

# **Z-Stack Large Mesh Network Performance Using the SimpleLink™ Wireless MCU Family**

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## **ABSTRACT**

This application report describes the process employed to perform a Zigbee® 3.0 large mesh network test using SimpleLink CC1352P and CC2652R devices operating from Z-Stack 3.5.0 as included in the SimpleLink CC13X2/CC26X2 v3.30 SDK. Network topology, stack configurations, and the test procedure are supplied to provide guidance on the best practices and design principles involved with reproducing a large Zigbee system. Pertinent results are also provided to demonstrate the performance reliability of a Z-Stack solution and instill confidence in users wishing to deploy such a robust mesh network for their own application.

## **Contents**

1	Introduction .....	2
2	Network Topology .....	2
3	Stack Configurations .....	3
4	Test Procedure and Results .....	4
5	Summary .....	4
6	References .....	4

## **List of Figures**

1	Zigbee Large Network Topology Block Diagram .....	2
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## **List of Tables**

1	Z-Stack 3.5.0 Modifications.....	3
2	Z-Stack 3.5.0 Large Mesh Network Test Results .....	4

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## 1 Introduction

The [CC2652R](#) device from Texas Instruments™ is the ideal System-on-Chip (SoC) for high-performance Zigbee applications, addressing many product specifications from a low-power standpoint. The CC2652R combines a powerful 48 MHz Arm® Cortex®-M4F CPU with up to 80KB of RAM and 352KB of on-chip flash. With a dedicated Radio Controller handling low-level RF protocol commands stored in ROM, it can handle complex network stacks ensuring ultra-low power and great flexibility.

In the world of IoT, battery life is tremendously valued by customers, cutting down on the bill of materials and battery replacement costs, while enabling easy maintenance and product convenience. Therefore, current consumption of devices inside a connected network must have their current consumption tightly controlled. The CC2652R is designed with the lowest power performance in sleep mode, active mode, and during sensor and data processing.

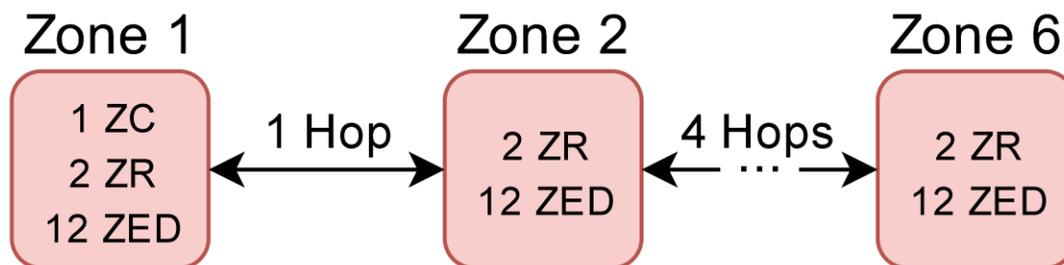
When range is an important consideration for an application, Texas Instruments offers the [CC1352P](#) device, which contains a +20-dBm integrated high-power amplifier with a best-in-class efficiency for long range applications. The CC1352P is a multiprotocol Sub-1 and 2.4-GHz with the same powerful system, offering the ability for a high-performance, long range Zigbee device.

This application report references examples from [Z-Stack 3.5.0](#), which is based on the Zigbee 3.0 profile. Z-Stack comes packaged as part of the [SimpleLink CC13X2/CC26X2 SDK](#), which is designed for simplified development within one environment using industry standard APIs, TI Drivers, and TI RTOS to provide a robust foundation for application development. The version used in this report's test is v3.30.

[Section 2](#) describes the hardware and topology used to test a large network. Changes to the default Z-Stack configuration are explained in [Section 3](#). The actual test procedure is provided in [Section 4](#), along with packet error rate (PER) and latency results.

## 2 Network Topology

A total of 75 Zigbee nodes were used to create the Z-Stack large mesh network test, consisting of one coordinator (ZC), 12 routers (ZR), and 62 end devices (ZED). Half of the devices use [LAUNCHXL-CC26X2R1](#) hardware, whereas, the other half consist of [LAUNCHXL-CC1352P](#), all using default output transmit power (5 and 20 dBm, accordingly). For a simple visual of the setup, see [Figure 1](#).



**Figure 1. Zigbee Large Network Topology Block Diagram**

Although all within radio proximity, the routing devices are evenly separated into six separate zones (2 ZR per zone), with the ZC in zone 1 and each zone only capable of communicating with the members of the adjacent zones. This is to ensure that a maximum of five hops (from zone 6 to zone 1) are analyzed during the test. The same was initially done with the end devices (twelve ZED per zone), however, these children would occasionally transfer zones while changing parents during execution of the test.

### 3 Stack Configurations

Several modifications were made to Z-Stack 3.5.0 definitions to help improve the reliability of the network during operation. These changes have all been listed and described in [Table 1](#).

**Table 1. Z-Stack 3.5.0 Modifications**

Node Type	Symbol	Location	Description	Value
ZC & ZR & ZED	BDB_FINDING_BINDING_CAPABILITY_ENABLED	bdb.h	Enables the finding and binding procedure, only necessary for binding ZCL attributes which is not needed in this test	0
ZC & ZR	NWK_MAX_DEVICE_LIST	nwk_globals.h	Number of children allowed	6
ZC & ZR	LINK_DOWN_TRIGGER	nwk_globals.h	Marks a route as faulty if the transfer count for unsuccessful transmissions exceeds this value	12
ZC & ZR	NWK_ROUTE_AGE_LIMIT	nwk_globals.h	Number of link status messages missed before a neighbor is aged out from the neighbor table	5
ZC & ZR	DEF_NWK_RADIUS	nwk_globals.h	Number of hops that messages can travel in the network	15
ZC & ZR	DEFAULT_ROUTE_REQUEST_RADIUS	nwk_globals.h	Radius of route request packets	8
ZC & ZR	ZDNWKMGGR_MIN_TRANSMISSIONS	zd_nwk_mgr.h	Minimum transmissions attempted for channel interference detection, if enabled	0
ZC & ZR	BCAST_DELIVERY_TIME	zglobals.h	Amount of time a broadcast message exists within the network	100
ZC & ZR	ROUTE_DISCOVERY_TIME	zglobals.h	Amount of time a route discovery lasts	13
ZC	SRC_RTG_EXPIRY_TIME	nwk_globals.h	Time for which the route is valid in the source routing table	2
ZC	MTO_RREQ_LIMIT_TIME	nwk_globals.h	Controls the delay of the MTO routing	5000
ZC	ZDSECMGR_TC_DEVICE_MAX	zd_nwk_mgr.h	Total number of devices, based on APS keys, a trust center can allow to join the network	85
ZC	CONCENTRATOR_DISCOVERY_TIME	zglobals.h	Controls the MTO routing period, in seconds	100
ZC	MAX_RTG_SRC_ENTRIES	zglobals.h	Sets the source routing table size	100
ZC	CONCENTRATOR_ENABLE	zglobals.h	Enables this device to be a concentrator node and turns on the periodic MTO routing event	TRUE
ZC	CONCENTRATOR_ROUTE_CACHE	zglobals.h	Enables route cache memory allocation for the concentrator	0
ZED	POLL_RATE	zstack_config.h	Frequency at which an end device sends a data request to its parent, in milliseconds	3000

Many-to-one (MTO) routing, which helps minimize traffic of Zigbee mesh networks involving centralized nodes (the concentrator), was implemented during this test. More information on this protocol can be obtained in the *Many-to-One Routing Protocol* section of the Z-Stack User's Guide [\[3\]](#).

The NV On-Chip Multi-Page (NVOCMP) driver has been implemented for Z-Stack version 3.5.0 and later. This allows for users to expand the number of flash storage pages reserved for NV items and is necessary if desiring to increase `NWK_MAX_DEVICE_LIST` and/or `ZDSECMGR_TC_DEVICE_MAX` past the values used in the large network test. However, this will require changes both to the CCS linker command file and SysConfig settings. Further details can be found in the *Non-Volatile Memory Items* section of the Z-Stack User's Guide [\[3\]](#).

## 4 Test Procedure and Results

The test was run for one days (24 hours or 1440 minutes) on channel 22 with each ZR and ZED sending application frames 68 bytes in length to the ZC every 4 minutes (720 packets per device over the entire test period). Before starting, each device was flashed with its corresponding firmware. The ZC then began by creating the network. ZR devices were joined in the zone for which they were designated, with a black list implementation from the ZC used to enforce proper assignments. After the link status of every ZR was checked to ensure the correct zone topology, the ZEDs were joined by proximity to the zone for which they were intended. After the network was fully situated, each device was enabled to start sending application data to the ZC.

The ZC kept a full log of the source and contents of each report that it received. PER and latency results were then produced from the information and are provided in [Table 2](#).

**Table 2. Z-Stack 3.5.0 Large Mesh Network Test Results**

Number of Hops From ZC	Final Number of ZEDs	Average Packet Error Rate (%)	Average Latency (ms)
1	23	0.00	40
2	10	0.00	60
3	9	0.00	82
4	9	0.00	104
5	11	0.00	160

The results presented were obtained with all devices within close proximity (less than one and half meters) from a clean radio lab environment in Dallas, Texas. Network performances can vary depending on a wide number of interference sources, both physical and electrical, as well as the range between nodes. Evaluation of 2.4 GHz frequency channels should be performed to further understand the communication traffic sustained by other existing sources. Similar or comparable results cannot be expected if subjected to factors which could easily influence network operation.

Packet Error Rates were calculated based on reception of an APS acknowledgement from the destination device. The device from which the packet originated will wait the full `APSC_ACK_WAIT_DURATION_POLLED` (default 6 seconds) before re-attempting to send the application packet up to `APSC_MAX_FRAME_RETRIES` (default 2). If no APS ACK is returned then the Stack will report a `ZApsNoAck` status on the sending device, which in this test is the Zigbee Coordinator. For more information, see the *End-to-End Acknowledgements* section of the Z-Stack User's Guide[3].

## 5 Summary

This application report has gone through the basics of performing a large Zigbee mesh network test using the CC1352P/CC2652R with Z-Stack 3.5.0 from the SimpleLink CC13X2/CC26X2 v3.30 SDK. The test's network topology was described in detail, modifications to the Z-Stack configuration were listed, and the test procedure was explained making it easier to understand how to re-create a similar setup or understand how to better employ such a network for their own end application. Any questions regarding the material provided can be raised on the [Zigbee & Thread E2E™ Forum](#).

## 6 References

1. CC2652R Product Page: <http://www.ti.com/product/CC2652R>
2. CC1352P Product Page: <http://www.ti.com/product/CC1352P>
3. Z-Stack 3.5.0 User's Guide (Look under Z-Stack documents from the SimpleLink CC13X2/CC26X2 SDK in <http://dev.ti.com/tirex>)
4. [SimpleLink CC13X2/CC26x2 SDK](#)
5. [LAUNCHXL-CC26X2R1 LaunchPad Development Kit](#)
6. [LAUNCHXL-CC1352P LaunchPad Development Kit](#)
7. [Zigbee & Thread E2E™ Forum](#)

## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from A Revision (November 2019) to B Revision</b>	<b>Page</b>
• Update was made in <a href="#">Section 3</a> .....	<b>3</b>
• Update was made in <a href="#">Section 4</a> .....	<b>4</b>

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