted up to 2 times more (the maximum number of frame transmission retries “aMacMaxFrameRetries”)
 - b. Then it increases the Sequence Number and tries again.
 - c. Re-transmissions wait a random period to prevent collisions with other frames that may be being sent at the same time.
 - d. On the Zniffer observe that after retransmitting, the Controller sends routed frames through the secondary Controller up to the “aMacMaxFrameRetries”.
 - e. After the second retransmission is attempted, the Controller sends a singlecast to the secondary Controller in order to reach the End node.
 - f. The secondary Controller attempts to reach the End node up to “aMacMaxFrameRetries”.

3.20.4 Pass criteria

1. The Controller sends only 2 retransmissions (“aMacMaxFrameRetries”) with the same Sequence Number waiting a random period of time after each attempt (8.1.1.4.2.3).
2. The Controller issues a new frame with the same contents but with its Sequence Number value changes and sent also only up to the value of “aMacMaxFrameRetries” waiting a random period of time after each attempt (8.1.1.4.2.3).
3. The singlecast from the Controller to the secondary Controller has Header **Type: 0x08 for 3-channel frequencies**.
4. The singlecast from the Controller to the secondary Controller has Repeaters: 1.
5. The singlecast from the Controller to the secondary Controller has ACK bit set to 0x00.
6. The secondary Controller sends a singlecast to the End node with the same MSDU.
7. The singlecast the secondary Controller sends has Header **Type: 0x08 for 3-channel frequencies**.
8. The singlecast the secondary Controller sends has Repeaters: 1.
9. The singlecast the secondary Controller sends has Hops: 0x01.
10. The singlecast the secondary Controller sends has ACK bit set to 0x00.
11. The secondary Controller retransmits the singlecast to the End node up to the value of “aMacMaxFrameRetries” waiting a random period of time after each attempt (8.1.1.4.2.3).

3.20.5 Fail criteria

1. When the Controllers retransmit the frames, the sequence number changes each time and does it a different amount of times than the one defined by “aMacMaxFrameRetries” (8.1.1.4.2.3).
2. The Controller does not issue any new frame, or it issues them with a Sequence Number entirely unrelated to the previously used one (8.1.1.4.2.3).
3. The singlecast from the Controller to the secondary Controller has a different Header **Type than: 0x08 for 3-channel frequencies**.
4. The singlecat from the Controller to the secondary Controller has a different number of repeaters than: 1.
5. The singlecast from the Controller to the secondary Controller as the ACK bit set to 0x01.
6. The secondary Controller sends a singlecast to the End node with a different MSDU.
7. The singlecast the secondary Controller sends has Heater **Type different than: 0x08 for 3-channel frequencies**.
8. The singlecast the secondary Controller sends has Repeaters other than: 1.
9. The singlecast the secondary Controller sends has set Hops other than: 0x01.
10. The singlecast the secondary Controller sends has ACK bit set to 0x01.
11. The secondary Controller does not retransmit the singlecast to the End node up to the same value of “aMacMaxFrameRetries” and waits a consistent period of time after each attempt or does not retransmit at all (8.1.1.4.2.3).

3.21 Network Robustness, Data Validation Corrupt FCS, 2-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.21.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node
- 1 x Frame Generator*

3.21.2 Test Setup

1. Include End node to PC Controller network.
2. On the Zniffer observe that communication between both Controllers and End node is possible.
3. Generate a frame that sends to the End node a singlecast with MSDU = 0x00 (NOP) making sure the 8/16 bits for FCS/CRC are random and not generated automatically.
4. Send this frame as singlecast to the End node.

3.21.3 Test Result

4. Observe on the Zniffer how the End node ignores the singlecast.

3.21.4 Pass criteria

1. The singlecast frame is not answered with an acknowledgement frame (8.1.1.4.2.5).
2. The controller retransmits the frames that weren't answered with an Acknowledgement (8.1.1.4.2.3)
3. When the Controller retransmit the frames, the End node remains without answering with an acknowledgement (8.1.1.4.2.2).

3.21.5 Fail criteria

1. The End node does respond using an Acknowledgement frame (8.1.1.4.2.2).
2. The End node answers the singlecasts with Acknowledgement frame even if it has bit errors as per FCS manipulation (8.1.1.4.2.2).
3. The controller does not retransmit the frames that weren't answered with an Acknowledgement (8.1.1.4.2.3)

3.22 Network Robustness, Acknowledgement Corrupt CRC 3-channel frequencies

A device must ensure robustness in data transmission. This is achieved by the mechanisms: Backoff Algorithm, Frame Acknowledgement, Data Verification and Frame Retransmission.

3.22.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node
- 1 x Frame Generator*

3.22.2 Test Setup

1. Include End node to PC Controller network.
2. On the Zniffer observe that communication between both Controllers and End node is possible.
3. Generate a frame that sends to the End node a singlecast with MSDU = 0x00 (NOP) making sure the 16 bits of CRC are random and not generated automatically.
4. Send this frame as singlecast to the End node.

3.22.3 Test Result

4. Observe on the Zniffer how the End node ignores the singlecast.

3.22.4 Pass criteria

1. The singlecast frames is not answered with an acknowledgement frame (8.1.1.4.2.2).
2. The controller retransmits the frames that weren't answered with an Acknowledgement (8.1.1.4.2.3)
3. When the Controller retransmit the frames, the End node remains without answering with an acknowledgement (8.1.1.4.2.2).

3.22.5 Fail criteria

1. The End node does respond using an Acknowledgement frame (8.1.1.4.2.2).
2. The End node answers the singlecasts with Acknowledgement frame even if it has bit errors as per CRC manipulation (8.1.1.4.2.2).
3. The controller does not retransmit the frames that weren't answered with an Acknowledgement (8.1.1.4.2.3)

3.23 MPDU Format, Components 2-channels

The MAC Protocol Data Unit (MPDU), consists of three basic components: A MAC Header (MHR), a MAC data payload (MAC Service Data Unit (MSDU)) and a MAC Footer (MFR).

3.23.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.23.2 Test Setup

1. Include the End nodes to the Controller's Network.
2. Send a singlecast with MPDU = 0x00 (NOP) to one End node.
3. Observe the structure of the singlecast sent.
4. Select both End nodes and Send a multicast to both devices.
5. Observe the structure of the multicast sent.

3.23.3 Test Result

3. The singlecast is displayed correctly on the Zniffer.
5. The multicast is displayed correctly on the Zniffer.

3.23.4 Pass Criteria

1. The singlecast shows:
 - a. MHR: (8.1.3 – Figure 8.5)
 - i. Home ID: 4 bytes (8.1.3.1)
 - ii. Source Node ID: 1 byte (8.1.3.2)
 - iii. Frame Control (2 bytes): (8.1.3.3 – Figure 8.11)
 1. 1st byte (properties 1):
 - a. Header type: 4 bits (8.1.3.3.5)
 - b. Speed Modifier: 1 bit (8.1.3.3.4)
 - c. Low Power: 1 bit (8.1.3.3.3)
 - d. Ack Req: 1 bit (8.1.3.3.2)
 - e. Routed: 1 bit (8.1.3.3.1)
 2. 2nd byte:
 - a. Sequence number: 4 bits (8.1.3.3.7)
 - b. Reserved: 1 bit
 - c. Beaming info: 2 bits (8.1.3.3.6)
 - d. Reserved (SUC Present): 1 bit
 - iv. Length: 1 byte (8.1.3.4)
 - v. Destination Node ID: 1byte (8.1.3.6)
 - b. MSDU Payload: (8.1.3.7)
 - i. 1 Byte = 0x00 (NOP)
 - c. MFR (not described in the structure in the Zniffer): (8.1.3.8)
 - i. FCS: 2 bytes

2. The multicast shows:
 - a. MHR: (8.1.3 – Figure 8.7)
 - i. Home ID: 4 bytes (8.1.3.1)
 - ii. Source Node ID: 1 byte (8.1.3.2)
 - iii. Frame Control (2 bytes): (8.1.3.3 – Figure 8.11)
 1. 1st byte (properties 1):
 - a. Header type: 4 bits (8.1.3.3.5)
 - b. Speed Modifier: 1 bit (8.1.3.3.4)
 - c. Low Power: 1 bit (8.1.3.3.3)
 - d. Ack Req: 1 bit (8.1.3.3.2)
 - e. Routed: 1 bit (8.1.3.3.1)
 2. 2nd byte:
 - a. Sequence number: 4 bits (8.1.3.3.7)
 - b. Reserved: 1 bit
 - c. Beaming info: 2 bits (8.1.3.3.6)
 - d. Reserved (SUC Present): 1 bit
 - iv. Length: 1 byte (8.1.3.4)
 - v. Destination Node ID (Properties 3): (8.1.3.6.1)
 1. Number of Mask bytes: 5 bits (set to value 29)
 2. Offset address: 3 bits (set to value 0)
 - vi. Mask Byte: A list of the nodes addressed (2 bytes & 27 bytes set to 0)
- b. MSDU Payload: (8.1.3.7)
 - i. 1 Byte = 0x00 (NOP)
- c. MFR (not described in the structure in the Zniffer): (8.1.3.8)
 - i. FCS: 2 bytes

3.23.5 Fail Criteria

1. At Least one of the components of the format of the MPDU for the different frame types has a different length.

3.24 MPDU Format, Components 3-channels

The MAC Protocol Data Unit (MPDU), consists of three basic components: A MAC Header (MHR), a MAC data payload (MAC Service Data Unit (MSDU)) and a MAC Footer (MFR).

3.24.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.24.2 Test Setup

1. Include the End nodes to the Controller's Network.
2. Send a singlecast with MPDU = 0x00 (NOP) to one End node.
3. Observe the structure of the singlecast sent.
4. Select both End nodes and Send a multicast to both devices.
5. Observe the structure of the multicast sent.

3.24.3 Test Result

3. The singlecast is displayed correctly on the Zniffer.
5. The multicast is displayed correctly on the Zniffer.

3.24.4 Pass Criteria

1. The singlecast shows:
 - a. MHR: (8.1.3 – Figure 8.6)
 - i. Home ID: 4 bytes (8.1.3.1)
 - ii. Source Node ID: 1 byte (8.1.3.2)
 - iii. Frame Control (2 bytes): (8.1.3.3 – Figure 8.12)
 1. 1st byte (properties 1):
 - a. Header type: 4 bits (8.1.3.3.5)
 - b. Reserved (Speed Modified & SUC Present): 2 bits (8.1.3.3.7)
 - c. Low Power: 1 bit (8.1.3.3.3)
 - d. Ack Req: 1 bit (8.1.3.3.1)
 2. 2nd byte:
 - a. Reserved: 4 bits
 - b. Beaming info: 3 bits (8.1.3.3.6)
 - c. Reserved (Extended): 1 bit
 - iv. Length: 1 byte (8.1.3.4)
 - v. Sequence Number: 1 byte (8.1.3.5)
 - vi. Destination Node ID: 1byte (8.1.3.6)
- b. MSDU Payload: (8.1.3.7)
 - i. 1 Byte = 0x00 (NOP)
- c. MFR (not described in the structure in the Zniffer): (8.1.3.9)
 - i. CRC: 2 bytes

2. The multicast shows:
 - a. MHR: (8.1.3 – Figure 8.8)
 - i. Home ID: 4 bytes (8.1.3.1)
 - ii. Source Node ID: 1 byte (8.1.3.2)
 - iii. Frame Control (2 bytes): (8.1.3.3 – Figure 8.12)
 1. 1st byte (properties 1):
 - a. Header type: 4 bits (8.1.3.3.5)
 - b. Reserved (Speed Modified & SUC Present): 2 bits (8.1.3.3.7)
 - c. Low Power: 1 bit (8.1.3.3.3)
 - d. Ack Req: 1 bit (8.1.3.3.2)
 2. 2nd byte:
 - a. Reserved: 4 bits
 - b. Beaming info: 3 bits (8.1.3.3.6)
 - c. Reserved (Extended): 1 bit
 - iv. Length: 1 byte (8.1.3.4)
 - v. Sequence Number: 1 byte (8.1.3.5)
 - vi. Destination Node ID (Properties 3): (8.1.3.6.1)
 1. Number of Mask bytes: 5 bits (set to value 29)
 2. Offset address: 3 bits (set to value 0)
 - vii. Mask Byte: A list of the nodes addressed (2 bytes & 27 bytes set to 0)
- b. MSDU Payload: (8.1.3.7)
 - i. 1 Byte = 0x00 (NOP)
- c. MFR (not described in the structure in the Zniffer): (8.1.3.9)
 - i. CRC: 2 bytes

3.24.5 Fail Criteria

1. At Least one of the components of the format of the MPDU for the different frame types has a different length.

3.25 MPDU Format, Home ID

The MAC Protocol Data Unit (MPDU), consists of three basic components: A MAC Header (MHR), a MAC data payload (MAC Service Data Unit (MSDU)) and a MAC Footer (MFR). Home ID are 4 bytes that identify all nodes in the same domain.

3.25.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.25.2 Test Setup

1. Include both End node devices to the Network of the Controller.
2. Verify the Controller can communicate with both End nodes by sending Singlecast to each of them and Multicast to both.
3. Send a singlecast to one of the End nodes, modifying the Home ID to be different from the original value.
4. Send a multicast to both End nodes with modified Home ID.

3.25.3 Test Result

2. Both End nodes answer with an Acknowledgement frame as expected to the singlecast and the singlecast follow-up after the Multicast.
3. The End node does not answer, since the Home ID is not the Home ID it has been included to.
4. Neither End node answers since the Home ID is different from the one, they have been included to.

3.25.4 Pass Criteria

1. On the singlecast the Home ID occupies only 4 bytes (8.1.3.1)
2. On the Multicast, the Home Id occupies only 4 bytes (8.1.3.1)
3. No node responds to any frame that holds a modified Home Id in any way, because of mis-matching Home ID value (8.1.3.1)

3.25.5 Fail Criteria

1. Any of the methods for altering the Home ID Component is accepted by the receiving node and answered with an acknowledgement frame.

3.26 MPDU Format, Source NodeID

The MAC Protocol Data Unit (MPDU), consists of three basic components: A MAC Header (MHR), a MAC data payload (MAC Service Data Unit (MSDU)) and a MAC Footer (MFR). Source Node ID is 1 byte that identifies the node within one domain that have transmitted the frame.

3.26.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.26.2 Test Setup

1. Include End nodes to Controller's network.
2. Verify the Controller can communicate with both End nodes by sending Singlecast to each of them and Multicast to both.
3. Send a singlecast to one of the End nodes, modifying the Source Node ID to be different from the original value.
4. Send a Multicast to both End nodes, modifying the Source Node Id to be different from the original value.
5. Send a singlecast to one of the End nodes, modifying the Source Node ID to be 0x00.
6. Send a singlecast to one of the End nodes, modifying the Source Node ID to be a value between 0xE9 & 0xFF (reserved values).

3.26.3 Test Result

3. End node received the singlecast and responds to the Source Node ID modified with an Acknowledgement frame.
4. The End nodes do not answer the multicast frame but answer to the singlecast follow-up frames originated after the Multicast
5. The End node receiving the singlecast with Source Node ID set to 0x00, will answer to it with an Acknowledgement frame.
6. The End node receiving the singlecast with Source Node ID set to a reserved value will not answer, since a network is limited to that number of nodes.

3.26.4 Pass Criteria

1. When the Controller does not receive the Acknowledgement frame, the Controller re-tries sending the same frame up to 3 times and then routing through the other End node because Each time the receiving End node answers to the modified Source Node ID. This happens for single cast, singlecast follow-up, frames addressed to Node 0 or frames with a structure affected by a longer Source Node ID field. (8.1.3.6) (8.1.1.4.2.3)
2. The End nodes will answer to a frame with Source Node Id set to a reserved value to avoid retransmissions.)

3.26.5 Fail Criteria

1. The End node answers to the controller with an Acknowledgement frame directly, ignoring the field Source Node ID (8.1.3.6)
2. The Controller does not re-transmit when the Acknowledgement frames are not addressed to it. (8.1.1.4.2.3)

3.27 MPDU Format, Frame Control, Routed (2-channel only)

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The Routed subfield is 1 bit in length. It should be set to 1 when routing and 0 otherwise. It is used only by 2-channel frequencies.

3.27.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node
- 1 x Frame Generator

3.27.2 Test Setup

1. Include End nodes to the Controller's network.
2. Create one hop distance between the Controller and the second End node
3. Make sure the Zniffer can see the communication between all devices.
4. Send a frame with MPDU = 0x00 (NOP) to this End node.
5. Generate a frame with the Routed flag (Byte 5, bit 7 in the frame) disabled and try to reach out to the same End node again.
6. Place the Frame generator in direct range to the second End Node. Generate again a frame with the Routed flag (Byte 5, bit 7 in the frame) disabled, but a new sequence number and try to reach out to the same End node again.

3.27.3 Test Result

2. There is a one-hop distance between the Controller and the second End node.
3. All devices are visible to the Zniffer.
4. The frame sent to the End node does not reach it and the controller Retransmits the frame without receiving an Acknowledgement frame and then it tries by routing the frame through the other End node. The End node answers with an Acknowledgement frame routed through the other End node.
5. The Frame Generator tries to reach directly but fails, its routed frame is displayed as a regular singlecast in the Zniffer and the repeater does not send this frame to the destination node.
6. The Frame Generator tries to reach directly and succeeds, its routed frame is displayed as a regular singlecast in the Zniffer and the repeater does not send this frame to the destination node. The second End node responds with an Acknowledgement frame.

3.27.4 Pass Criteria

1. The routed frames have their Routed flag (Byte 7, bit 7) set to 1 (8.1.3.3.1)
2. The routed frames have their Destination node Id Set to the selected End node value (8.1.3.6)
3. The Routed frame also sets its repeaters count to 1 and sets the Repeater field to the Node ID of the repeater Node.
4. The first Routed Acknowledgement frame has the Routed flag set to 1 (8.1.3.3.1)
5. The first routed Acknowledgement frame has its Destination node Id Set to the Controller node value (8.1.3.6)
6. The first Routed Acknowledgement frame also sets its repeaters count to 1 and sets the Repeater field to the Node ID of the repeater Node.
7. The first Routed Acknowledgement frame (from the second End node) has its Ack bit set to 0x00 (8.1.3.3.2)
8. The second Routed Acknowledgement frame (from the Routing End node) has its Ack bit set to 0x01
9. The Controller sends an Acknowledgement frame to the Repeater. (8.1.3.3.2)
10. When The frame has the routed flag disabled (set to 0), the Ack Request field is still enabled, and the Repeater responds with an Acknowledgement frame to the Frame Generator when in direct range. (8.1.3.3.1)

3.27.5 Fail Criteria

1. The Routed flag is not set to 1 in the standard routed frames.
2. The Routed frame is not Acknowledged with a routed Acknowledgement frame.
3. The first Routed Acknowledgement frame (from the Destination Node) has its Ack flag set to 1.
4. The Controller does not respond to the Repeater with a single Acknowledgement Frame at the end of the transmission.
5. The Repeater ignores the Routed flag set to 0 and Repeats the frame to the Destination Node.
6. The Destination Node responds with a Non-routed Acknowledgement Frame to either the Controller or the Repeating Node to a Routed frame.

3.28 MPDU Format, Frame Control, Low Power 2-channel

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The Low Power subfield is 1 bit that informs a destination node that the actual transmission was using low power. A receiving node shall return an acknowledgement Frame in low power in response to a frame with this bit enabled.

3.28.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.28.2 Test Setup

1. Include End nodes to Controller's Network.
2. Send a regular singlecast to one End node with MDPU = 0x00 (NOP)
3. Generate a Frame that has Low Power bit (Bye 5, bit 5), set to 1 and send it to End node.
4. Send a multicast to both End nodes with the Low Power bit set to 1.

3.28.3 Test Results

2. End node answers with an Acknowledgement Frame to the Controller in regular Power.
3. The End node answers to the Controller with an Acknowledgement frame in Low Power.
4. The Multicast is sent in Low Power.

3.28.4 Pass Criteria

1. The singlecast is sent by default with the Low Power bit set to 0. (8.1.3.3.3)
2. The End node answers with an Acknowledgement frame in regular power and its Low Power bit set to 0 (8.1.3.3.3).
3. The modified singlecast is responded with an Acknowledgement frame in low Power with its Low Power bit set to 1 (8.1.3.3.3).
4. The Multicast is not answered by any of the End nodes (8.1.3.6.1).

3.28.5 Fail Criteria

1. The default singlecast is sent in Low Power with its Low Power bit set to 1 (8.1.3.3.3).
2. The End nodes answer to a regular singlecast with a Low Power Acknowledgement frame with the Low Power bit enabled (8.1.3.3.3).
3. The End nodes do not answer to the singlecast with its Low Power bit set to 1 (8.1.3.3.3).
4. The End nodes answer to the singlecast with Low power set to 1 in regular power and with their Low Power bit set to 0 (8.1.3.3.3).
5. The End nodes answer to the modified Multicast frame directly with an Acknowledgement frame (8.1.3.6.1).

3.29 MPDU Format, Frame Control, Low Power 3-channel

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The Low Power subfield is 1 bit that informs a destination node that the actual transmission was using low power. A receiving node shall return an acknowledgement Frame in low power in response to a frame with this bit enabled.

3.29.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.29.2 Test Setup

1. Include End nodes to Controller's Network.
2. Send a regular singlecast to one End node with MDPU = 0x00 (NOP)
3. Generate a Frame that has Low Power bit (Byte 5, bit 6), set to 1 and send it to End node.
4. Send a multicast to both End nodes with the Low Power bit set to 1.

3.29.3 Test Results

2. End node answers with an Acknowledgement Frame to the Controller in regular Power.
3. The End node answers to the Controller with an Acknowledgement frame in Low Power.
4. The Multicast is sent in Low Power.

3.29.4 Pass Criteria

1. The singlecast is sent by default with the Low Power bit set to 0. (8.1.3.3.3)
2. The End node answers with an Acknowledgement frame in regular power and its Low Power bit set to 0. (8.1.3.3.3)
3. The modified singlecast is responded with an Acknowledgement frame in low Power with its Low Power bit set to 1. (8.1.3.3.3)
4. The Multicast is not answered by any of the End nodes. (8.1.3.6.1)

3.29.5 Fail Criteria

1. The default singlecast is sent in Low Power with its Low Power bit set to 1. (8.1.3.3.3)
2. The End nodes answer to a regular singlecast with a Low Power Acknowledgement frame with the Low Power bit enabled. (8.1.3.3.3)
3. The End nodes do not answer to the singlecast with its Low Power bit set to 1. (8.1.3.3.3)
4. The End nodes answer to the singlecast with Low power set to 1 in regular power and with their Low Power bit set to 0. (8.1.3.3.3)
5. The End nodes answer to the modified Multicast frame directly with an Acknowledgement frame. (8.1.3.6.1)

3.30 MPDU Format, Frame Control, Speed Modified subfield (2-channel Only)

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The Speed modified subfield is one bit used to show that the frame is sent at a lower speed than supported by the source and destination. It should not be used for routing nor multicast frame. It should be reset to 0 if the Frame is sent at the highest supported speed.

3.30.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.30.2 Test Setup

1. Include both End nodes to Controller's Network
2. Send a singlecast to one of them with MPDU = 0x00 (NOP)
3. Send a multicast to both nodes with MPDU = 0x00 (NOP)
4. Generate a frame modifying the Speed Modified subfield to 1 and send it as a singlecast to one of the nodes
5. Generate a frame modifying the Speed Modified subfield to 1 and send it to both End nodes as a multicast
6. Disable one of the End nodes and send a singlecast to it from the Controller
7. Generate a routed frame with Speed Modified subfield set to 1 and try to send it to the disabled End node
8. Enable all end nodes again
9. Exclude both nodes from the Controller's Network

3.30.3 Test Result

2. Singlecast has the Speed Modified subfield set to 0
3. The Multicast as well as the singlecast follow-up frames have the Speed Modified subfield set to 0x00
4. The Singlecast is sent in Lower speed and it's received correctly by the End node
5. The multicast is sent in nominal speed with its Speed Modified subfield set to 1.
6. The routed singlecast has its Speed Modified subfield set to 0.
7. The direct singlecast has its Speed Modified subfield set to 1.
9. During exclusion Observe that the last exclusion NOP frame has enabled Speed Modified field.

3.30.4 Pass Criteria

1. Other than for the mentioned exclusion frames, no frame has its Speed Modified subfield set to 0x01. (8.1.3.3.4)

3.30.5 Fail Criteria

1. Speed Modified subfield is set to 1 in any other case than in the last exclusion NOP frame. (8.1.3.3.4)

3.31 MPDU Format, Frame Control, Header Type, singlecast 2-channel

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The header type defines the frame Header type. A broadcast MPDU is a singlecast MPDU (type 0x01) carrying destination Node ID = 0xFF.

3.31.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.31.2 Test Setup

1. Include the End node to Controller's Network.
2. Send one single cast to the End node with MPDU 0x00 (NOP).
3. Generate a frame with Header going from 0x02 to 0x0F according to table 8-14 and send it to the End node.
4. Generate a frame with Header going from 0x02 to 0x0F according to table 8-14 and send it to Node ID 0xFF (255).

3.31.3 Test Results

2. Singlecast is sent correctly and it's answered with an Acknowledgement frame.
3. Each frame sent to the node is displayed as the corresponding type on the Zniffer, it's ignored by the End node and no Acknowledgement frame is responded. (0x08 is shown as a singlecast).
4. Each frame sent to Node ID 255 is displayed as the corresponding type on the Zniffer.

3.31.4 Pass Criteria

1. Each frame sent by the Controller in 3. & 4. is displayed as the corresponding type on the Zniffer, making each frame correctly defined. (8.1.3.3.5)
2. None of the frames sent in 3. Are answered by definition.
3. None of the frames sent in 4. Are answered by definition nor by being addressed to a reserved Destination Node ID.

3.31.5 Fail Criteria

1. Any frame is displayed as singlecast on the Zniffer regardless of the different Header. (8.1.3.3.5)
2. Any frame sent in 3. received an Acknowledgement frame.
3. Any frame sent in 4. received an Acknowledgement frame.

3.32 MPDU Format, Frame Control, Header Type, singlecast 3-channel

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The header type defines the frame Header type. A broadcast MPDU is a singlecast MPDU (type 0x01) carrying destination Node ID = 0xFF.

3.32.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.32.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include the End node to the Controller's Network.
2. Send one single cast to the End node with MPDU 0x00 (NOP).
3. Generate a frame with Header going from 0x02 to 0x0F according to table 8-14 and send it to the End node.
4. Generate a frame with Header going from 0x02 to 0x0F according to table 8-14 and send it to Node ID 0xFF (255).

3.32.3 Test Results

2. Singlecast is answered correctly with an Acknowledgement frame.
3. Each frame sent to the node is displayed as the corresponding type on the Zniffer, it's ignored by the End node and no Acknowledgement frame is responded. (0x08 is shown as a routed frame).
4. Each frame sent to Node ID 255 is displayed as the corresponding type on the Zniffer.

3.32.4 Pass Criteria

1. Each frame sent by the Controller in 3. & 4. is displayed as the corresponding type on the Zniffer, making each frame correctly defined. (8.1.3.3.5)
2. None of the frames sent in 3. Are answered by definition.
3. None of the frames sent in 4. Are answered by definition nor by being addressed to a reserved Destination Node ID.

3.32.5 Fail Criteria

1. Any frame is displayed as singlecast on the Zniffer regardless of the different Header. (8.1.3.3.5)
2. Any frame sent in 3. received an Acknowledgement frame.
3. Any frame sent in 4. received an Acknowledgement frame.

3.33 MPDU Format, Frame Control, Header Type, Multicast

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The header type defines the frame Header type. A broadcast MPDU is a singlecast MPDU (type 0x01) carrying destination Node ID = 0xFF.

3.33.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.33.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include both End nodes to the Controller's network.
2. Send one multicast to both End nodes with MPDU 0x00 (NOP).
3. Generate a frame with Header going from 0x01 to 0x0F (except 0x02) according to table 8-14 and send it to both End nodes.

3.33.3 Test Result

2. The Multicast is sent correctly, followed by its corresponding singlecast Follow-up frames, which are answered with Acknowledgement frames from the End nodes.
3. Each frame sent is constructed as a multicast frame, but with the corresponding header from table 8-14. Therefore, it's displayed on the zniffer as the expected type with a longer structure.

3.33.4 Pass Criteria

1. Each frame sent by the Controller in 3 is displayed as the corresponding type on the Zniffer, making each frame correctly defined. (8.1.3.3.5)
2. None of the frames sent in 3. Are answered by definition.

3.33.5 Fail Criteria

1. Any frame is displayed as multicast on the Zniffer regardless of the different Header. (8.1.3.3.5)
2. Any frame sent in 3. received an Acknowledgement frame.

3.34 MPDU Format, Frame Control, Header Type, Acknowledgement

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The header type defines the frame Header type. A broadcast MPDU is a singlecast MPDU (type 0x01) carrying destination Node ID = 0xFF.

3.34.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.34.2 Test Setup

1. Include the End node Controller to Primary Controller's network.
2. Send one singlecast to the End node with MPDU 0x00 (NOP).

3.34.3 Test Result

2. The singlecast is sent correctly and it's answered with an Acknowledgement frame from the End node.

3.34.4 Pass Criteria

1. Acknowledgement frame only uses Header Type 3 (8.1.3.3.5)

3.34.5 Fail Criteria

1. The Acknowledgemnt frame is displayed as any other type of frame except Type 3 (8.1.3.3.5)

3.35 MPDU Format, Frame Control, Header Type, Routed MPDU (3-channel only)

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The header type defines the frame Header type. A broadcast MPDU is a singlecast MPDU (type 0x01) carrying destination Node ID = 0xFF.

3.35.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.35.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include both End nodes to the Controller's network
2. Send a singlecast to each End node
3. Disable one of the End nodes Antenna and try to reach to it from the Controller
4. Generate a Routed frame with its Header type going from 0x01 to 0x0F (except 0x08) according to table 8-14 and send them to the End node with Antenna disabled.
5. Generate a Routed frame with its Header type going from 0x01 to 0x0F (except 0x08) according to table 8-14 and address it to Node ID 0xFF (255).

3.35.3 Test Result

2. The End node does not respond to the routed frame.
3. The Controller tries to reach the disabled End node through the other one sending a routing frame (Header type 0x08 – Routing).
 - a. The End node responds with an Acknowledgement frame routed through the repeater.
4. The Controller tries to reach the End node with disabled antenna through the repeater with each frame constructed as a Routed frame but with header types from table 8-14.
 - a. Each frame is displayed on the Zniffer as the corresponding type.
5. The Controller sends each frame constructed as a Routed frame but with header types from table 8-14 and addressed it to Node ID 0xFF (255). Each frame is displayed on the Zniffer as the corresponding type. No frame is answered with Acknowledgement frame.

3.35.4 Pass Criteria

1. The routed frame has Header Type 0x08 (Routed). (8.1.3.3.5)
2. None of the frames sent in 4. Other than 0x01, received an Acknowledgement frame.
3. None of the frames sent in 5. received an Acknowledgement frame.

3.35.5 Fail Criteria

1. Any frame is displayed as Routing on the Ziffer regardless of the different Header. (8.1.3.3.5)
2. Any frame sent in 4. Except for 0x01 received an Acknowledgement frame.
3. Any frame sent in 5. received an Acknowledgement frame.

3.36 MPDU Format, Frame Control, Sequence number 2-channel

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The sequence number is a 4-bit sub-field provided by higher layers when transmitting. The same Sequence Number shall be used for all retransmissions of a given MPDU that first fails being delivered. A receiving node shall return the same value in an Acknowledgement frame if the Ack bit is present in the received frame. For Backwards compatibility, an Acknowledgement frame received can hold Sequence number = 0.

3.36.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 2 x End node

3.36.2 Test Setup

1. Include both End nodes and secondary Controller to the Primary Controller's network.
2. Disable one of the End nodes' antenna and send a singlecast with MPDU = 0x00 (NOP) to it.
3. Enable the End node again and try sending a singlecast to it again.
4. Select both End nodes and send a multicast from the controller.

3.36.3 Test Result

2. Observe that the Controller re-tries sending the command to the disabled End node and all frames have the same sequence number.
 - a. The Controller tries reaching the destination node routing through the other End node and/or the Secondary Controller. The routed frames have the same sequence number.
3. The Controller transmits directly and the frame reaches correctly the destination Node.
 - a. The End node Answers with an Acknowledgement frame using either the same sequence number or sequence number = 0x0.
4. The multicast frame and its respective single cast follow-up frames have their own sequence numbers

3.36.4 Pass Criteria

1. The re-transmitted frames when the Controller doesn't reach the End node have the same Sequence Number. (8.1.3.3.7)
2. The routed frames that are repeated by the secondary Controller and the second End node have the same Sequence Number. (8.1.3.3.7)
3. The Ack frames, both routed and the final one directed from the Controller to the repeater have the same Sequence number as the original singlecast frame sent from the Controller. (8.1.3.3.7)
4. The Multicast and its follow-up singlecast have successive Sequence numbers. (8.1.3.3.7)
5. Sequence Number only has 4 bits going from 0x1 to 0xF. (8.1.3.3.7)

3.36.5 Fail Criteria

1. The retransmitted frames have their own Sequence Number value. (8.1.3.3.7)
2. The routed frames repeated by either of the repeaters have their own Sequence Number value. (8.1.3.3.7)
3. The Ack frames routed and the final one from the Controller to the repeater have different Sequence Number value. (8.1.3.3.7)
4. The Multicast and its successive Follow-up singlecast frames have the same Sequence Number value. (8.1.3.3.7)
5. Sequence Number has more than 4 bits of length and the singlecast can hold value 0x0. (8.1.3.3.7)

3.37 MPDU Format, Sequence number 3-channel

The Sequence Number in 3-channel is an 8-bit field of the MPDU Header (MHR). The same Sequence Number shall be used for all retransmissions of a given MPDU that first fails being delivered. A receiving node shall return the same value in an Acknowledgement frame if the Ack bit is present in the received frame. Sequence Number can be in the range from 0x00 to 0xFF, cycling through with 0x00 used after 0xFF.

3.37.1 Prerequisites

- 1 x Z-Wave Ziffer
- 2 x Z-Wave PC Controller
- 2 x End node

3.37.2 Test Setup

1. Include both End nodes and secondary Controller to the Primary Controller's network.
2. Disable one of the End nodes' antenna and send a singlecast with MPDU = 0x00 (NOP) to it.
3. Enable the End node again and try sending a singlecast to it again.
4. Select both End nodes and send a multicast from the controller.

3.37.3 Test Result

2. Observe that the Controller re-tries sending the command to the disabled End node and all frames have the same sequence number.
 - a. The Controller tries reaching the destination node routing through the other End node and/or the Secondary Controller. The routed frames have the same sequence number.
3. The Controller transmits directly the frame and it reaches correctly the destination Node.
 - a. The End node Answers with an Acknowledgement frame using either the same sequence number or sequence number = 0x0.
4. The multicast frame and its respective single cast follow-up frames have their own sequence numbers.

3.37.4 Pass Criteria

1. The re-transmitted frames when the Controller doesn't reach the End node have the same Sequence Number. (8.1.3.5)
2. The routed frames that are repeated by the secondary Controller and the second End node have the same Sequence Number. (8.1.3.5)
3. The Ack frames, both routed and the final one directed from the Controller to the repeater have the same Sequence number as the original singlecast frame sent from the Controller. (8.1.3.5)
4. The Multicast and its follow-up singlecast have successive Sequence numbers. (8.1.3.5)
5. Sequence Number only has 8 bits going from 0x00 to 0xFF. (8.1.3.5)

3.37.5 Fail Criteria

1. The retransmitted frames have their own Sequence Number value. (8.1.3.5)
2. The routed frames repeated by either of the repeaters have their own Sequence Number value. (8.1.3.5)
3. The Ack frames routed and the final one from the Controller to the repeater have different Sequence Number value. (8.1.3.5)
4. The Multicast and its successive Follow-up singlecast frames have the same Sequence Number value. (8.1.3.5)
5. Sequence Number has more than 8 bits of length (8.1.3.5)

3.38 MPDU Format, Length, 2-channel singlecast

The length field is 1 byte that indicates the length of the MPDU in bytes. It's limited by "aMacMaxMSDUSizeX" defined on table 8-18. A receiving node shall not accept a frame larger than the maximum length allowed for the actual data rate. For Singlecast in 2 channels, it's "aMacMaxMSDUSizeR1"/"aMacMaxMSDUSizeR2".

3.38.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.38.2 Test Setup

1. Include the End node to the Controller's Network.
2. Send a singlecast with MPDU = 0x00 (NOP) to the End node.
3. Look for the Length field.
4. Populate the MPDU with a long amount of random data (in Command Classes View, in the 'Send Data' section introduce the random bytes), less than "aMacMaxMSDUSizeR1"/"aMacMaxMSDUSizeR2" (54 Bytes) and send it to the End node.

3.38.3 Test Result

2. Communication is possible and End node answers with an Acknowledgement frame. Check on the Singlecast the Length field.
3. The Length field should be in Byte 7 of the frame and be show value 12 (0x0C) for a NOP MPDU.
4. The singlecast should show the corresponding size in the length field.

3.38.4 Pass Criteria

1. The Length field is only one byte in length. (8.1.3.4)
2. The Length field is in byte 7 of the Frame (8.1.3 – Figure 8.5)
3. The value of the Length field is always less or equal than "aMacMaxMSDUSizeR1"/"aMacMaxMSDUSizeR2". (8.1.3.4)

3.38.5 Fail Criteria

1. The Length field is different from one byte in length. (8.1.3.4)
2. The Length field is located outside byte 7 of the Frame (8.1.3 – Figure 8.5)
3. The value of the length field can be more than "aMacMaxMSDUSizeR1"/"aMacMaxMSDUSizeR2". (8.1.3.4)

3.39 MPDU Format, Length, 2-channel multicast

The length field is 1 byte that indicates the length of the MPDU in bytes. It's limited by "aMacMaxMSDUSizeX" defined on table 8-18. A receiving node shall not accept a frame larger than the maximum length allowed for the actual data rate. For multicast in 2 channels, it's "aMacMaxMSDUSizeMultiR1"/"aMacMaxMSDUSizeMultiR2", the full size comprises both the MPDU and the 29 bytes for the multicast mask.

3.39.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.39.2 Test Setup

1. Include the End nodes to the Controller's Network.
2. Send a singlecast with MPDU = 0x00 (NOP) to each End node.
3. Send a multicast with MPDU = 0x00 (NOP) to both End nodes.
4. Populate the MPDU with a long amount of random data, less than "aMacMaxMSDUSizeMultiR1"/"aMacMaxMSDUSizeMultiR2" and send it to both End nodes.

3.39.3 Test Result

2. Communication is possible and each End node answers with an Acknowledgement frame. Check on the Singlecast the Length field.
 - a. The Length field should be in Byte 7 of each frame and be show value 12 (0x0C) for a NOP MPDU.
3. The multicast is sent followed by a singlecast follow-up for each End node.
 - a. The Multicast frame has its Length byte in Byte 7, with a value of 41 (0x29) for a NOP MPDU for 2 End nodes.
4. The Multicast and follow-up singlecast should show the corresponding size in length.

3.39.4 Pass Criteria

1. The Length field is only one byte in length. (8.1.3.4)
2. The Length field is in byte 7 of the Frame (8.1.3 – Figure 8.6)
3. The value of the Length field is always less or equal than “aMacMaxMSDUSizeMultiR1”/“aMacMaxMSDUSizeMultiR2”. (8.1.3.4)

3.39.5 Fail Criteria

1. The Length field is different from one byte in length. (8.1.3.4)
2. The Length field is located outside byte 7 of the Frame (8.1.3 – Figure 8.6)
3. The value of the length field can be more than “aMacMaxMSDUSizeMultiR1”/“aMacMaxMSDUSizeMultiR2”. (8.1.3.4)

3.40 MPDU Format, Length, 3-channel singlecast

The length field is 1 byte that indicates the length of the MPDU in bytes. It's limited by "aMacMaxMSDUSizeX" defined on table 8-18. A receiving node shall not accept a frame larger than the maximum length allowed for the actual data rate. For Singlecast in 3 channels, it's "aMacMaxMSDUSizeR3".

3.40.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.40.2 Test Setup

1. Include the End node to the Controller's Network.
2. Send a singlecast with MPDU = 0x00 (NOP) to the End node.
3. Look for the Length field.
4. Populate the MPDU with a long amount of random data (in Command Classes View, in the 'Send Data' section introduce the random bytes), less than "aMacMaxMSDUSizeR3" and send it to the End node.

3.40.3 Test Result

2. Communication is possible and End node answers with an Acknowledgement frame. Check on the Singlecast the Length field.
3. The Length field should be in Byte 7 of the frame and be show value 13 (0x0D) for a NOP MPDU.
4. The singlecast should show the corresponding size in length.

3.40.4 Pass Criteria

1. The Length field is only one byte in length. (8.1.3.4)
2. The Length field is in byte 7 of the Frame (8.1.3 – Figure 8.7)
3. The value of the Length field is always less or equal than "aMacMaxMSDUSizeR3". (8.1.3.4)

3.40.5 Fail Criteria

1. The Length field is different from one byte in length. (8.1.3.4)
2. The Length field is located outside byte 7 of the Frame (8.1.3 – Figure 8.7)
3. The value of the length field can be more than "aMacMaxMSDUSizeR3". (8.1.3.4)

3.41 MPDU Format, Length, 3-channel multicast

The length field is 1 byte that indicates the length of the MPDU in bytes. It's limited by "aMacMaxMSDUSizeX" defined on table 8-18. A receiving node shall not accept a frame larger than the maximum length allowed for the actual data rate. For multicast in 3 channels, it's "aMacMaxMSDUSizeMultiR3", the full size comprises both the MPDU and the 29 bytes for the multicast mask.

3.41.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.41.2 Test Setup

1. Include the End nodes to the Controller's Network.
2. Send a singlecast with MPDU = 0x00 (NOP) to each End node.
3. Send a multicast with MPDU = 0x00 (NOP) to both End nodes.
4. Populate the MPDU with a long amount of random data (in Command Classes View, in the 'Send Data' section introduce the random bytes), less than "aMacMaxMSDUSizeMultiR3" and send it to both End nodes.

3.41.3 Test Result

2. Communication is possible and each End node answers with an Acknowledgement frame. Check on the Singlecast the Length field.
 - a. The Length field should be in Byte 7 of each frame and be show value 13 (0x0D) for a NOP MPDU.
3. The multicast is sent followed by a singlecast follow-up for each End node.
 - a. The Multicast frame has its Length byte in Byte 7, with a value of 42 (0x2A) for a NOP MPDU for 2 End nodes.
4. The Multicast and follow-up singlecast should show the corresponding size in length.

3.41.4 Pass Criteria

1. The Length field is only one byte in length. (8.1.3.4)
2. The Length field is in byte 7 of the Frame (8.1.3 – Figure 8.8)
3. The value of the Length field is always less or equal than “aMacMaxMSDUSizeMultiR3”. (8.1.3.4)

3.41.5 Fail Criteria

1. The Length field is different from one byte in length. (8.1.3.4)
2. The Length field is located outside byte 7 of the Frame (8.1.3 – Figure 8.8)
3. The value of the length field can be more than “aMacMaxMSDUSizeMultiR3”. (8.1.3.4)

3.42 MPDU Format, Destination ID, singlecast – 2-channel

The destination Node ID specifies a destination node in the same domain identified by the HomeID. It shall comply with table 8-15.

3.42.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 2 x End node

3.42.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include End nodes to Controller's network.
2. Send a singlecast with MPDU = 0x00 (NOP) to each End node.
3. Look for the Destination NodeID field in the frames on the Zniffer.
4. Remove one of the End Nodes with the second Controller.
5. Send a singlecast frame with MPDU = 0x00 (NOP) to the removed End node.

3.42.3 Test Result

2. Communication is correct. End nodes answer with an Acknowledgement frame.
3. Destination NodeID is byte 8 in the frames. It holds the value of the End node's NodeID.
4. The End node is removed from the first Controller's network.
5. The Controller tries to reach this End node but can't reach it.
 - a. The Controller retransmits and routes through the existing End node.
 - b. The remaining End node tries to route the frame to this node but can't reach it.

3.42.4 Pass Criteria

1. The Destination Node ID is one byte in length. (8.1.3.6)
2. The Destination Node ID can be any value up to 0xE8 (232) (8.1.3.6)
3. The Destination Node ID is in Byte 8 of the frame (8.1.3 – Figure 8.5)

3.42.5 Fail Criteria

1. The Destination Node ID is more than one byte in length (8.1.3.6).
2. The Destination Node ID can be any value beyond 0xE8 (232) (8.1.3.6).
3. Routing devices don't repeat all frames regardless of the Destination Node ID all the same (8.1.3.6).

3.43 MPDU Format, Destination ID, singlecast – 3-channel

The destination Node ID specifies a destination node in the same domain identified by the HomeID. It shall comply with table 8-15.

3.43.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 2 x End node

3.43.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include the two End nodes to Controller's network.
2. Send a singlecast with MPDU = 0x00 (NOP) to each End node.
3. Look for the Destination NodeID field in the frames on the Zniffer.
4. Remove one of the End Nodes with the second Controller.
5. Send a singlecast frame with MPDU = 0x00 (NOP) to the removed End node.

3.43.3 Test Result

2. Communication is correct. End nodes answer with an Acknowledgement frame.
3. Destination NodeID is byte 9 in the frames. It holds the value of the End node's NodeID.
4. The End node is removed from the first Controller's network.
5. The Controller tries to reach this End node but can't reach it.
 - a. The Controller retransmits and routes through the existing End node.
 - b. The remaining End node tries to route the frame to this node but can't reach it.

3.43.4 Pass Criteria

1. The Destination Node ID is one byte in length. (8.1.3.6)
2. The destination Node ID can be any value up to 0xE8 (232) (8.1.3.6)
3. The Destination Node ID is in Byte 9 of the frame (8.1.3 – Figure 8.6)

3.43.5 Fail Criteria

1. The Destination Node ID is more than one byte in length (8.1.3.6).
2. The Destination Node ID can be any value beyond 0xE8 (232) (8.1.3.6).
3. Routing devices don't repeat all frames regardless of the Destination Node ID all the same (8.1.3.6).

3.44 MPDU Format, Destination ID, multicast – 2-channel

The destination Node ID specifies a destination node in the same domain identified by the HomeID. It shall comply with table 8-15. A multicast shall carry a Multicast Control field and a multi-byte Multicast Bit Mask complying with Figure 8.14.

3.44.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.44.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include End nodes to Controller's network.
2. Send a Multicast to both End nodes with MPDU 0x00 (NOP).
3. Look for the Multicast Control byte in the multicast frame.
4. Look for the Multicast Bit Mask.
5. Look at the singlecast follow-up frames sent to each of the End nodes.
6. Generate a Multicast frame with the Acknowledgement Request bit set to 1, send it to both End nodes.
7. Generate a Multicast frame with the Address Offset sub-field set to 1, set the destination Node IDs to have +8 value turning into 10 & 11. Send it.
8. Generate a Multicast frame with Address Offset set to 0 and Number of Mask Bytes set to 20, send it to both End nodes.
9. Generate a Multicast frame with Address Offset set to 0 and Number of Mask Bytes set to 30, send it to both End nodes.
10. Generate a Multicast frame with Address Offset set to 0 and Number of Mask Bytes set to 29, include a list of 30 bytes set to 0x00 in the Mask Bytes list, send it.

3.44.3 Test Result

2. Multicast is sent to both End nodes correctly with a singlecast follow-up for each of them.
3. The Multicast Control Byte is byte 8 in the frame.
 - a. The Number of Mask Bytes sub-field is 5 bits in length, and it's set to 0x1D (length of mask bytes is 29).
 - b. The Address Offset sub-field is 3 bits in length, and it's set to 0x00.
4. The Multicast Bit Mask section starts in byte 9 and is 29 bytes in length.
 - a. It holds the mask for the selected End nodes (for End nodes 2 & 3, the mask should be $0x06 = 0110 \Rightarrow$ For bits 2 & 3 in the mask).
5. Each of the singlecast follow-up frames complies with the results step 3 for TC 41.
6. Both End nodes ignore the Multicast frame and don't respond to it because the Multicast frame does not have header type 0x01 (singlecast).
7. The multicast frame has Address Offset sub-field set to 1.
 - a. The Mask Byte fields show: 10 & 11.
 - b. The destination Nodes in the Zniffer are 10 & 11.
8. The multicast frame has is addressed correctly to Node ID's 2 & 3.
 - a. The multicast frame has a total of only 20 Mask Bytes.
 - b. The frame is not answered by the End nodes.
9. The Multicast is transmitted correctly
 - a. The Mask Bytes Subfield is set to 30.
 - b. The amount of Mask Bytes is 30.
10. The Multicast is transmitted correctly
 - a. The Mask Bytes subfield is set to 29.
 - b. Setting 30 Bytes on 00 considers the first one to be destination NodeID = 0x00.
 - c. The amount of Bytes set to 0x00 is 30.

3.44.4 Pass Criteria

1. The multicast frame has the Multicast Control Byte in position 8 in the frame. (8.1.3, Figure 8.7).
2. The multicast frame has its Acknowledgement Request bit set to 0 (8.1.3.6.1)
3. The Address Offset sub-field is 3 bits long (8.1.3.6.1 – Figure 8.14)
4. The Number of Mask Bytes sub-field is 5 bits long and be set to 0x1D (29) (8.1.3.6.1 – Figure 8.14)
5. The amount of Mask Bytes is exactly 29 (8.1.3.6.1 – Figure 8.14)

3.44.5 Fail Criteria

1. The Multicast Control Byte is NOT in position 8 in the frame. (8.1.3, Figure 8.7).
2. The multicast frame has its Acknowledgement Request bit set to 1 (8.1.3.6.1)
3. The Address Offset sub-field is NOT 3 bits long (8.1.3.6.1 – Figure 8.14)
4. The Number of Mask Bytes sub-field is NOT 5 bits long (8.1.3.6.1 – Figure 8.14)
5. There is a different amount of Mask Bytes than 29 (8.1.3.6.1 – Figure 8.14)

3.45 MPDU Format, Destination ID, multicast – 3-channel

The destination Node ID specifies a destination node in the same domain identified by the HomeID. It shall comply with table 8-15. A multicast shall carry a Multicast Control field and a multi-byte Multicast Bit Mask complying with Figure 8.14.

3.45.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x AL End node
- 2 x FL End node

3.45.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include all End nodes to Controller's network.
2. Send a Multicast to both AL End nodes with MPDU 0x00 (NOP).
3. Look for the Multicast Control byte in the multicast frame.
4. Repeat steps 2 & 3 for the FL nodes in order to Test R2.
5. Look for the Multicast Bit Mask.
6. Look at the singlecast follow-up frames sent to each of the End nodes.
7. Generate a Multicast frame with the Acknowledgement Request bit set to 1, send it to both End nodes.
8. Generate a Multicast frame with the Address Offset sub-field set to 1 and configure destination NodeID to be 10 & 11, send it.
9. Generate a Multicast frame with Address Offset set to 0 and Number of Mask Bytes set to 20, send it to both End nodes.
10. Repeat steps 8 & 9 for the FL nodes in order to Test R2.
11. Generate a Multicast frame with Address Offset set to 0 and Number of Mask Bytes set to 30, send it to both End nodes.
12. Generate a Multicast frame with Address Offset set to 0 and Number of Mask Bytes set to 29, include a list of 30 bytes set to 0x00 in the Mask Bytes list, send it to both End nodes.

3.45.3 Test Result

2. Multicast is sent to both End nodes correctly with a singlecast follow-up for each of them.
3. The Multicast Control Byte is byte 9 in the frame.
 - a. The Number of Mask Bytes sub-field is 5 bits in length, and it's set to 0x1D (length of mask bytes is 29).
 - b. The Address Offset sub-field is 3 bits in length, and it's set to 0x00.
4. Results 2 & 3 for the FL are the same but in R2.
5. The Multicast Bit Mask section starts in byte 10 and is 29 bytes in length.
 - a. It holds the mask for the selected End nodes (for End nodes 2 & 3, the mask should be 0x06 = 0110 => For bits 2 & 3 in the mask).
6. Each of the singlecast follow-up frames complies with the results step 3 for TC 39.
7. Both End nodes ignore the Multicast frame and don't respond to it because the Multicast frame does not have header type 0x01 (singlecast).
 - a. The follow-up singlecast have the Acknowledgement Request bit set to 1 and they are answered with an Acknowledgement frame.
8. The multicast frame has Address Offset sub-field set to 1.
 - a. The Mask Byte fields show: 10 & 11.
 - b. The destination Nodes in the Zniffer are 10 & 11.
9. The multicast frame has is addressed correctly to Node ID's 2 & 3.
 - a. The multicast frame has a total of only 20 Mask Bytes.
 - b. The frame is not answered by the End nodes.
10. Results 8 & 9 are the same for the FL nodes in R2.
11. The Multicast is transmitted correctly
 - a. The Mask Bytes Subfield is set to 30.
 - b. The amount of Mask Bytes is 30.
12. The Multicast is transmitted correctly
 - a. The Mask Bytes subfield is set to 29.
 - b. Setting 30 Bytes on 00 considers the first one to be destination NodeID = 0x00.
 - c. The amount of Bytes set to 0x00 is 30.

3.45.4 Pass Criteria

1. The multicast frame has the Multicast Control Byte in position 8 in the frame. (8.1.3, Figure 8.7).
2. The multicast frame has its Acknowledgement Request bit set to 0 (8.1.3.6.1)
3. The Address Offset sub-field is 3 bits long (8.1.3.6.1 – Figure 8.14)
4. The Number of Mask Bytes sub-field is 5 bits long and be set to 0x1D (29) (8.1.3.6.1 – Figure 8.14)
5. The amount of Mask Bytes is exactly 29 (8.1.3.6.1 – Figure 8.14)

3.45.5 Fail Criteria

1. The Multicast Control Byte is NOT in position 8 in the frame. (8.1.3, Figure 8.7).
2. The multicast frame has its Acknowledgement Request bit set to 1 (8.1.3.6.1)
3. The Address Offset sub-field is NOT 3 bits long (8.1.3.6.1 – Figure 8.14)
4. The Number of Mask Bytes sub-field is NOT 5 bits long (8.1.3.6.1 – Figure 8.14)
5. There is a different amount of Mask Bytes than 29 (8.1.3.6.1 – Figure 8.14)

3.46 MPDU Format, Mac Footer (MFR): FCS – 2-channel

FCS is the 8-bit non-correcting Frame Check Sequence (FCS) used for validating the integrity of a frame, used in 2-channel frequencies. It shall be calculated from the HomeID field to the Data Payload, both included. This applies only for Rates R1 & R2.

3.46.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End nodes
- 1 x Frame Generator

3.46.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include End nodes to the Controller's Network.
2. Send a singlecast with MPDU = 0x00 (NOP) to each End node.
3. Look for the FCS field in each frame.
4. Generate a singlecast frame with MPDU = 0x00 (NOP) and modify its FCS value to a random hardcoded value, send it to each End node separately.
5. Generate a singlecast frame with MPDU = 0x00 (NOP) and modify its FCS value to be more than 8 bits, send it to each End node separately.
6. Generate a singlecast frame with MPDU = 0x00 (NOP) and modify its FCS value to be less than 8 bits, send it to each End node separately.
7. Send an unmodified multicast frame with MPDU = 0x00 (NOP) to both End nodes. Look for the FCS in the multicast.
8. Generate a multicast frame with MPDU = 0x00 (NOP) and modify its FCS value to a random hardcoded value, send it to both End nodes. Look for the FCS in the multicast.
9. Generate a multicast frame with MPDU = 0x00 (NOP) and modify its FCS value to be less than 8 bits, send it to both End nodes. Look for the FCS in the multicast.

3.46.3 Test Result

2. Communication is correct with both End nodes and they answer with an Acknowledgement frame each.
3. Make sure there are 8 MFR bits corresponding to the FCS section in each frame.
4. Neither End node answers to the frame, since the FCS does not allow to verify its integrity.
 - a. Each time the frame is displayed on the Ziffer as a CRC error.
5. Neither End node answers to the frame, since the modified FCS does not allow to verify its integrity.
 - a. Each time the frame is displayed on the Ziffer as a CRC error.
6. Neither End node answers to the frame, since the modified FCS does not allow to verify its integrity.
 - a. Each time the frame is displayed on the Ziffer as a CRC error.
 - b. The controller tries retransmitting the frame since it doesn't receive an Acknowledgement frame and tries routing it through the other End node.
 - c. Neither End node routes the retransmitted frame, since it still holds the same shortened FCS and they are unable to distinguish the contents of the frame.
7. The multicast is not responded with an Acknowledgement frame by either End node.
 - a. The FCS in the multicast frame is 8 bits long.
8. The multicast is not responded with an Acknowledgement frame by either End node.
 - a. The multicast frame is displayed on the Ziffer as a CRC error.
 - b. The FCS in the multicast frame is 8 bits long.
9. The multicast is not responded with an Acknowledgement frame by either End node.
 - a. The multicast frame is displayed on the Ziffer as a CRC error.
 - b. The FCS in the multicast frame is less than 8 bits long and makes the frame end in values not defined by the user.

3.46.4 Pass Criteria

1. The FCS can only be 8 bits long at the end of the frame (8.1.3.8)
2. It signals the integrity of the frame and when it is modified, the receiver and Ziffer are incapable of identifying it (8.1.3.8)

3.46.5 Fail Criteria

1. The FCS can be different from 8 bits long at the end of the frame (8.1.3.8)
2. When it is modified, the receiver and Ziffer are capable of identifying it and responding to the frame (8.1.3.8)

3.47 MPDU Format, Mac Footer (MFR): CRC – 3-channel

CRC is the 16-bit non-correcting Cyclic Redundancy Code (CRC) used for validating the integrity of a frame, used in 3-channel frequencies. It shall be calculated from the HomeID field to the Data Payload, both included.

3.47.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.47.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include End nodes to the Controller's Network.
2. Send a singlecast with MPDU = 0x00 (NOP) to each End node.
3. Look for the CRC field in each frame.
4. Generate a singlecast frame with MPDU = 0x00 (NOP) and modify its CRC value to a random hardcoded value, send it to each End node separately.
5. Generate a singlecast frame with MPDU = 0x00 (NOP) and modify its CRC value to be more than 16 bits, send it to each End node separately.
6. Generate a singlecast frame with MPDU = 0x00 (NOP) and modify its CRC value to be less than 16 bits, send it to each End node separately.
7. Send an unmodified multicast frame with MPDU = 0x00 (NOP) to both End nodes. Look for the CRC in the multicast.
8. Look for the CRC field in each singlecast follow-up frame.
9. Generate a multicast frame with MPDU = 0x00 (NOP) and modify its CRC value to a random hardcoded value, send it to both End nodes. Look for the CRC in the multicast.
10. Generate a multicast frame with MPDU = 0x00 (NOP) and modify its CRC value to be less than 8 bits, send it to both End nodes. Look for the CRC in the multicast.

3.47.3 Test Result

2. Communication is correct with both End nodes and they answer with an Acknowledgement frame each.
3. Make sure there are 16 MFR bits corresponding to the CRC section in each frame.
4. Neither End node answers to the frame, since the CRC does not allow to verify its integrity.
 - a. Each time the frame is displayed on the Zniffer as a CRC error.
5. Neither End node answers to the frame, since the modified CRC does not allow to verify its integrity.
 - a. Each time the frame is displayed on the Zniffer as a CRC error.
6. Neither End node answers to the frame, since the modified CRC does not allow to verify its integrity.
 - a. Each time the frame is displayed on the Zniffer as a CRC error.
7. The multicast is not responded with an Acknowledgement frame by either End node.
 - a. The CRC in the multicast frame is 16 bits long.
8. Same as in step 3.
9. The multicast is not responded with an Acknowledgement frame by either End node.
 - a. The multicast frame is displayed on the Zniffer as a CRC error.
 - b. The FCS in the multicast frame is 16 bits long.
10. The multicast is not responded with an Acknowledgement frame by either End node.
 - a. The multicast frame is displayed on the Zniffer as a CRC error.
 - b. The CRC in the multicast frame is less than 12 bits long and makes the frame end in values not defined by the user.

3.47.4 Pass Criteria

1. The CRC can only be 16 bits long at the end of the frame (8.1.3.9)
2. It signalizes the integrity of the frame and when it is modified, the receiver and Zniffer are incapable of identifying it (8.1.3.9)

3.47.5 Fail Criteria

1. The CRC can be different from 16 bits long at the end of the frame (8.1.3.9)
2. When it is modified, the receiver and Zniffer are capable of identifying it and responding to the frame (8.1.3.9)

3.48 MPDU Format, Beam Frame Format, 2-channel

Beam frames are used to awake Frequently Listening (FL) nodes. They are transmitted back to back to ensure an FL node can detect a beam within a short time window. Each beam frame shall carry the Beam Tag and NodeID fields. The NodeID field should be followed by the optional HomeID Hash field. HomeID Hash values 0x0A, 0x4A, 0x55 shall be accepted as potential match for the actual HomeID. An FL node shall stay awake to receive the MPDU that follows if there is a match with the Hash or NodeID, else it may return to sleep.

3.48.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x FLiRS End nodes

3.48.2 Test Setup

1. Include FLiRS End node to the Controller's Network.
2. After inclusion, reset/power cycle FLiRS to wake it up and send right away a singlecast with MPDU 0x00 (NOP) to the End node.
3. Wait 10 seconds to make sure FLiRS is asleep. Send the frame again.
4. Observe the Beam frame is sent to the End node.
5. Observe the Beam Stop frame.
6. Once the beaming reaches the FLiRS in a waking up state, the FLiRs stays awake so that the Controller tries with a transmission of the original singlecast again.

3.48.3 Test Result

2. Communication is correct and FLiRS End node answers with an Acknowledgement frame.
3. Observe that Controller can't deliver the frame and retransmits it.
 - a. As soon as it fails, it starts sending Beam frames to the FLiRs End node.
4. The Beam is shown correctly in the Zniffer.
5. The Beam Stop frame shows the beam count of 230.
6. After the beaming, the Controller tries with the original singlecast sent and the FLiRS End node answers with an Acknowledgement frame in response.

3.48.4 Pass Criteria

1. The Beam frame consists of: (8.1.3.10 – Figure 8-18)
 - a. A Beam tag: 0x55 (1 byte). (8.1.3.10 – Table 8-17)
 - b. Destination NodeId: 0x01 .. 0xE8, 0xFF (1 byte). (8.1.3.10 – Table 8-17)
 - c. (Optional) Field “HomeID Hash Included”: 0x01 (1 byte). (8.1.3.10 – Table 8-17)
 - d. (Optional) Home ID Hash: the actual Hash or 0x0A, 0x4A or 0x55. (8.1.3.10 – Table 8-17)

3.48.5 Fail Criteria

1. Any of the elements of the Beam frame deviates from the description (8.1.3.10 – Table 8-17)

3.49 MPDU Format, Beam Frame Format, 3-channel

Beam frames are used to awake Frequently Listening (FL) nodes. They are transmitted back to back to ensure an FL node can detect a beam within a short time window. Each beam frame shall carry the Beam Tag and NodeID fields. The NodeID field should be followed by the optional HomeID Hash field. HomeID Hash values 0x0A, 0z4A, 0x55 shall be accepted as potential match for the actual HomeID. An FL node shall stay awake to receive the MPDU that follows if there is a match with the Hash or NodeID, else it may return to sleep.

3.49.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x FLiRS End nodes

3.49.2 Test Setup

1. Include FLiRS End node to the Controller's Network.
2. Send right away a singlecast with MPDU 0x00 (NOP) to the End node.
3. Wait 10 seconds to make sure FLiRS is asleep. Send the frame again.
4. Observe one of the Beam frames sent to the End node.
5. Observe the Beam Stop frames.
6. Once the beaming reaches the FLiRS in a waking up state, the FLiRS stays awake so that the Controller tries with a transmission of the original singlecast again.

3.49.3 Test Result

2. Communication is correct and FLiRS End node answers with an Acknowledgement frame.
3. Observe that Controller can't deliver the frame and retransmits it.
 - a. As soon as it fails, it starts sending Beam frames to the FLiRS End node.
4. The Beam is shown correctly in the Zniffer. Ignore CRC errors.
5. The Beam Stop frames show a beam count value. This value can vary between different Beam Stop frames without abiding to any range.
6. After the beaming, the Controller tries with the original singlecast sent and the FLiRS End node answers with an Acknowledgement frame in response.

3.49.4 Pass Criteria

1. The Beam frame consists of: (8.1.3.10 – Figure 8-18)
 - a. A Beam tag: 0x55 (1 byte). (8.1.3.10 – Table 8-17)
 - b. Destination NodeId: 0x01 .. 0xE8, 0xFF (1 byte). (8.1.3.10 – Table 8-17)
 - c. (Optional) Field “HomeID Hash Included”: 0x01 (1 byte). (8.1.3.10 – Table 8-17)
 - d. (Optional) Home ID Hash: the actual Hash or 0x0A, 0x4A or 0x55. Present only if the “homeID Hash included” field is set to ‘true’ (8.1.3.10 – Table 8-17)

3.49.5 Fail Criteria

1. Any of the elements of the Beam frame deviates from the description (8.1.3.10 – Table 8-17)

3.50 MPDU Format, Fragmented Frame Format, 3-channel frequency

A Beam Fragment is used for 3-channel frequencies. It comprises a number of beam frames. The Beam Fragment duration is in the range 110-115 ms. Beam frames shall be sent back to back to ensure the FL node can detect it upon waking up. The next Beam Fragment shall begin 190 – 200 ms after the beginning of the previous one. They shall be sent in different channels. When recognizing a Beam the receiving node shall answer with an Acknowledgement frame, upon receiving it, the Controller shall send the original singlecast but only if the Acknowledgement frame matches the originating HomeId and the NodeID of the destination NodeID on the original singlecast. A Beam Fragment can be addressed to 0xFF (255) turning it into a broadcast Wake Up Beam, but it can't be answered directly by the End node.

3.50.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 2 x FLiRS End nodes

3.50.2 Test Setup

1. Include both FLiRS End node to the Controller's Network.
2. Wait 10 seconds for FLiRs to sleep. Send a singlecast with MPDU 0x00 (NOP) to one of the End nodes.
3. Remove the second FLiRs End Node with the second Controller.
4. Send a singlecast with MPDU 0x00 (NOP) to the removed End node.

3.50.3 Test Result

2. Observe there is at least one wake up Beam frames sent to the End node.
 - a. Each Beam Fragment is sent between 80 and 90ms after the Beam Stop from the previous Beam Fragment (as to begin between 190 – 200 ms from the beginning of the previous Beam Fragment).
 - b. Each Wake Up Beam Start is sent in a different channel than the corresponding Wake Up Beam Stop.
 - c. When the End node recognizes the Beam, it answers with an Acknowledgement frame.
 - d. Controller repeats the original singlecast.
3. The second FLiRs is removed from the first Controller's Network but its NodeID remains in the first Controller's Node List.
4. Observe there are 3 wake up Beam frames sent to the End node.
 - a. The End node never recognizes the beam and the Controller continues sending the Wake Up Fragment until it times out.

3.50.4 Pass Criteria

1. There is at least one wake up Beam frames sent to the End node before the End Node wakes up (8.1.3.11).
2. The fragment lasts between 110-115ms (8.1.3.11).
3. There are between 190 – 200ms between two WakeUp Beam Start in the Fragment (8.1.3.11).
4. The Fragments are sent in different Channels (8.1.3.11).
5. The End node answers the Beam with an Acknowledgement frame and the Controller repeats the original singlecast (8.1.3.11).
6. It's used only in 3-channel frequencies (8.1.3.15)

3.50.5 Fail Criteria

1. Any of the Pass Criteria is not met.

3.51 MPDU Format, Continuous Beam Format, 2-channel frequency

A continuous beam is used for 2-channel frequencies. It's a series of Beam Frames sent over a period of time. They shall be sent back to back to prevent interruptions. It can address any node from 1 to 232 and 255. It may be a short continuous beam up to 300ms or a long continuous beam up to 1160ms. IT shall always be followed by a singlecast frame.

3.51.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 2 x FLiRS End nodes

3.51.2 Test Setup

1. Include both FLiRS End nodes to the first Controller's Network.
2. Wait 10 seconds for FLiRs to sleep. Send a singlecast with MPDU 0x00 (NOP) to one of the End nodes.
3. Using the second Controller, the second FLiRs is removed from the first Controller's Network but its NodeID remains in the first Controller's Node List.
4. On the First Controller, send a singlecast with MPDU 0x00 (NOP) to the removed End node.

3.51.3 Test Result

2. Observe there is at least 1 wake up Beam frame sent to the End node.
 - a. The Continuous Beam sends the Start and the Stop with approximately 1100ms of difference.
 - b. When the Controller finishes the Continuous Beam, it repeats the original singlecast.
 - c. Since the End node recognizes the Beam, it answers with an Acknowledgement frame.
3. The second FLiRs is removed from the first Controller's Network but its NodeID remains in the first Controller's Node List
4. Observe there is 1 wake up Beam frame sent to the End node.
 - a. The End node never recognizes the beam and never wakes up.
 - b. The Controller continues sending the Wake Up Continuous Beam.
 - c. The Controller tries sending the singlecast again unsuccessfully.
 - d. The Controller sends Continuous Beam followed by the singlecast until it times out.

3.51.4 Pass Criteria

1. There is at least 1 wake up Continuous Beam frame sent to the End node (8.1.3.13).
2. The Continuous Beam lasts between 300-1160ms (8.1.3.13).
3. The Continuous Beams are sent in the same Channel.
4. After the Continuous Beam, the Controller repeats the original singlecast and The End node answers with an Acknowledgement frame if it validated the Beam correctly (8.1.3.13).
5. It's used only in 2-channel frequencies (8.1.3.14).

3.51.5 Fail Criteria

1. Any of the Pass Criteria is not met.

3.52 (3.34 – Negative Testing) MPDU Format, Frame Control, Header Type, Acknowledgement

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The header type defines the frame Header type. A broadcast MPDU is a singlecast MPDU (type 0x01) carrying destination Node ID = 0xFF.

3.52.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.52.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include the End node Controller to Primary Controller's network.
2. Generate an Acknowledgement frame with Header going from 0x01 to 0x0F (except 0x03) according to table 8-14 to be answered by the End node to the Primary Controller and send a singlecast to the End node for each header type.
3. Generate an Acknowledgement frame with Header going from 0x01 to 0x0F (except 0x03) according to table 8-14 to be answered by the End node to Node ID 0xFF (255) and send a singlecast to the End node for each header type.

3.52.3 Test Result

2. Each frame answered is constructed as an Acknowledgement frame, but with the corresponding header from table 8-14.
 - a. Therefore, it's displayed on the zniffer as the expected type.
 - b. Since the frames are not identified as Acknowledgement Header Type, the Primary Controller tries to retransmit each time.
3. Each frame answered is constructed as an Acknowledgement frame, but with the corresponding header from table 8-14 and addressed to Node ID 0xFF.
 - a. Therefore, it's displayed on the zniffer as the expected type except for type 0x01, showing as a Broadcast.
 - b. Since the frames are not identified as Acknowledgement Header Type, the Primary Controller tries to retransmit each time.

3.52.4 Pass Criteria

1. Each frame sent by the Controller in 2. is answered with the corresponding type on the Zniffer, making each frame correctly defined. (8.1.3.3.5)
2. None of the frames sent in 2. Are answered by the Primary Controller by definition.
3. None of the frames sent in 3. Are answered by the Primary Controller by definition.

3.52.5 Fail Criteria

1. Any frame is displayed as Acknowledgement on the Zniffer regardless of the different Header. (8.1.3.3.5)
2. Any frame sent in 2. received an Acknowledgement frame.
3. Any frame sent in 3. received an Acknowledgement frame.

3.53 (3.36 - Negative Testing) MPDU Format, Frame Control, Sequence number 2-channel

The Frame Control field is 16 bits (2 bytes) in length. It defines the frame type and other control flags. The sequence number is a 4-bit sub-field provided by higher layers when transmitting. The same Sequence Number shall be used for all retransmissions of a given MPDU that first fails being delivered. A receiving node shall return the same value in an Acknowledgement frame if the Ack bit is present in the received frame. For Backwards compatibility, an Acknowledgement frame received can hold Sequence number = 0.

3.53.1 Prerequisites

- 1 x Z-Wave Ziffer
- 2 x Z-Wave PC Controller
- 2 x End node

3.53.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include both End nodes and secondary Controller to the Primary Controller's network.
2. Configure an Acknowledgement frame so that it has a random non-zero static value on the Secondary Controller when the Primary Controller transmits a singlecast to it and proceed to send a singlecast to the Secondary Controller.
3. Configure an Acknowledgement frame so that it has a static value of zero on the Secondary Controller when the Primary Controller transmits a singlecast to it and proceed to send a singlecast to the Secondary Controller.
4. Configure a singlecast frame with static sequence number and send it twice or more to one of the End nodes from the Primary Controller.
5. Configure a singlecast frame with static sequence number set to 0 and send it twice or more to one of the End nodes from the Primary Controller.

3.53.3 Test Result

2. When receiving the Singlecast, the secondary Controller responds with the generated Acknowledgement frame with the static Sequence Number value.
 - a. When the Controller received this Acknowledgement frame with a Sequence Number value different from the singlecast it transmitted, it tries to retransmit the frame again. Since this is equivalent to not having received the proper Acknowledgement frame.
3. When receiving the Singlecast, the secondary Controller responds with the generated Acknowledgement frame with the static Number value set to 0.
 - a. The Primary Controller accepts this Acknowledgement frame correctly.
4. The End node receiving the Singlecast answers correctly to the first one with an Acknowledgement frame using the same Sequence Number.
 - a. In the following frames, it answers the frame, as with the first one.
5. The End node receiving the Singlecast with Sequence Number set to answers to it with sequence number 0

3.53.4 Pass Criteria

1. The Ack frames with Sequence Number set to zero are accepted by the Primary Controller. (8.1.3.3.7)
2. Acknowledgement frames with value that do not match the one of the singlecast that originated them are rejected by the Controller and re-transmitted by the receiving node. (8.1.3.3.7)
3. The Receiving node returns an Acknowledgement frame with the same sequence number value (8.1.3.3.7)

3.53.5 Fail Criteria

1. The Ack frames with Sequence number set to 0 are rejected by the Primary Controller. (8.1.3.3.7)
2. All Acknowledgement frames with non-zero value different from the singlecast that originated them are accepted. (8.1.3.3.7)
3. The Acknowledgement frames are responded with a different value to the sequence number of the received singlecast, except to 0 (8.1.3.3.7)

3.54 (3.37 - Negative Testing) MPDU Format, Sequence number 3-channel

The Sequence Number in 3-channel is an 8-bit field of the MPDU Header (MHR). The same Sequence Number shall be used for all retransmissions of a given MPDU that first fails being delivered. A receiving node shall return the same value in an Acknowledgement frame if the Ack bit is present in the received frame. Sequence Number can be in the range from 0x00 to 0xFF, cycling through with 0x00 used after 0xFF.

3.54.1 Prerequisites

- 1 x Z-Wave Zniffer
- 2 x Z-Wave PC Controller
- 2 x End node

3.54.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include both End nodes and secondary Controller to the Primary Controller's network.
2. Configure an Acknowledgement frame so that it has a random static value on the Secondary Controller when the Primary Controller transmits a singlecast to it and proceed to send a singlecast to the Secondary Controller.
3. Configure a singlecast frame with static sequence number and send it twice or more to one of the End nodes from the Primary Controller.

3.54.3 Test Result

2. When receiving the Singlecast, the secondary Controller responds with the generated Acknowledgement frame with the static Sequence Number value.
 - a. When the Controller received this Acknowledgement frame with a Sequence Number value different from the singlecast it transmitted, it tries to retransmit the frame again. Since this is equivalent to not having received the proper Acknowledgement frame.
3. The End node receiving the Singlecast answers correctly to all the frames using the same Sequence Number.
 - a. In the following frames, it answers the frame, in the same way as the previous ones.

3.54.4 Pass Criteria

1. Acknowledgement frames with value that do not match the one of the singlecast that originated them are rejected by the Controller and re-transmitted by the receiving node. (8.1.3.5)

3.54.5 Fail Criteria

1. All Acknowledgement frames with value different from the singlecast that originated them are accepted. (8.1.3.5)

3.55 (3.38 - Negative Testing) MPDU Format, Length, 2-channel singlecast

The length field is 1 byte that indicates the length of the MPDU in bytes. It's limited by "aMacMaxMSDUSizeX" defined on table 8-18. A receiving node shall not accept a frame larger than the maximum length allowed for the actual data rate. For Singlecast in 2 channels, it's "aMacMaxMSDUSizeR1"/"aMacMaxMSDUSizeR2".

3.55.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.55.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include the End node to the Controller's Network.
2. Generate a singlecast with MPDU = 0x00 (NOP) and modify the value of the Length field (Byte 7) to be assigned a value more than 11 and less than 54. Send it to the End node.

3.55.3 Test Result

2. When the End node receives it, the stated size and the actual size as well as the FCS values do not correspond, and the End node ignores the singlecast.

3.55.4 Pass Criteria

1. The receiving node ignores all instances where the Length field does not match the actual length of the frame. (8.1.3.4)

3.55.5 Fail Criteria

1. The receiving node accepts and answers with an Acknowledgement frame any frame regardless of the size and value of the Length field. (8.1.3.4)

3.56 (3.39 - Negative Testing) MPDU Format, Length, 2-channel multicast

The length field is 1 byte that indicates the length of the MPDU in bytes. It's limited by "aMacMaxMSDUSizeX" defined on table 8-18. A receiving node shall not accept a frame larger than the maximum length allowed for the actual data rate. For multicast in 2 channels, it's "aMacMaxMSDUSizeMultiR1"/"aMacMaxMSDUSizeMultiR2", the full size comprises both the MPDU and the 29 bytes for the multicast mask.

3.56.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.56.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include the End nodes to the Controller's Network.
2. Generate a multicast with MPDU = 0x00 (NOP) and modify the Length field to be more than 42 and less than 54. Send it to the End nodes.

3.56.3 Test Result

2. The multicast is not responded, and the End nodes ignore the singlecast follow-up frames.
 - a. The Controller tries re-transmitting the same singlecasts because of not receiving an Acknowledgement frame from either End node.

3.56.4 Pass Criteria

1. The receiving node ignores all instances where the Length field does not match the actual length of the frame. (8.1.3.4)

3.56.5 Fail Criteria

1. The receiving node accepts and answers with an Acknowledgement frame any frame regardless of the size and value of the Length field. (8.1.3.4)

3.57 (3.40 - Negative Testing) MPDU Format, Length, 3-channel singlecast

The length field is 1 byte that indicates the length of the MPDU in bytes. It's limited by "aMacMaxMSDUSizeX" defined on table 8-18. A receiving node shall not accept a frame larger than the maximum length allowed for the actual data rate. For Singlecast in 3 channels, it's "aMacMaxMSDUSizeR3".

3.57.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x End node

3.57.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include the End node to the Controller's Network.
2. Generate a singlecast with MPDU = 0x00 (NOP) and modify the Length field to be more than 12 and less than 158. Send it to the End node.

3.57.3 Test Result

2. When the End node receives it, the stated size and the actual size as well as the FCS values do not correspond, and the End node ignores the singlecast.

3.57.4 Pass Criteria

1. The receiving node ignores all instances where the Length field does not match the actual length of the frame. (8.1.3.4)

3.57.5 Fail Criteria

1. The receiving node accepts and answers with an Acknowledgement frame any frame regardless of the size and value of the Length field. (8.1.3.4)

3.58 (3.41 - Negative Testing) MPDU Format, Length, 3-channel multicast

The length field is 1 byte that indicates the length of the MPDU in bytes. It's limited by "aMacMaxMSDUSizeX" defined on table 8-18. A receiving node shall not accept a frame larger than the maximum length allowed for the actual data rate. For multicast in 3 channels, it's "aMacMaxMSDUSizeMultiR3", the full size comprises both the MPDU and the 29 bytes for the multicast mask.

3.58.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.58.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include the End nodes to the Controller's Network.
2. Generate a multicast with MPDU = 0x00 (NOP) and modify the Length field to be more than 42 and less than 158. Send it to the End nodes.

3.58.3 Test Result

2. The multicast is not responded, and the End nodes ignore the singlecast follow-up frames. *

3.58.4 Pass Criteria

1. The receiving node ignores all instances where the Length field does not match the actual length of the frame. (8.1.3.4)

3.58.5 Fail Criteria

1. The receiving node accepts and answers with an Acknowledgement frame any frame regardless of the size and value of the Length field. (8.1.3.4)

3.59 (3.42 - Negative Testing) MPDU Format, Destination ID, singlecast – 2-channel

The destination Node ID specifies a destination node in the same domain identified by the HomeID. It shall comply with table 8-15.

3.59.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.59.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include End nodes to Controller's network.
2. Generate a singlecast frame with Destination ID value of 0xFF (255), send it.

3.59.3 Test Result

2. The Controller sends this frame as a Broadcast.
 - a. The End nodes don't respond to this Broadcast frame.

3.59.4 Pass Criteria

1. Frames sent with a reserved or broadcast destination ID are not acknowledged by any node in the network. (8.1.3.6)
2. Frames sent with a reserved destination ID are not forwarded to the higher layers by any node in the network. (8.1.3.6)

3.59.5 Fail Criteria

1. Listening devices respond the singlecast addressed to reserved or Broadcast destination ID. (8.1.3.6)
2. Listening devices forward the frame with a reserved destination ID to the higher layers. (8.1.3.6)

3.60 (3.43 - Negative Testing) MPDU Format, Destination ID, singlecast – 3-channel

The destination Node ID specifies a destination node in the same domain identified by the HomeID. It shall comply with table 8-15.

3.60.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 2 x End node

3.60.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include End nodes to Controller's network.
2. Generate a singlecast frame with Destination ID value of 0xFF (255), send it.

3.60.3 Test Result

2. The Controller sends this frame as a Broadcast.
 - a. The End nodes don't respond to this Broadcast frame.

3.60.4 Pass Criteria

1. Frames sent with a reserved or broadcast destination ID are not acknowledged by any node in the network. (8.1.3.6)
2. Frames sent with a reserved destination ID are not forwarded to the higher layers by any node in the network. (8.1.3.6)

3.60.5 Fail Criteria

1. Listening devices respond the singlecast addressed to reserved or Broadcast destination ID. (8.1.3.6)
2. Listening devices forward the frame with a reserved destination ID to the higher layers. (8.1.3.6)

3.61 (3.50 - Negative Testing) MPDU Format, Fragmented Frame Format, 3-channel frequency

A Beam Fragment is used for 3-channel frequencies. It comprises a number of beam frames. The Beam Fragment duration is in the range 110-115 ms. Beam frames shall be sent back to back to ensure the FL node can detect it upon waking up. The next Beam Fragment shall begin 190 – 200 ms after the beginning of the previous one. They shall be sent in different channels. When recognizing a Beam the receiving node shall answer with an Acknowledgement frame, upon receiving it, the Controller shall send the original singlecast but only if the Acknowledgement frame matches the originating HomeId and the NodeID of the destination NodeID on the original singlecast. A Beam Fragment can be addressed to 0xFF (255) turning it into a broadcast Wake Up Beam, but it can't be answered directly by the End node.

3.61.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x FLiRS End nodes

3.61.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include FLiRS End node to the Controller's Network.
2. Generate a Wake up Beam Frame with Beam Tag different from 0x55, send it to the End node.
3. Generate a Wake Up Beam Frame with a Destination ID 0xFF "Broadcast", send it to the End node.
4. Generate a Wake Up Beam Frame with a random HomeID Hash hardcoded, send it to the End node.
5. Generate a Wake Up Beam Frame with a HomeID Hash hardcoded with values: 0x0A, 0x4A or 0x55, send each of them to the End node.
6. Generate a Wake Up Beam Frame and set it to be delayed more 300ms, send it to the End node.

3.61.3 Test Result

2. Observe there are 3 wake up Beam frames sent to the End node.
 - a. The End node never recognizes the beam and the Controller continues sending the Wake Up Fragment until it times out.
3. Observe there are 3 wake up Beam frames sent to the End node
 - a. The End node recognizes the beam but does not respond to the “Broadcast” Wake Up Fragment with an Acknowledgemnt Frame, the Controller continues sending the Wake Up Fragment until it times out.
4. Observe there are 3 wake up Beam frames sent to the End node.
 - a. The End node never recognizes the beam and the Controller continues sending the Wake Up Fragment until it times out.
5. The End node actually accepts the frame and recognizes it.
6. Observe there are 3 wake up Beam frames sent to the End node with 300ms between transmissions.
 - a. The End node never manages to catch the beam when waking up and the Controller continues sending the Wake Up Fragment until it times out.

3.61.4 Pass Criteria

1. The Beams can be addressed to any node from 1 to 232 and 255 (8.1.3.11).
2. The Receiving Node can validate a Hash of the HomeID or values 0x0A, 0x4A or 0x55 (8.1.3.10).

3.61.5 Fail Criteria

1. Any of the Pass Criteria is not met.

3.62 (3.51 - Negative Testing) MPDU Format, Continuous Beam Format, 2-channel frequency

A continuous beam is used for 2-channel frequencies. It's a series of Beam Frames sent over a period of time. They shall be sent back to back to prevent interruptions. It can address any node from 1 to 232 and 255. It may be a short continuous beam up to 300ms or a long continuous beam up to 1160ms. IT shall always be followed by a singlecast frame.

3.62.1 Prerequisites

- 1 x Z-Wave Zniffer
- 1 x Z-Wave PC Controller
- 1 x FLiRS End nodes

3.62.2 Test Setup

We assume a Frame Generator is available in order to generate frames with individual bits, bytes or sections modified individually in order to test the behavior of the receiver.

1. Include FLiRS End node to the Controller's Network.
2. Generate a Wake up Beam Frame with Beam Tag different from 0x55, send it to the End node.
3. Generate a Wake Up Beam Frame with a Destination ID 0xFF "Broadcast", send it.
4. Generate a Wake Up Beam Frame with a random HomeID Hash hardcoded, send it to the End node.
5. Generate a Wake Up Beam Frame with a HomeID Hash hardcoded with values: 0x0A, 0x4A or 0x55, send each of them to the End node.
6. Generate a Wake Up Beam Frame and set it to be sent during less than 300ms, send it to the End node.

3.62.3 Test Result

2. Observe there is 1 wake up Beam frame sent to the End node.
 - a. The End node never recognizes the beam and never wakes up.
 - b. The Controller continues sending the Wake Up Continuous Beam.
 - c. The Controller tries sending the singlecast again unsuccessfully.
 - d. The Controller sends Continuous Beam followed by the singlecast until it times out.
3. Observe there is 1 wake up Beam frame sent to the End node.
 - a. The End node recognizes the beam but does not respond to the retransmission of the singlecast.
 - b. The End Node does not answer the “Broadcast” Wake Up Continuous Beam with an Acknowledgement Frame.
 - c. The Controller continues sending the Wake Up Fragment until it times out.
4. Observe there is 1 wake up Beam frame sent to the End node.
 - a. The End node never recognizes the beam and never wakes up.
 - b. The Controller continues sending the Wake Up Continuous Beam.
 - c. The Controller tries sending the singlecast again unsuccessfully.
 - d. The Controller sends Continuous Beam followed by the singlecast until it times out.
5. The End node actually accepts the frame and recognizes it.
6. Observe there is 1 wake up Beam frame sent to the End node.
 - a. The Controller sends Continuous Beam Start and the Stop with approximately less than 300ms of difference.
 - b. The End node never manages to catch the beam when waking up and the Controller continues sending the Continuous Beam until it times out.

3.62.4 Pass Criteria

1. The Beams can be addressed to any node from 1 to 232 and 255 (8.1.3.13).
2. The Receiving Node can validate a Hash of the HomeID or values 0x0A, 0x4A or 0x55 (8.1.3.10).

3.62.5 Fail Criteria

1. Any of the Pass Criteria is not met.

References

- [1] ITU-T, G.9959, Short range narrowband digital radiocommunication transceivers – PHY & MAC layer specifications.